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

December 13, 2019

Flight Data Recorder

Specialist's Factual Report
By Charles Cates

1. EVENT SUMMARY

Location:	Baytown, Texas
Date:	February 23, 2019
Aircraft:	Boeing 767-300
Registration:	N1217A
Operator:	Atlas Air Cargo
NTSB Number:	DCA19MA086

On February 23, 2019, about 1239 central standard time (CST), Atlas Air flight 3591, a Boeing 767-300, N1217A, entered a rapid descent from 6,000 feet and impacted a marshy bay area about 30 miles from Houston George Bush Intercontinental Airport (IAH), Houston, Texas. The airplane was destroyed and highly fragmented, and the main debris field was approximately 200 yards by 100 yards in shallow water and a muddy marshland. The two pilots and one non-revenue jumpseat pilot were fatally injured. The domestic cargo flight was operating under Title 14 *Code of Federal Regulations* (CFR) Part 121 from Miami International Airport (MIA), Miami, Florida, to IAH.

2. FLIGHT DATA RECORDER GROUP

A flight data recorder (FDR) group was not convened.

3. FDR Carriage Requirements

The event aircraft, N1217A, was manufactured by Boeing in 1992, and was operating such that it was required to be equipped with an FDR that recorded, at a minimum, 34 parameters, as cited in 14 CFR Part 121.344(d).

4. DETAILS OF FDR INVESTIGATION

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

Recorder Manufacturer/Model:	**Honeywell 4700 64 wps**
Recorder Serial Number:	**4572**

4.1. Honeywell 4700 64 wps Description

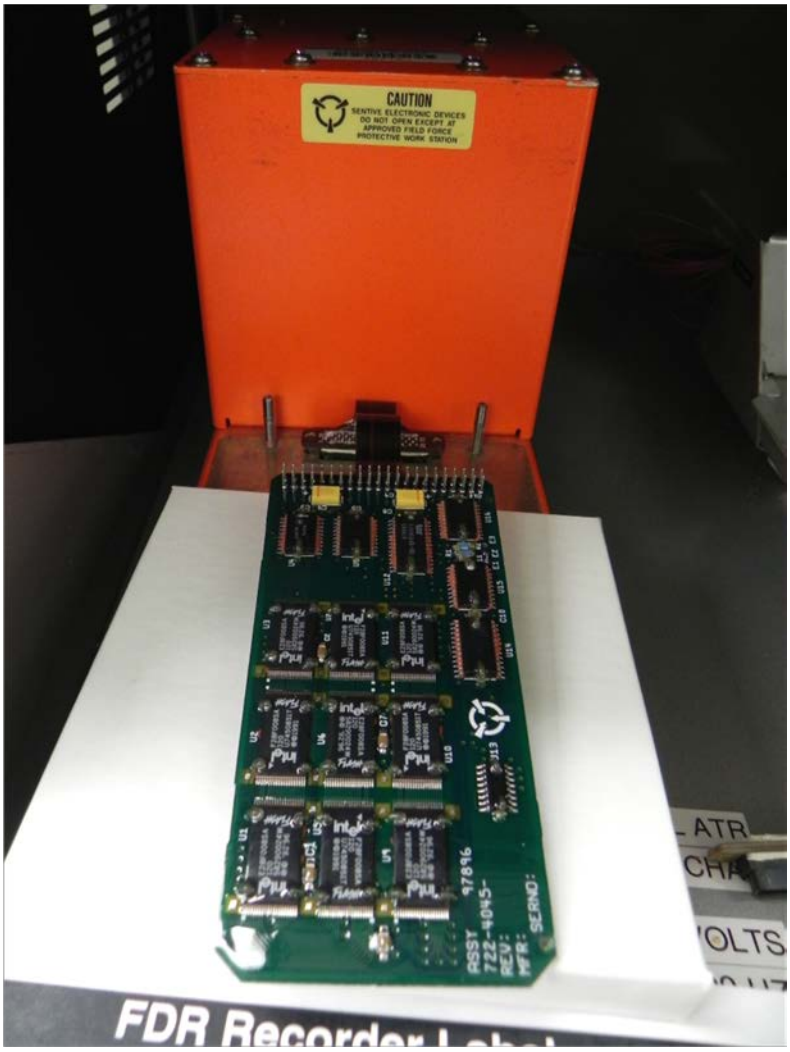
The Honeywell solid state flight data recorder (SSFDR) records airplane flight information in a digital format using solid-state flash memory as the recording medium. The SSFDR can receive data in the ARINC 573/717/747 configurations and can record a minimum of 25 hours of flight data. It is configured to record 64 12-bit words of digital information every second. Each grouping of 64 words (each second) is called a subframe. Each subframe has a unique 12-bit synchronization (sync) word identifying it as subframe 1, 2, 3, or 4. The sync word is the first word in each subframe. The data stream is "in sync" when successive sync words appear at proper 64-word intervals. Each data parameter (for example, altitude, heading, and airspeed) has a specifically assigned word number within the subframe. The SSFDR is designed to meet the crash-survivability requirements of TSO-C124.

4.1.1. Recorder Condition

The recorder was damaged in the event by impact forces and found underwater. The extent of the damage is shown in figure 1. A detailed inspection of the memory module found that water had not reached the electronics and no corrosion was present. The extracted memory module installed in a surrogate recorder is shown in figure 2.

Figure 1. Damaged exterior of flight recorder.

Figure 2. Memory module from accident recorder extracted and installed in surrogate recorder for download.



4.1.2. Recording Description

The FDR recording contained approximately 54 hours of data. Timing of the FDR data is measured in subframe reference number (SRN), where each SRN equals one elapsed second. The event flight was the last flight of the recording and its duration was approximately 2 hours and 6 minutes. The parameters evaluated for the purpose of this report appeared to be in accordance with federal FDR carriage requirements.

4.1.3. Engineering Units Conversions

The engineering units conversions used for the data contained in this report are based on documentation from the operator and aircraft manufacturer. Where applicable, the conversions have been changed to ensure that the parameters conform to the NTSB's standard sign convention that climbing right turns are positive (CRT=+).[1]

Table A-1 lists the FDR parameters verified and provided in this report. Additionally, table A-2 describes the unit and discrete abbreviations used in this report.

4.2. Time Correlation

Correlation of the FDR data from SRN to the event local time, CST, was established by using the recorded Time GMT[2] hours, Time GMT Minutes, and Time GMT Seconds and then applying an additional -6 hours offset to change GMT to CST.

Accordingly, the time offset for the event flight data from SRN to local CST is the following: CST = SRN – 150374.375. Therefore, for the rest of this report, all times are referenced as CST, not SRN.

4.3. FDR Plots and Corresponding Tabular Data

Figures 3 to 11 contain FDR data recorded during the February 23, 2019 event. All the parameters listed in table A-1 are either plotted or provided in tabular data in Appendix 1 to this report.

Figures 3 to 6 contain data encompassing the full flight, from 10:30 to 12:40 CST. Figure 3 contains aircraft basic parameters, figure 4 contains flight control parameters, figure 5 contains engine parameters, and figure 6 contains autoflight mode parameters.

Figure 7 contains aircraft basic parameters from the final three minutes of flight, from 12:36 to 12:39 CST.

Figures 8 to 10 contain parameters significant to the investigative sequence of events for the final three minutes of the flight. Figure 8 covers a time period from 12:36 to 12:37 CST, figure 9 covers a time period from 12:37 to 12:38 CST, and figure 10 covers a time period from 12:38 through the end of the recording at 12:39:03 CST. Figure 9 also annotates the time that the autoflight go around mode was activated and annunciated to the pilots.

Figure 11 is a map overlay created in Google Earth of the flight path for the final three minutes of the flight. Weather and atmospheric conditions in the overlay are not representative of conditions at the time of the flight.

[1] 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 = +, Pitch Up = +, Elevator Trailing Edge Up = +, Right Rudder = +.

[2] GMT is Greenwich Mean Time which is also known as Coordinated Universal Time (UTC).

These figures are configured such that right turns are indicated by the trace moving toward the bottom of the page, left turns towards the top of the page, and nose up attitudes towards the top of the page.

The data show that the aircraft departed at about 10:33 CST and climbed for about 20 minutes to a cruise altitude of 40,000 ft. The center autopilot and autothrottle systems were engaged shortly after takeoff and remained engaged through the remainder of the flight. The aircraft cruised uneventfully on a westerly heading at 240-250 knots. The aircraft continued to cruise at 40,000 ft for about 1 hour 15 minutes before descending to 34,000 ft and cruising at that altitude for an additional 14 minutes. The initial descent out of 34,000 ft began at 12:25 CST. Autoflight systems were in LNAV/VNAV modes. All engine and flight control parameters appeared normal throughout the takeoff, climb, and cruise.

The aircraft descended and reached 10,000 ft at about 12:36:35 CST. Immediately before reaching 10,000 ft the captain's radio mic was keyed, consistent with speaking on the radio, and the autopilot lateral mode changed from LNAV to Heading Select at 12:36:27. About 30 seconds later, the autopilot vertical mode was changed from VNAV to Flight Level Change and the MCP altitude selection was changed from 7,000 ft to 3,000 ft in this time[3].

After the autopilot mode change, the speedbrake handle was extended and the rate of descent increased. For the next minute, the aircraft descended steadily and flaps were selected from up to position 1 at 12:38:04. The autoflight go around modes were armed at the time the flaps began to move into position.

At about 12:38:26 at an altitude of about 6,500 ft, triaxial acceleration magnitudes increased, consistent with the aircraft entering light to moderate turbulence. At 12:38:31 the autoflight system entered go around mode, the engines began advancing to go around thrust setting, the control column, which had been neutral, moved slightly aft and elevator deflected up, the aircraft pitch began to increase, and altitude stopped descending and began to climb. At 12:38:37 the speedbrake handle was retracted and the engines approached their commanded go around power settings.

At 12:38:40 a Master Caution was recorded along with Autopilot Caution. The control column was had moved to be deflected forward at the time, pitch was decreasing, and airspeed began to accelerate rapidly from 240 knots. Autoflight systems remained in Go Around modes and the aircraft continued a shallow climb for a short time before entering a rapid descent. Control column remained deflected forward for the next 10 seconds.

At 12:38:46 the throttles were brought to idle for about 2 seconds then readvanced to the previous power setting. At this point the aircraft pitch was rapidly decreasing and vertical g became negative for nearly 11 seconds. At 12:38:47 a split between left and right elevators was noted ranging between 2 to 7 degrees split until 12:38:57. The aircraft Overspeed and

[3] MCP altitude, speed, and heading parameters were recorded as superframe parameters, meaning they were recorded once every 64 seconds. It is impossible to know where changes to these parameters occurred other than at their recorded points. The last points of these parameters were recorded slightly under one minute prior to the end of the recording.

Master Warning alerts were recorded at 12:38:55 with airspeed increasing beyond 350 knots.

At 12:38:57, altitude crossed through 3,000 ft and the autothrottle switched out of go around mode and engine TRA began to decrease. 12:38:58 with altitude at about 2,000 ft, the control column moved to the aft stop until the end of the recording. Aircraft pitch was about 50 degrees nose down. Vertical acceleration went from 0 g to 4.2 g and pitch increased rapidly until its final recorded position of 16 degrees nose down at 12:39:03. The final recorded airspeed was 433.5 kts.

The corresponding tabular data used to create figures 3 to 11 including Time GMT Hours, Time GMT Minutes, and Time GMT Seconds are provided in electronic comma separated value (*.csv) format as attachment 1 to this report.

Figure 3. Plot of basic parameters during entire flight.

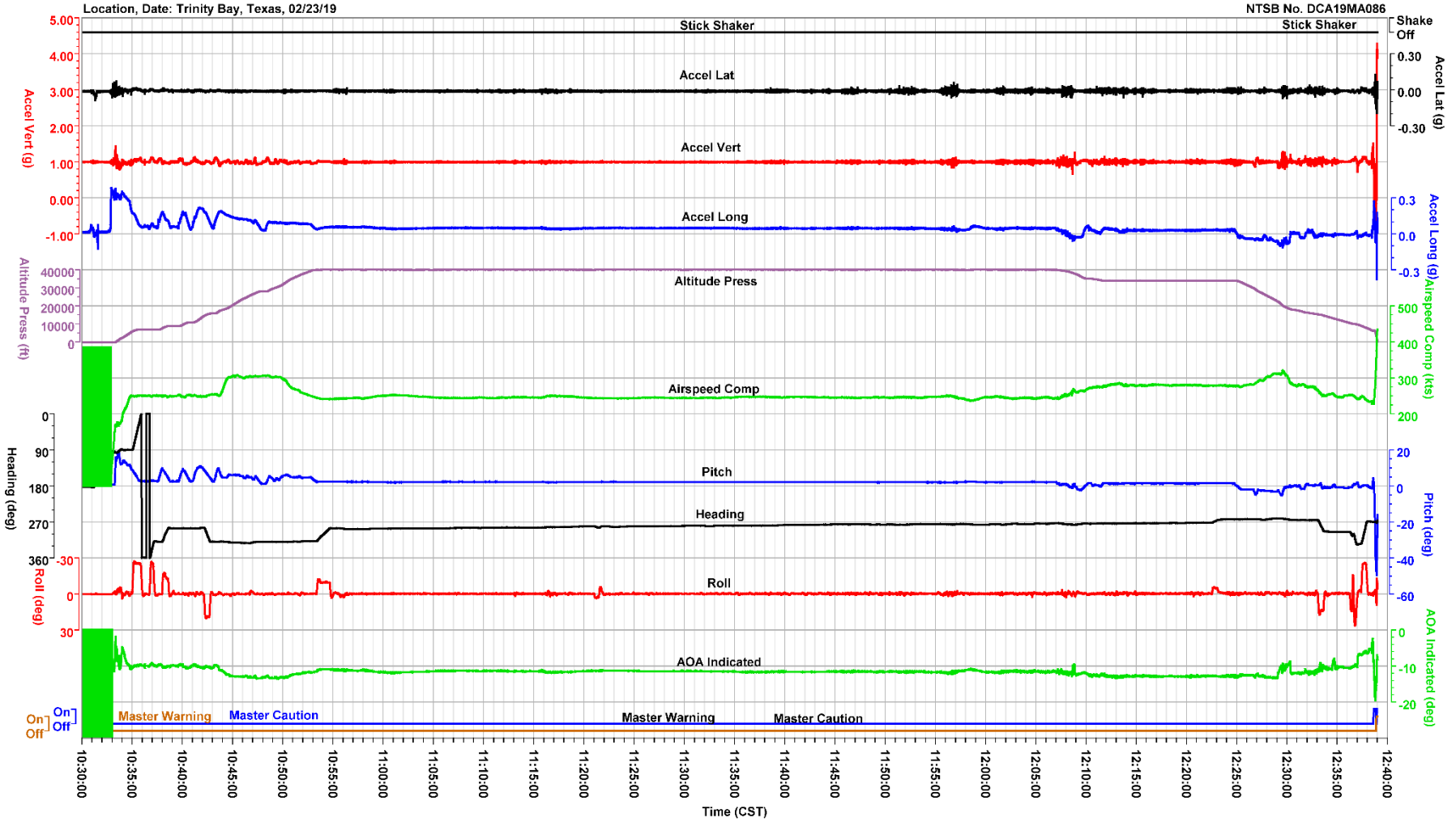


Figure 4. Plot of flight controls parameters during entire flight.

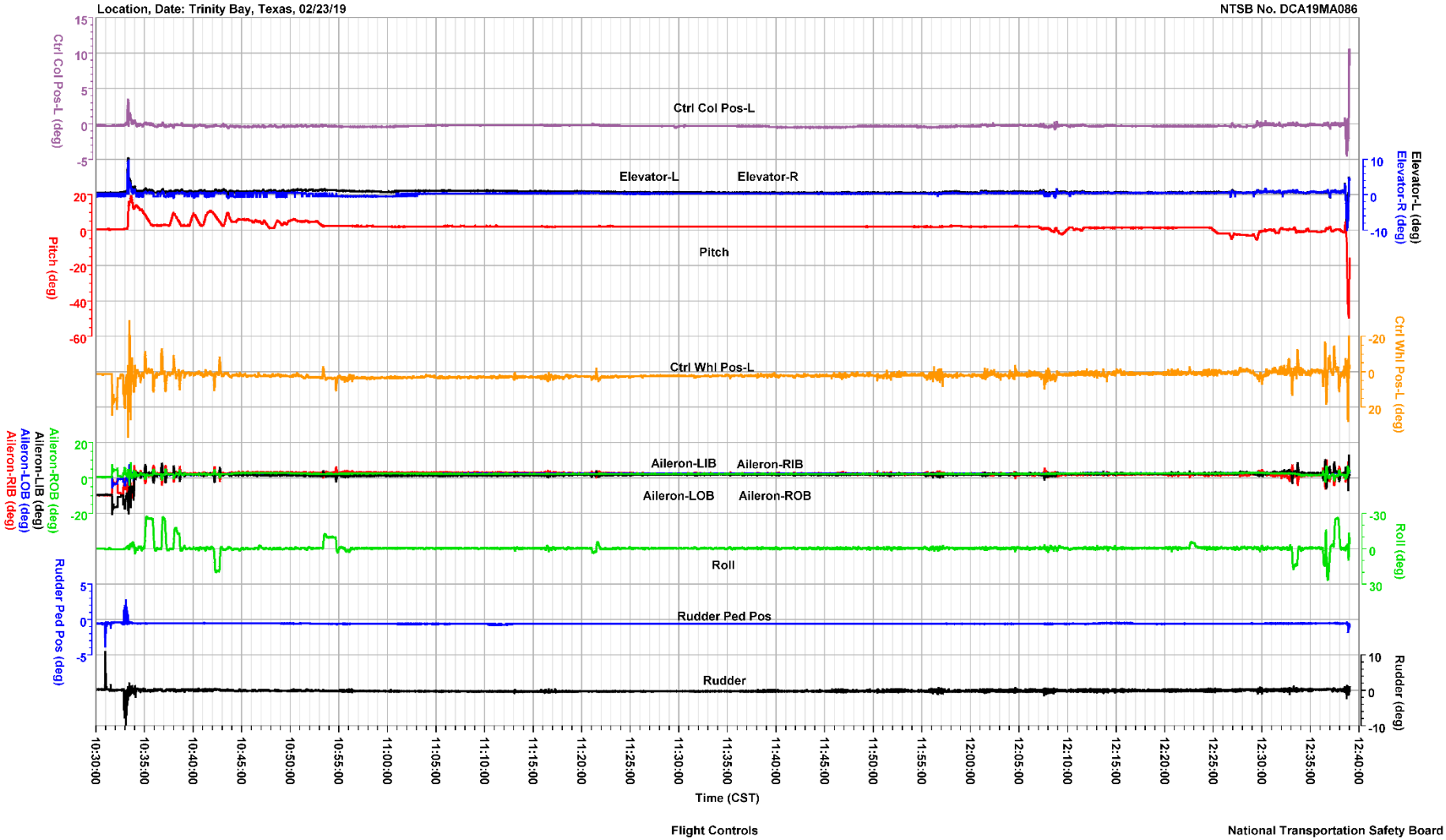


Figure 5. Plot of engine parameters during full flight.

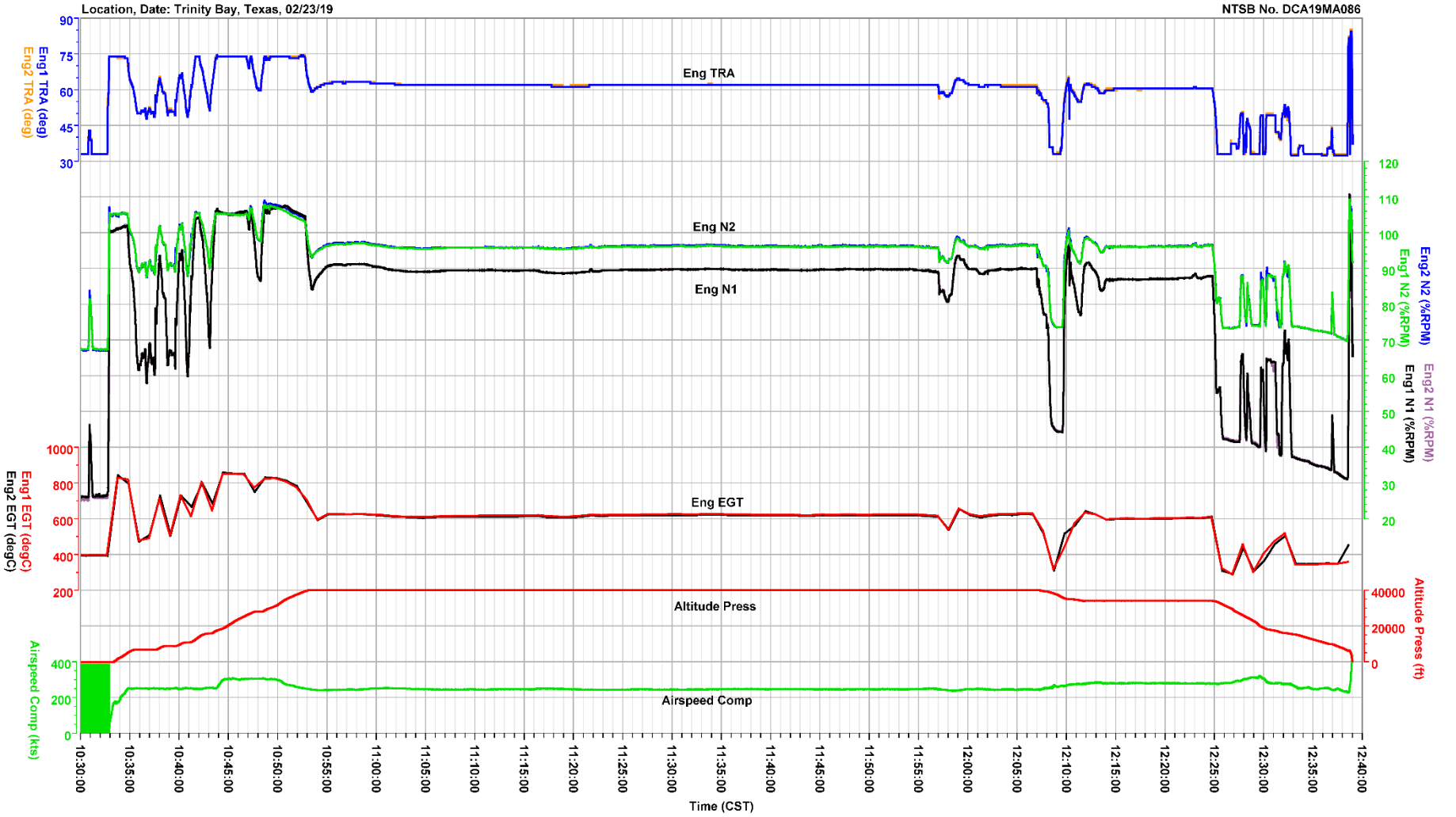


Figure 6. Plot of autopilot and autothrottle mode parameters during full flight.

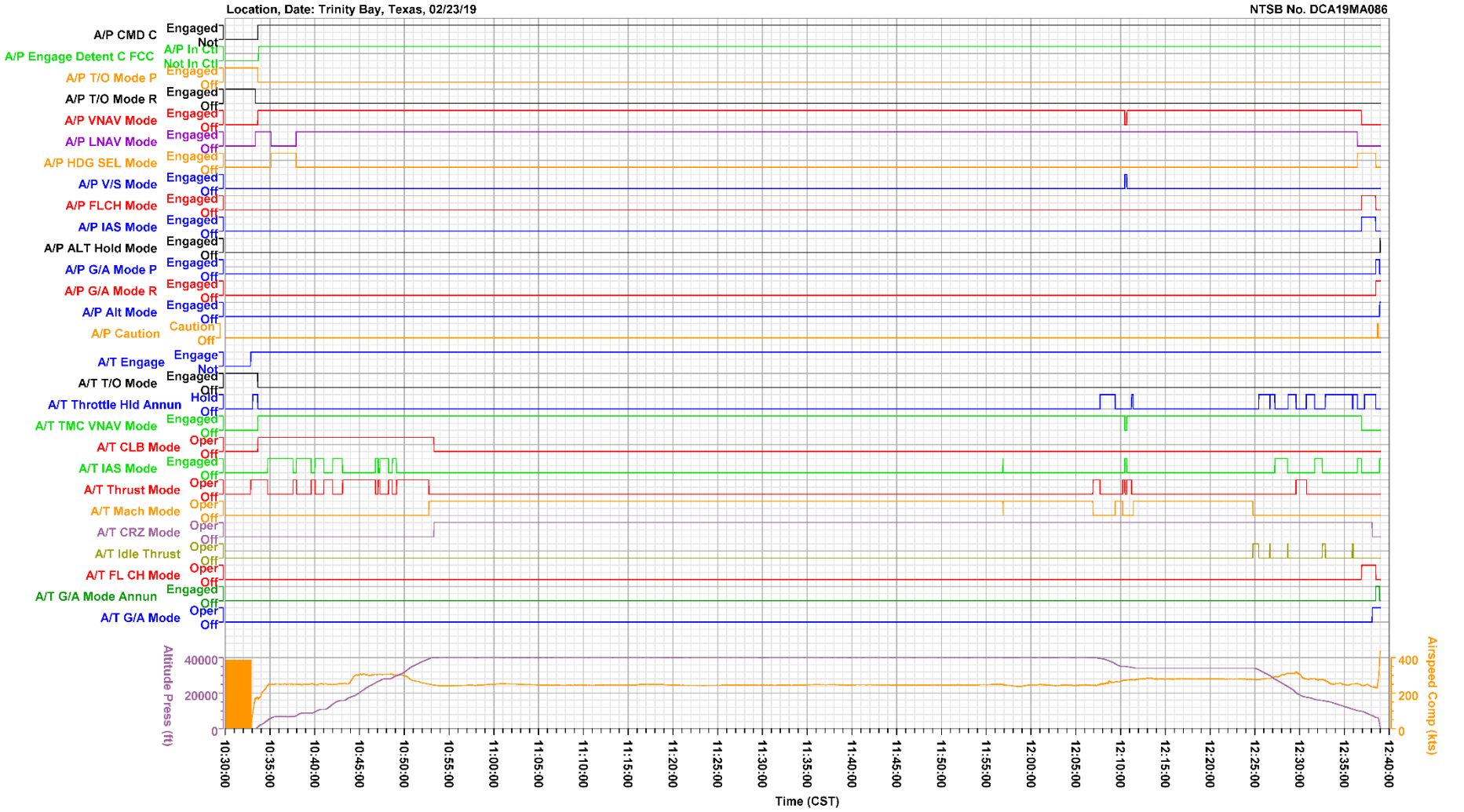


Figure 7. Plot of basic parameters for final three minutes of flight.

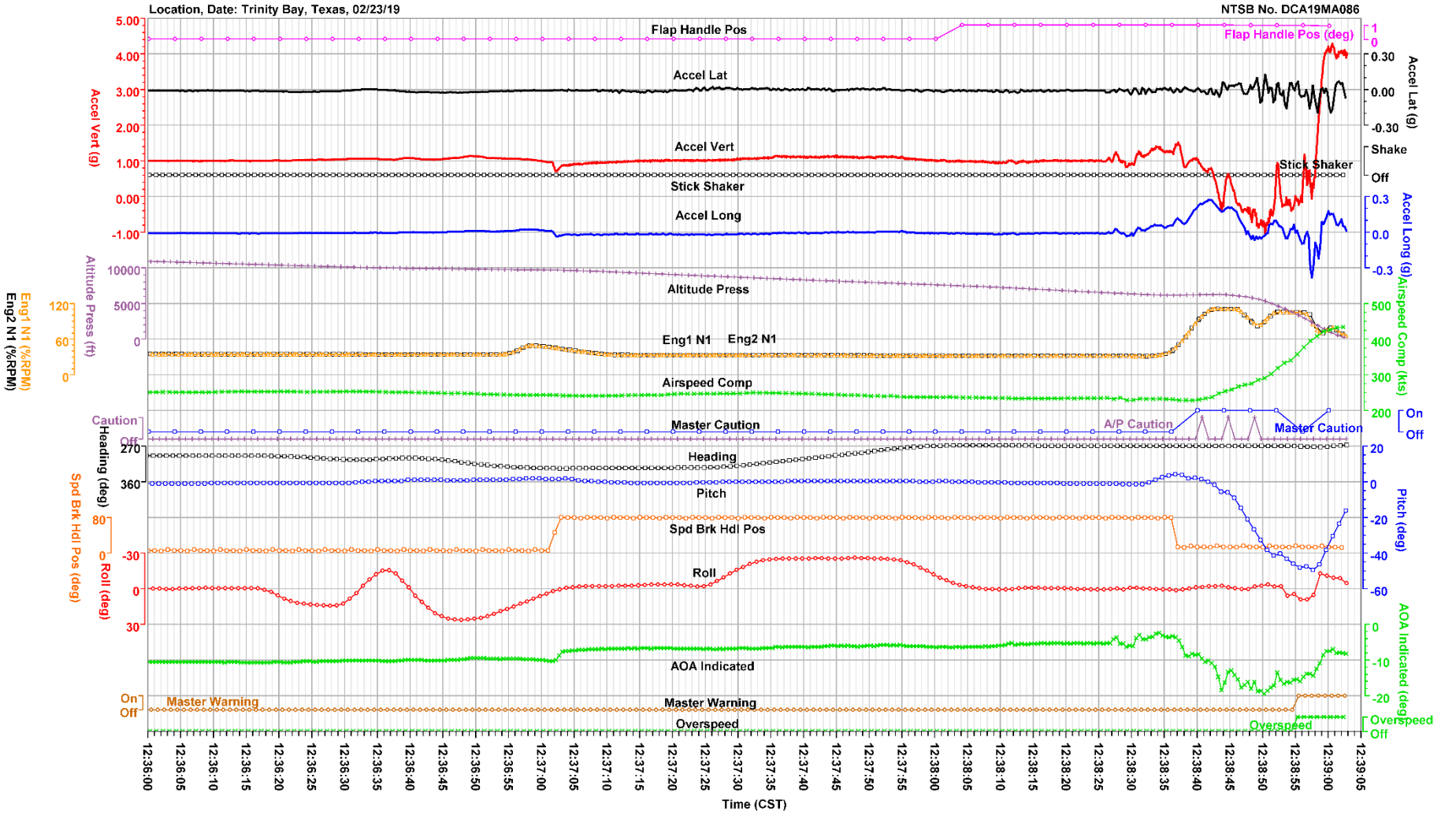


Figure 8. Plot of significant parameters during three minutes leading up to the crash, part 1 of 3.

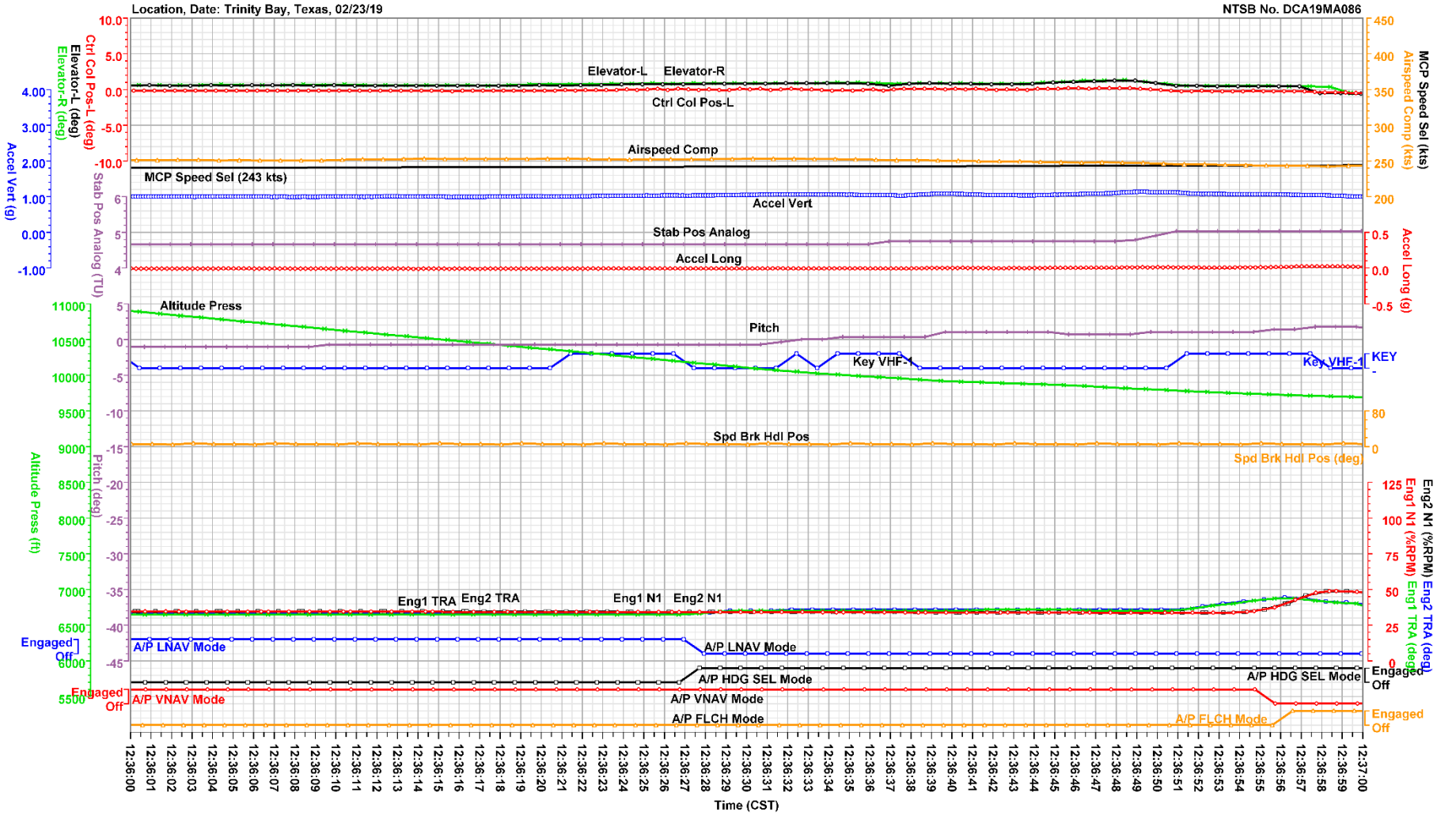


Figure 9. Plot of significant parameters during three minutes leading up to the crash, part 2 of 3.

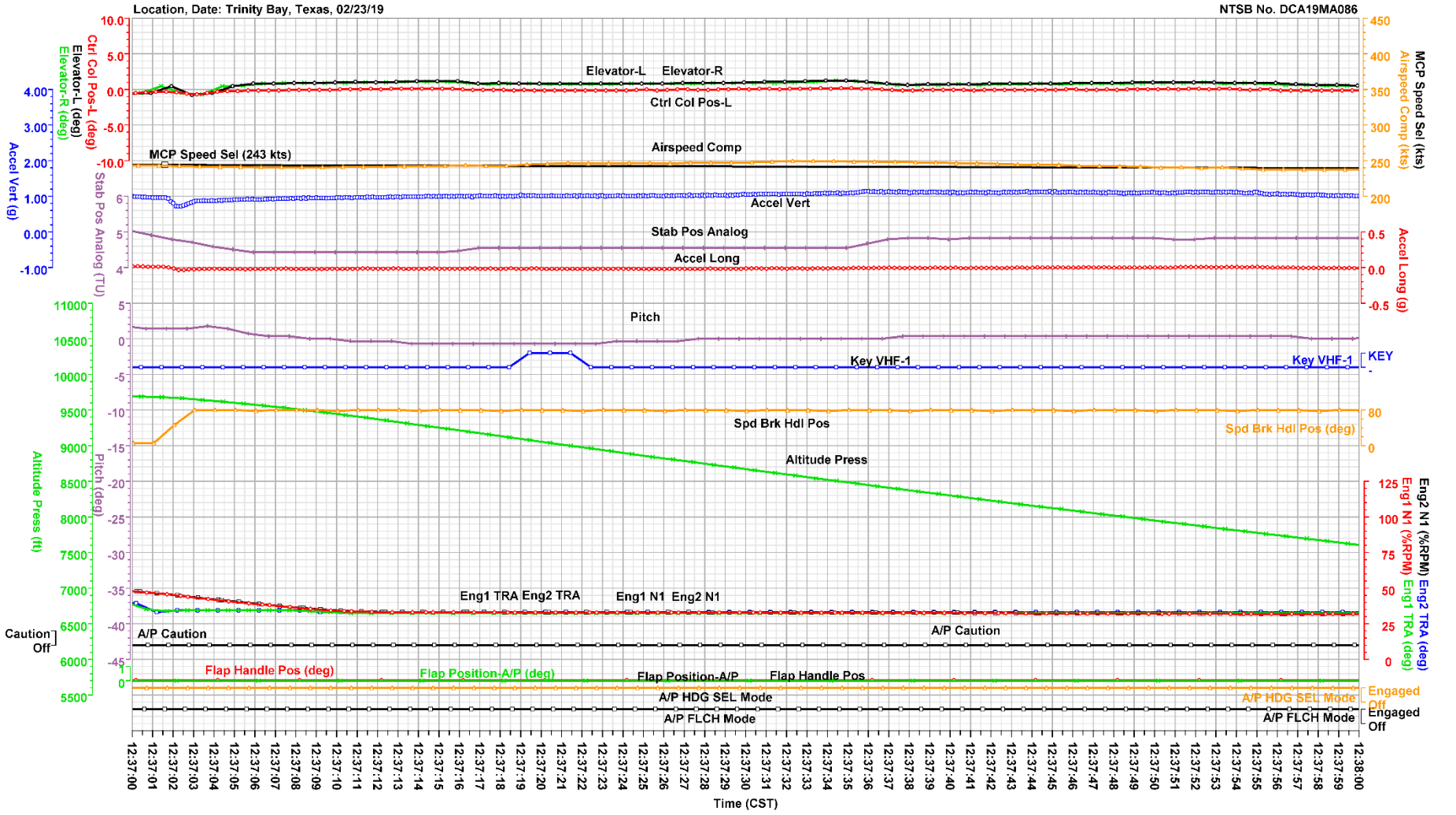


Figure 10. Plot of significant parameters during three minutes leading up to the crash, part 3 of 3.

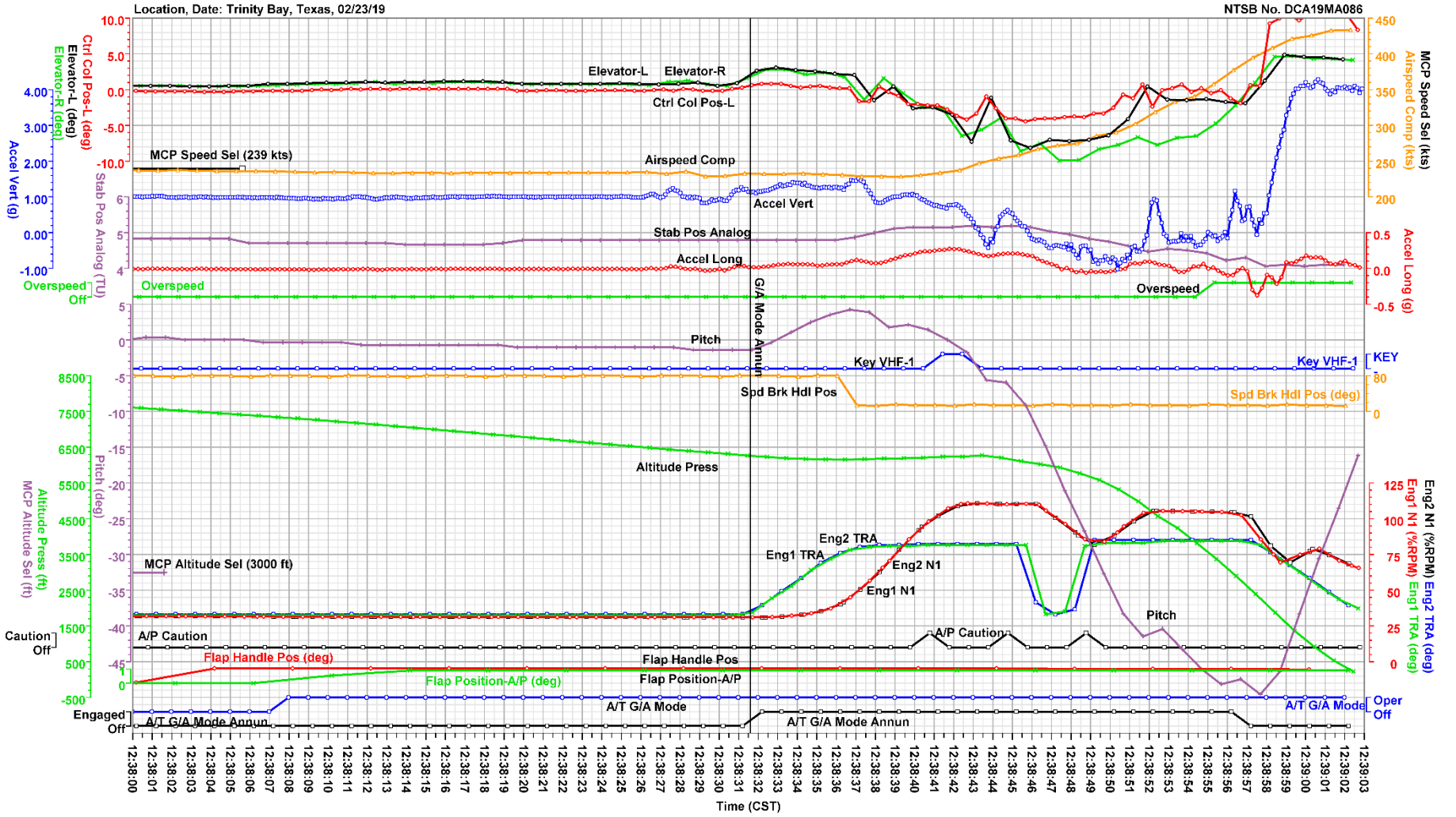
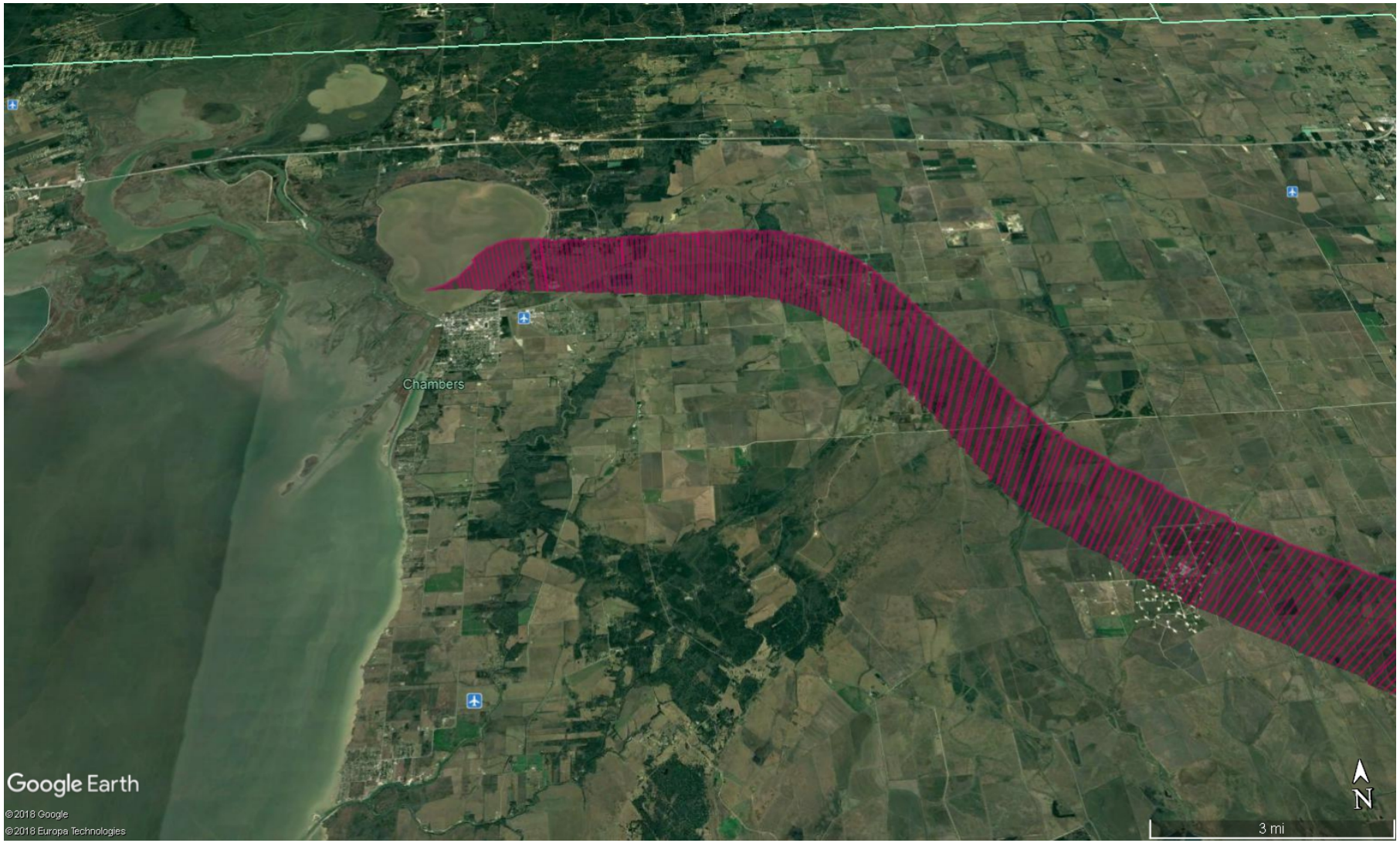


Figure 11. Map overlay of flight path recorded by FDR from 10k ft to end of recording.



APPENDIX A

This appendix describes the parameters provided and verified in this report. Table A-1 lists the plot/table labels, parameter names, and units. Additionally, table A-2 describes the unit and discrete abbreviations used in this report.

Table A-1. Verified and provided FDR parameters.

Plot/Table Label	Description	Units
1. A/P Alt Mode	Autopilot Altitude mode	-
2. A/P Caution	Autopilot Caution	-
3. A/P CMD C	Center Autopilot Commanded	-
4. A/P CMD L	Left Autopilot Commanded	-
5. A/P CMD R	Right Autopilot Commanded	-
6. A/P Engage Detent	Autopilot Switch engaged	-
7. A/P Engage Detent C FCC	Center FCC Autopilot engaged	-
8. A/P Engage Detent L FCC	Left FCC Autopilot engaged	-
9. A/P Engage Detent R FCC	Right FCC Autopilot engaged	-
10. A/P FLCH Mode	Autopilot Flight Level Change mode	-
11. A/P Flt Dir On-Capt	Captain Flight Director On	-
12. A/P Flt Dir On-F/O	First Officer Flight Director On	-
13. A/P G/A Mode P	Autopilot Go Around Pitch mode	-
14. A/P G/A Mode R	Autopilot Go Around Roll mode	-
15. A/P HDG SEL Mode	Autopilot Heading Select mode	-
16. A/P IAS Mode	Autopilot Indicated Airspeed mode	-
17. A/P LNAV Mode	Autopilot Lateral Navigation mode	-
18. A/P T/O Mode P	Autopilot Takeoff Pitch mode	-
19. A/P T/O Mode R	Autopilot Takeoff Roll mode	-
20. A/P V/S Mode	Autopilot Vertical Speed mode	-
21. A/P VNAV Mode	Atuopilot Vertical Navigaion mode	-
22. A/P Warning	Autopilot Warning	-
23. A/T CLB Mode	Autothrottle Climb mode	-

Plot/Table Label	Description	Units
24. A/T CRZ Mode	Autothrottle Cruise mode	-
25. A/T Disc	Autothrottle Disconnect EICAS alert	-
26. A/T Disconnect	Autothrottle Disconnect signal to TMC	-
27. A/T Engage	Autothrottle Engaged	-
28. A/T FL CH Mode	Autothrottle Flight Level Change mode	-
29. A/T G/A Mode	Autothrottle Go Around mode	-
30. A/T G/A Mode Annun	Autothrottle Go Around mode Annunciated	-
31. A/T IAS Mode	Autothrottle Indicated Airspeed mode	-
32. A/T Idle Thrust	Autothrottle Idle Thrust mode	-
33. A/T Mach Mode	Autothrottle Mach mode	-
34. A/T T/O Mode	Autothrottle Takeoff mode	-
35. A/T Throttle Hld Annun	Autothrottle Throttle Hold Annunciated	-
36. A/T Thrust Mode	Autothrottle Thrust mode	-
37. A/T TMC VNAV Mode	Autothrottle Thrust Management Computer Vertical Navigation mode	-
38. Accel Lat	Lateral Acceleration	g
39. Accel Long	Longitudinal Acceleration	g
40. Accel Vert	Vertical Acceleration	g
41. ADC Invalid	Air Data Computer Detected Invalid	-
42. ADC Select SW-Capt	Captain Air Data Computer Select Switch Position	-
43. ADC Select SW-F/O	First Officer Air Data Computer Select Switch Position	-
44. Aileron-LIB	Left Inboard Aileron Position	deg
45. Aileron-LOB	Left Outboard Aileron Position	deg
46. Aileron-RIB	Right Inboard Aileron Position	deg
47. Aileron-ROB	Right Outboard Aileron Position	deg
48. Airspeed Comp	Computed Airspeed	kts
49. Altitude Press	Pressure Altitude	ft
50. Altitude Radio	Radio Altitude	ft
51. AOA Indicated	Indicated Angle of Attack	deg
52. Bus AC Volts L	Left Aircraft Electrical Bus Voltage	V

Plot/Table Label	Description	Units
53. Bus AC Volts R	Right Aircraft Electrical Bus Voltage	V
54. Ctrl Col Pos-L	Left Control Column Position	deg
55. Ctrl Whl Pos-L	Left Control Wheel Position	deg
56. Drift Angle	Aircraft Drift Angle	deg
57. EFIS Select SW-Capt	Captain Electronic Flight Instrument System Select Switch Position	-
58. EFIS Select SW-F/O	First Officer Electronic Flight Instrument System Select Switch Position	-
59. Elevator-L	Left Elevator Position	deg
60. Elevator-R	Right Elevator Position	deg
61. Eng1 EGT	Left Engine Exhaust Gas Temperature	deg C
62. Eng1 N1	Left Engine Fan Speed	% rpm
63. Eng1 N2	Left engine Core Speed	% rpm
64. Eng1 TRA	Left Engine Throttle Resolver Angle	deg
65. Eng2 EGT	Right Engine Exhaust Gas Temperature	deg C
66. Eng2 N1	Right Engine Fan Speed	% rpm
67. Eng2 N2	Right Engine Core Speed	% rpm
68. Eng2 TRA	Right Engine Throttle Resolver Angle	deg
69. Flap Handle Pos	Flap Handle Position	deg
70. Flap Position-A/P	Flap Position read by Autopilot system	deg
71. Gross Weight	Aircraft Weight	lbs
72. Groundspeed	Ground Speed	kts
73. Heading	Magnetic Heading	deg
74. Hyd Sys Pres-C	Center Hydraulic System Pressure	psi
75. Hyd Sys Pres-L	Left Hydraulic System Pressure	psi
76. Hyd Sys Pres-R	Right Hydraulic System Pressure	psi
77. Hyd Sys Qty-C	Center Hydraulic System Quantity	% full
78. Hyd Sys Qty-L	Left Hydraulic System Quantity	% full
79. Hyd Sys Qty-R	Right Hydraulic System Quantity	% full
80. IRS Select SW-Capt	Captian Inertial Reference System Select Switch Position	-
81. IRS Select SW-F/O	First Officer Inertial Reference System Select Switch Position	-

Plot/Table Label	Description	Units
82. Key VHF-1	VHF Radio 1 Keyed	-
83. Key VHF-2	VHF Radio 2 Keyed	-
84. Key VHF-3	VHF Radio 3 Keyed	-
85. Latitude	Latitude	deg
86. Longitude	Longitude	deg
87. Mach	Aircraft Mach Number	Mach
88. Master Caution	Master Caution Active	-
89. Master Warning	Master Warning Active	-
90. MCP Altitude Sel	Mode Control Panel Selected Altitude	ft
91. MCP Heading Sel	Mode Control Panel Selected Heading	deg
92. MCP Mach Sel	Mode Control Panel Selected Mach Number	Mach
93. MCP SPD Display Blank	Mode Control Panel Speed Window Blank	-
94. MCP Speed Sel	Mode Control Panel Selected Airspeed	-
95. MCP V/S Sel	Mode Control Panel Selected Vertical Speed	-
96. Overspeed	Overspeed Warning Active	-
97. Pitch	Pitch Angle	deg
98. Roll	Roll Angle	deg
99. Rudder	Rudder Position	deg
100. Rudder Ped Pos	Rudder Pedal Position	deg
101. Spd Brk Hdl Pos	Speed Brake Handle Position	deg
102. Stab Pos Analog	Horizontal Stabilizer Position	deg
103. Stick Shaker	Stick Shaker Active	-
104. Temp TAT	Total Air Temperature	deg C
105. Time GMT Hrs	GMT Hours	hrs
106. Time GMT Min	GMT Minutes	min
107. Time GMT Sec	GMT seconds	sec
108. Wind Direction	Wind Direction	deg
109. Wind Spd	Wind Speed	kts

NOTE: This FDR 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 FDR plots and in the electronic data has not been corrected for the local altimeter setting at the time of the event.

NOTE: Parameters with a blank unit description in table A-1 are discretes. 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.

Table A-2. Unit and discrete abbreviations.

Unit and Discrete Abbreviation	Description
A/P	Autopilot
A/T	Autothrottle
ADC	Air Data Computer
Capt	Captain
deg	degrees
deg C	degrees Celsius
EFIS	Electronic Flight Instrument System
EICAS	Engine Indicating and Crew Alerting System
F/O	First Officer
FCC	Flight Control Computer
ft	feet
G/A	Go Around
hrs	hours
IAS	Indicated Airspeed
IRS	Inertial Reference System
kts	knots
lbs	pounds
LNAV	Lateral Navigation
MCP	Mode Control Panel
min	minutes
psi	pounds per square inch
rpm	revolutions per minute
sec	seconds
SW	switch

Unit and Discrete Abbreviation	Description
T/O	Takeoff
TMC	Thrust Management Computer
V	volts
V/S	Vertical Speed
VNAV	Vertical Navigation