

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

March 28, 2018

Flight Data Recorder

Specialist's Factual Report
By Cassandra Johnson

1. EVENT SUMMARY

Location: Pensacola, Florida
Date: August 27, 2016
Aircraft: Boeing 737-700
Registration: N766SW
Operator: Southwest Airlines
NTSB Number: DCA16FA217

On August 27, 2016, about 0930 central daylight time (CDT), a Boeing 737-700, N766SW, operating as Southwest Airlines flight 3472, experienced an uncontained engine failure and cabin depressurization while climbing through flight level 310. None of the 99 passengers and 5 crewmembers onboard were injured and the airplane sustained substantial damage. The flight crew declared an emergency and diverted to Pensacola International Airport (PNS), Pensacola, Florida. The regularly scheduled passenger flight was operating under Title 14 *Code of Federal Regulations* (CFR) Part 121 from Louis Armstrong New Orleans International Airport (MSY), New Orleans, Louisiana, to Orlando International Airport (MCO), Orlando, Florida.

2. FLIGHT DATA RECORDER GROUP

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

3. FDR Carriage Requirements

The event aircraft, N766SW, was delivered on February 5, 2000, 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**
Recorder Serial Number: **08251**

4.1. Honeywell 4700

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 256 12-bit words of digital information every second. Each grouping of 256 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 256-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. Recording Description

The FDR recording contained approximately 27 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 which ended 21 minutes and 15 seconds after takeoff while the aircraft was at a pressure altitude of 17,413 feet (ft). The parameters evaluated for the purpose of this report appeared to be in accordance with federal FDR carriage requirements.

4.1.2. Engineering Units Conversions

The engineering units conversions used for the data contained in this report are based on documentation from the 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 and lists the parameter names, parameter descriptions, and units. Additionally, table A-2 describes the unit and discrete abbreviations used in this report.

4.1.3. Non-Computed Data Pattern

A non-computed data (NCD) pattern is indicative that the raw data for a given parameter is no longer reliable or not available. The following six parameters had NCD pattern during the flight: auxiliary power unit (APU) N1, APU oil temperature (APU Oil Temp), engine 1 oil temperature (Eng1 Oil Temp), engine 1 oil pressure (Eng1 Oil Pressure), engine 1 fuel flow (Eng1 Fuel Flow), and engine 1 exhaust gas temperature (Eng1 EGT).

4.2. Time Correlation

The timing of the FDR data is elapsed time (SRN) based on four sequential sync codes with each sync code followed by 256 12-bit words. SRN is not real time and is typically correlated to the recorded GMT time parameters² by applying an offset.

Approximately 13 minutes and 23 seconds after takeoff there was a gap of about 0.5 seconds of data within one subframe (within 1 second). This gap is most likely due to the engine failure. After this subframe, the next sequential subframe was recorded. Review of

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). The recorded GMT parameters are Time GMT hours, Time GMT Minutes, and Time GMT Seconds.

the recorded GMT time parameters after the gap showed the elapsed time (SRN) and GMT time no longer matched and calculating one time offset between SRN and GMT cannot be done. Therefore, time in the plots (x-axis) and in the tabular data file were left as SRN.

However, the recorded GMT time parameters appear to be consistent with local time and are used in Section 4.3. For the description in Section 4.3, GMT was converted to CDT by subtracting 5 hours (CDT = GMT - 5 hours).

4.3. FDR Plots and Corresponding Tabular Data

Figures 1 to 4 contain FDR data recorded during the event on August 27, 2016. These figures cover the event flight from when the data began recording at 9:04:34 CDT (96,524 SRN) before takeoff until the data ended at 9:29:37 CDT (98,027 SRN). The x-axis scale for these four figures is from 96,520 SRN to 98,080 SRN. Figures 5 to 8 contain FDR data recorded during the previous flight (x-axis scale is from 93,200 SRN to 96,320 SRN). Lastly, figure 9 contains FDR data recorded during the entire FDR recording (x-axis scale is from 0 SRN to 98,400 SRN). All the parameters listed in table A-1 are plotted except Time GMT Hours, Time GMT Minutes, and Time GMT Seconds.

Figures 1 and 5 contain basic parameters; figures 2 and 6 contain select engine parameters; figures 3 and 7 contain additional engine parameters; and lastly, figures 4, 8 and 9 contain engine vibration parameters.

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.

In brief, the FDR data indicated at 9:21:46 CDT (97,555 SRN), approximately 13 minutes and 23 seconds after takeoff, while climbing through a pressure altitude of about 31,259 ft, there was a discontinuity of the FDR data most likely due to the engine failure. At this time, the engine 1 N1 was at 99% revolutions per minute (RPM). About 3 seconds later, at 9:21:49 CDT (97,559 SRN), engine 1 N1 decreased to 39% RPM and the pressure altitude increased slightly to 31,341 ft. About 29 seconds later at 9:22:18 CDT (97,588 SRN), the cabin altitude warning (Cabin Alt Warn) transitioned from No Warn to Warn and remained at Warn for the rest of the FDR data. At this time engine 1 N1 decreased to 33% RPM and the pressure altitude decreased to 31,068 ft. During the next 7 minutes and 19 seconds until the data ended at 9:29:37 CDT (98,027 SRN), pressure altitude and engine 1 N1 continued to decrease. The last recorded pressure altitude was 17,413 ft and the last recorded engine 1 N1 was 17% RPM.

The tabular data from 93,200 SRN to 96,300 SRN and from 96,525 SRN to 98,027 SRN for all the parameters listed in table A-1 are provided in electronic comma separated value (.csv) format as attachments 1 and 2, respectively, to this factual report. Additionally, the tabular data used to create figure 9 including Time GMT Hours, Time GMT Minutes and Time GMT Seconds are provided in electronic comma separated value (.csv) format as attachment 3 to this factual report.

Figure 1. Plot of basic parameters during entire flight.

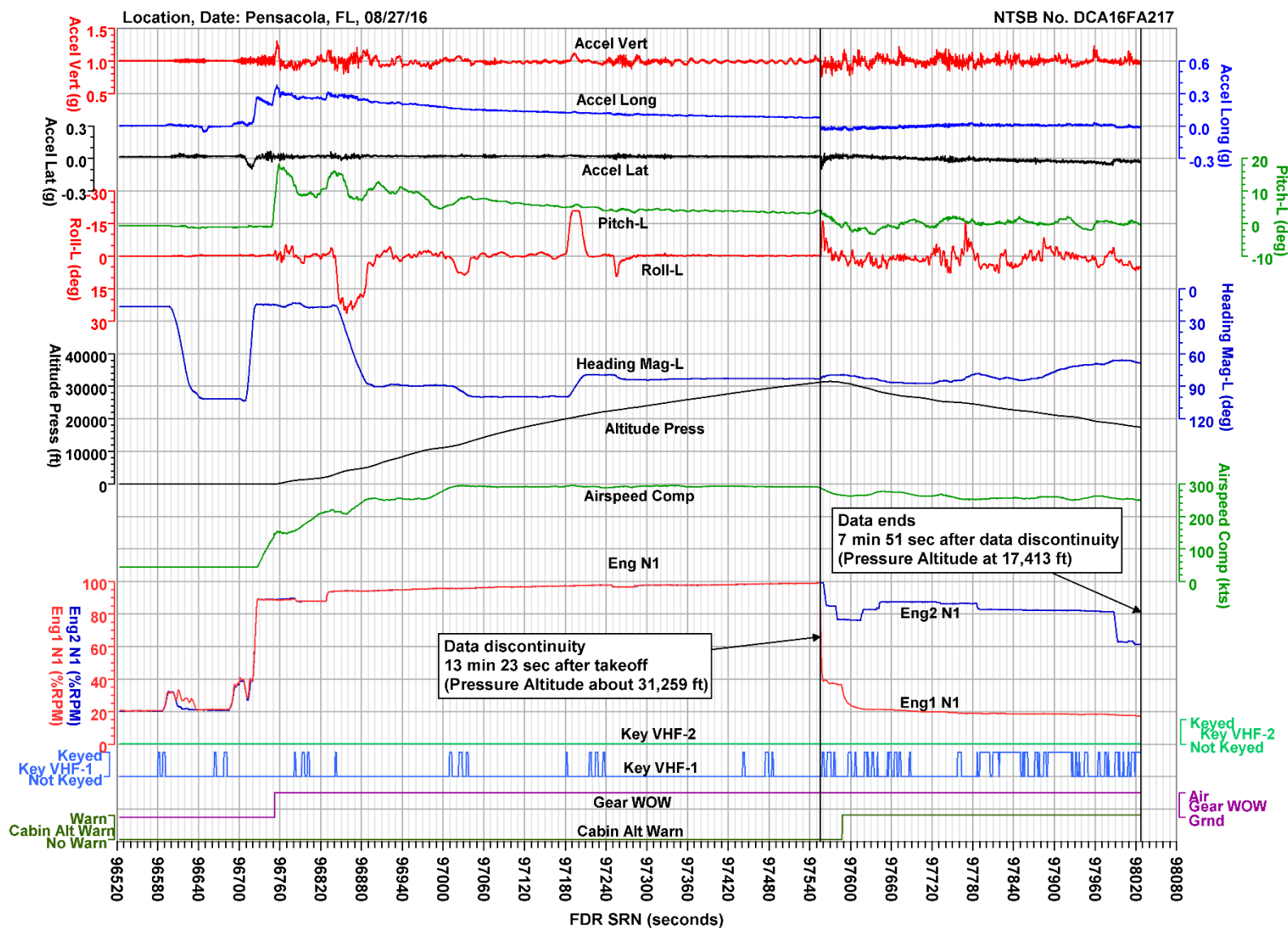
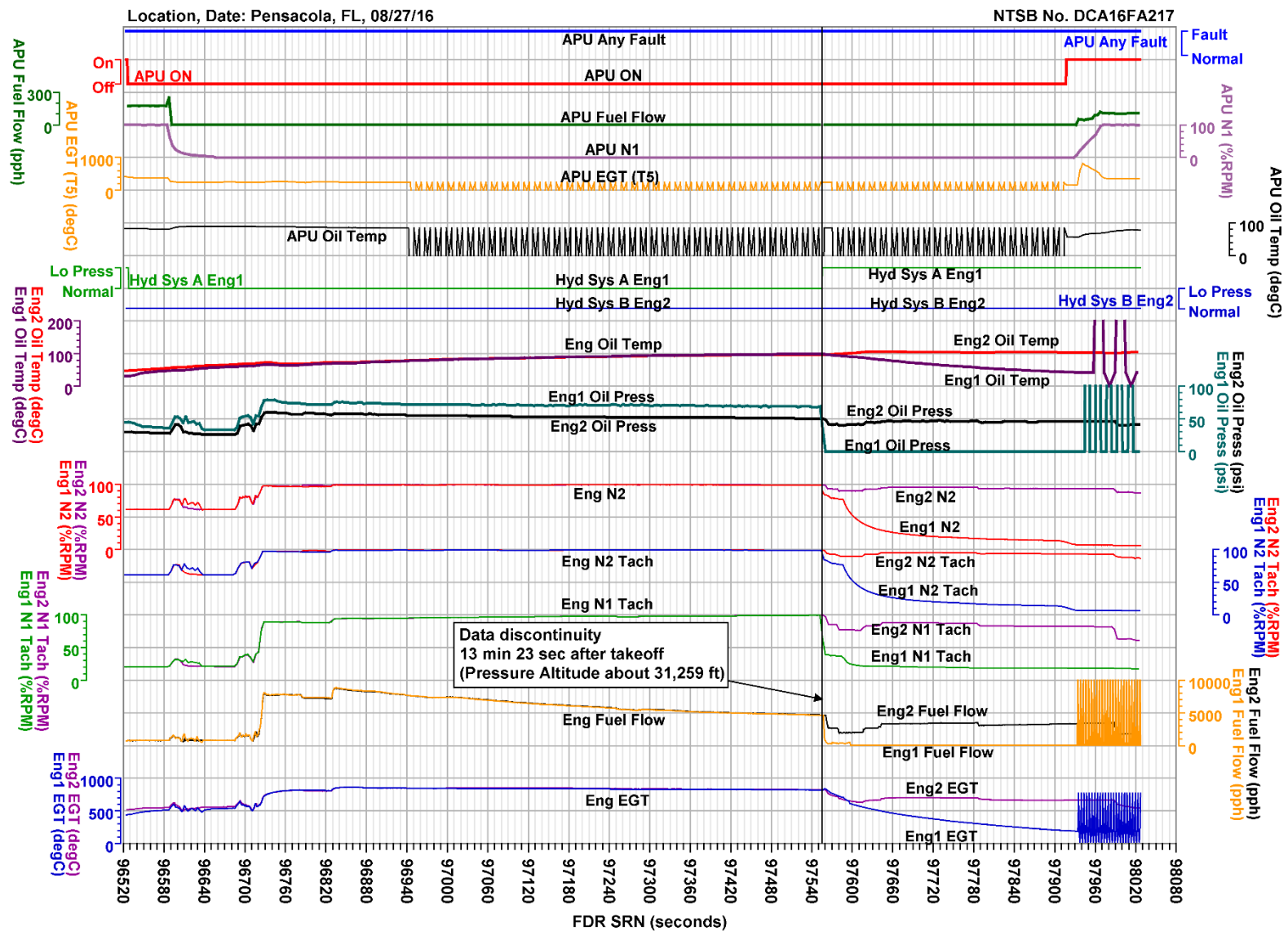


Figure 2. Plot of select engine parameters during entire flight.



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Figure 3. Plot of additional engine parameters during entire flight.

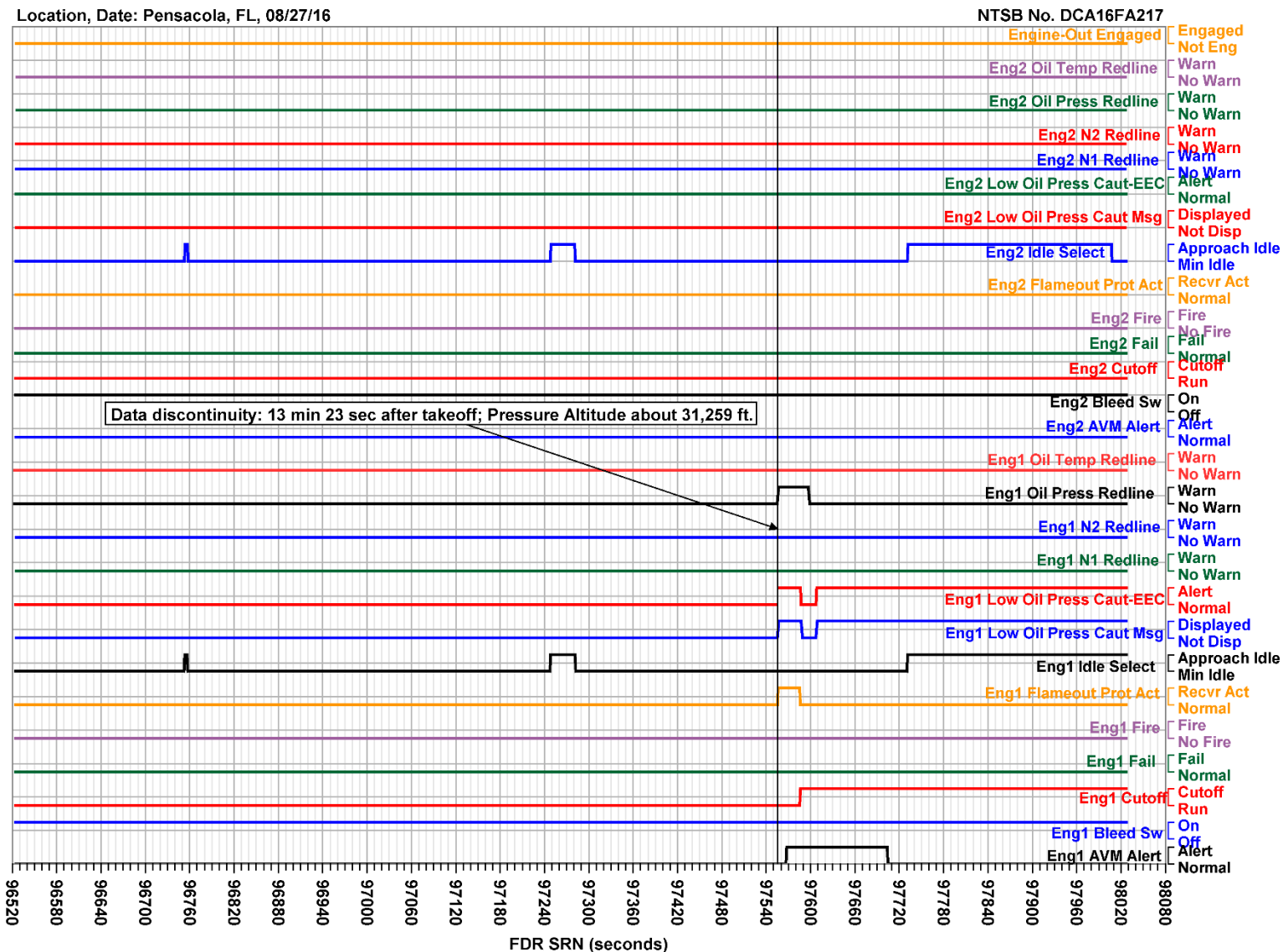


Figure 4. Plot of engine vibration parameters during entire flight.

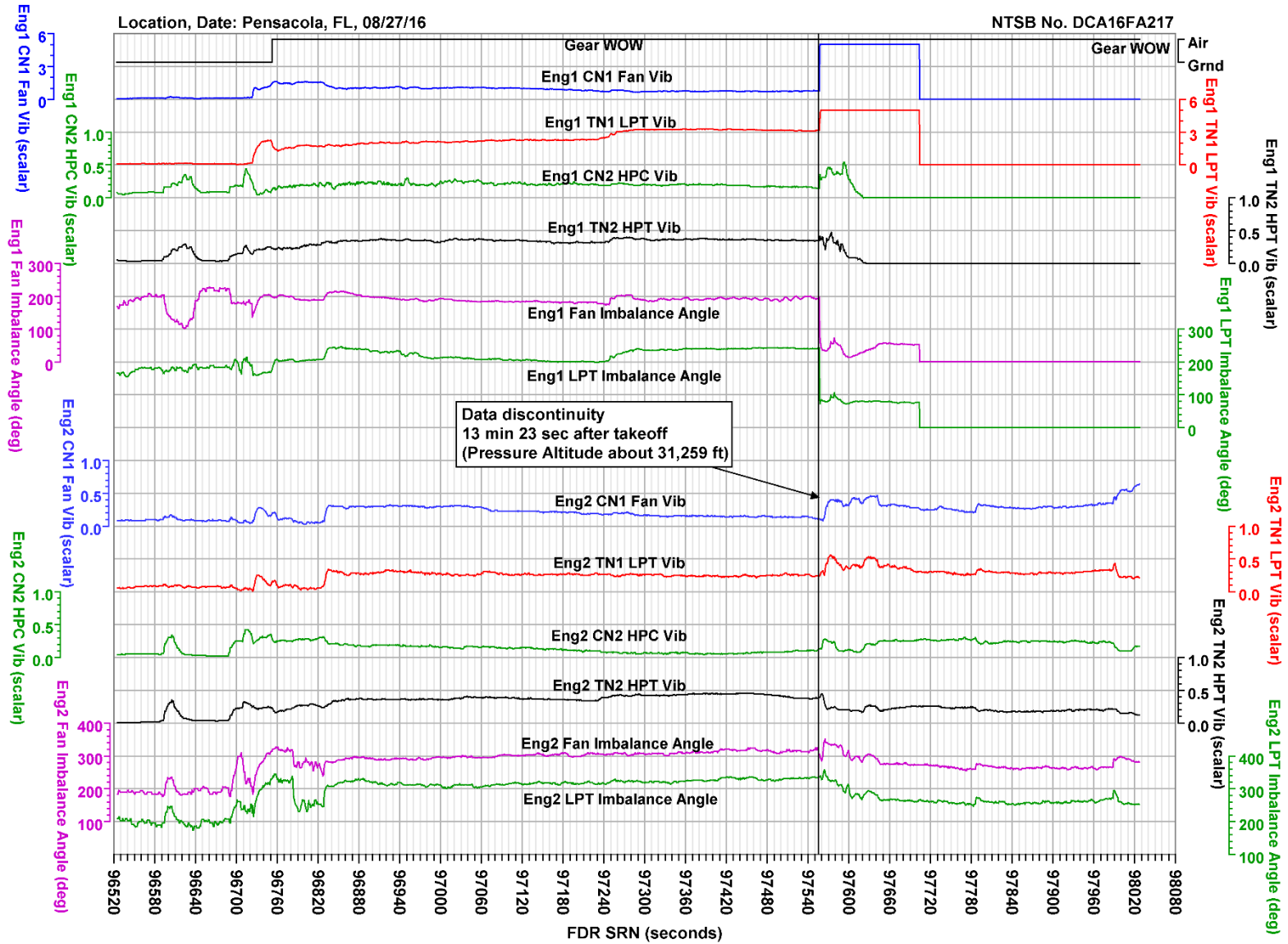


Figure 5. Plot of basic parameters during previous flight.

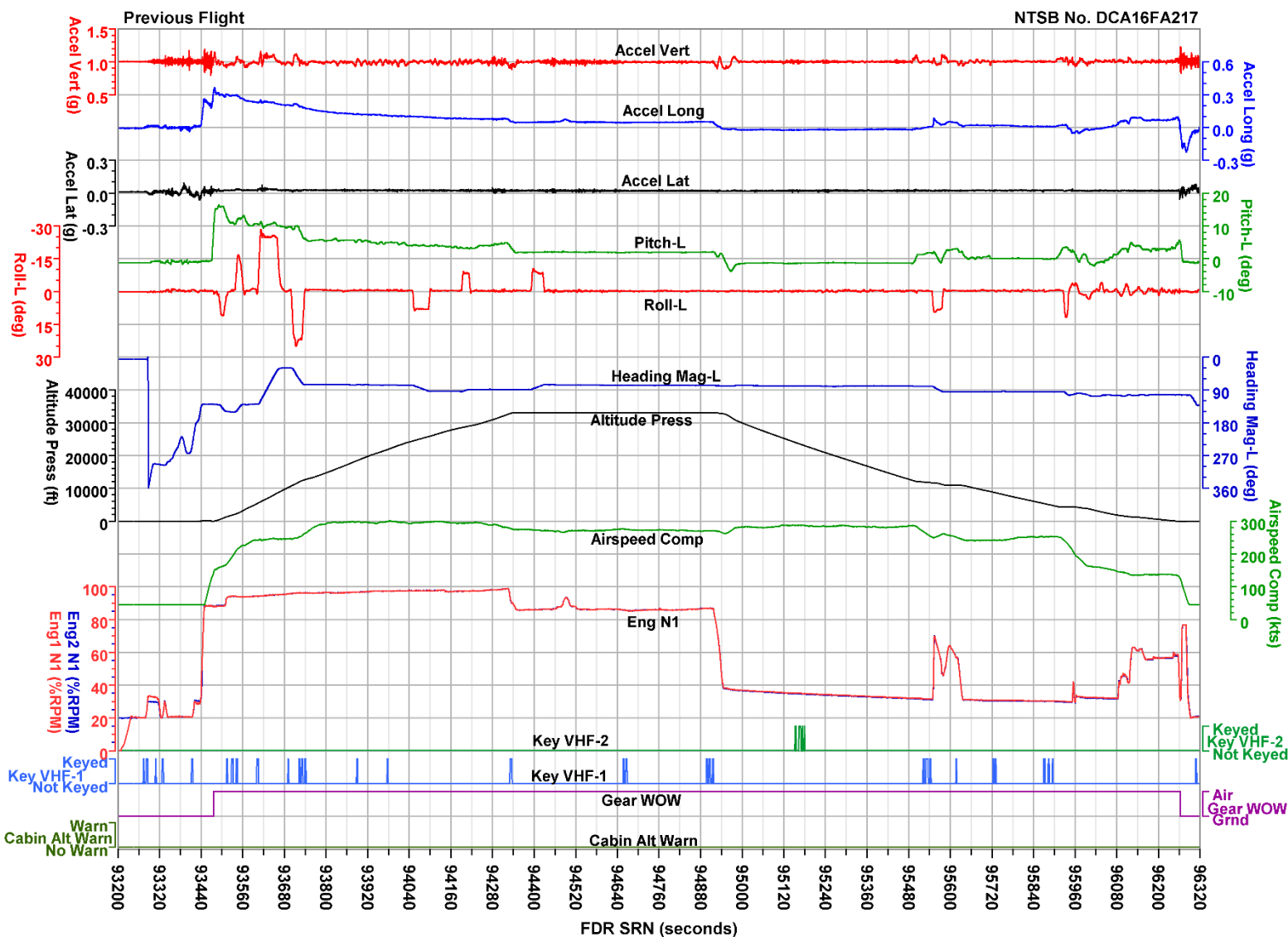
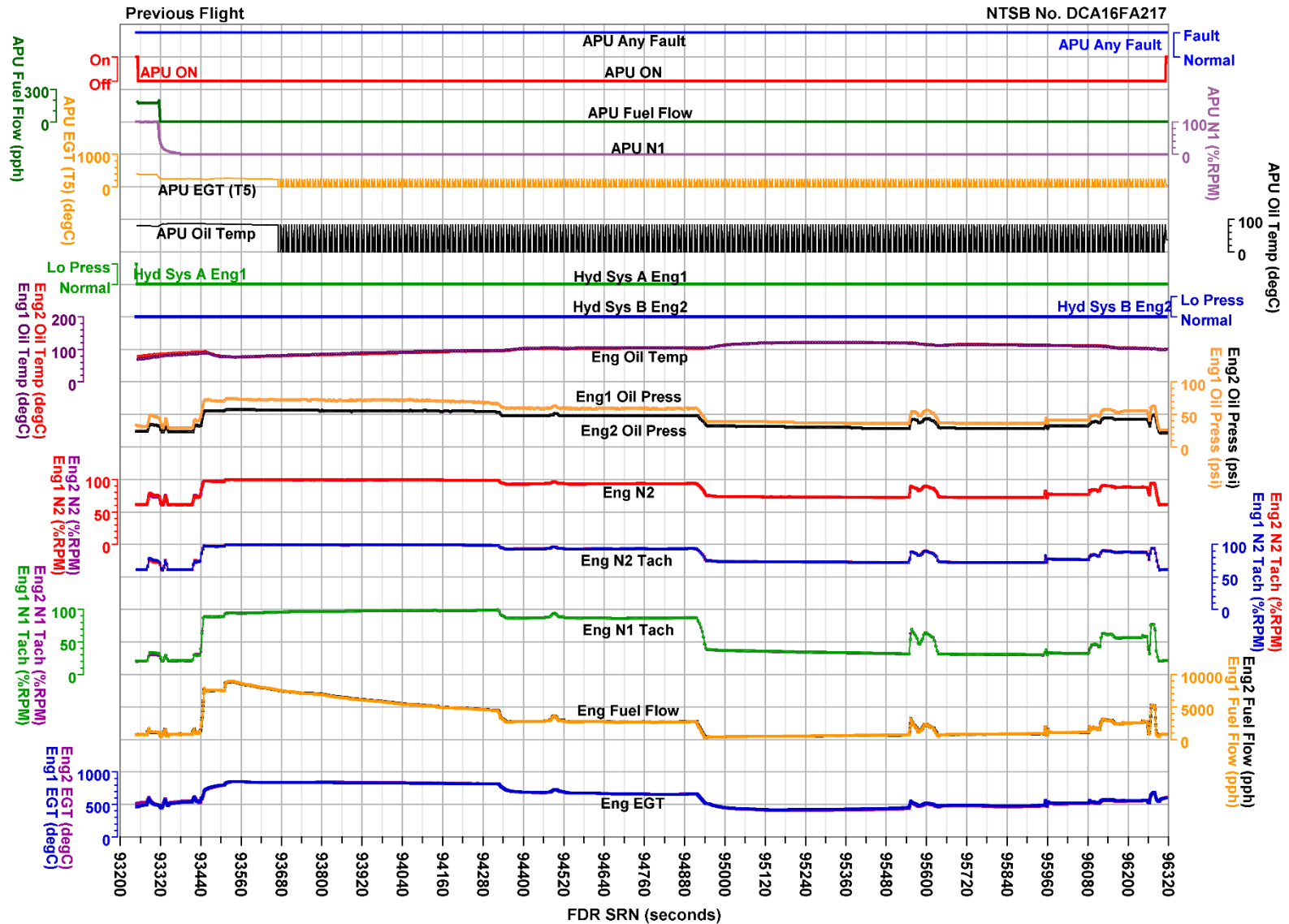


Figure 6. Plot of select engine parameters during previous flight.



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Figure 7. Plot of additional engine parameters during previous flight.

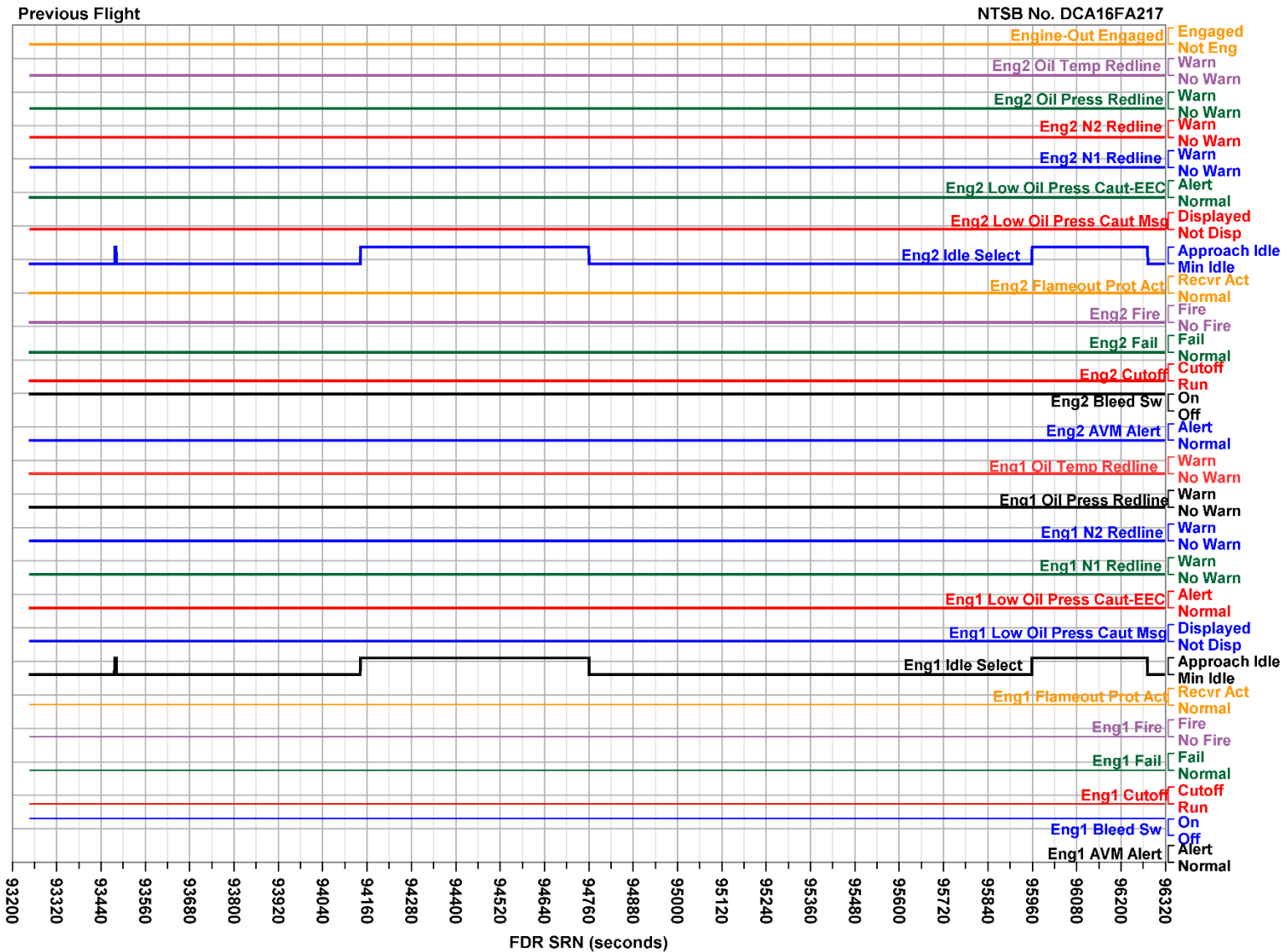


Figure 8. Plot of engine vibration parameters during previous flight.

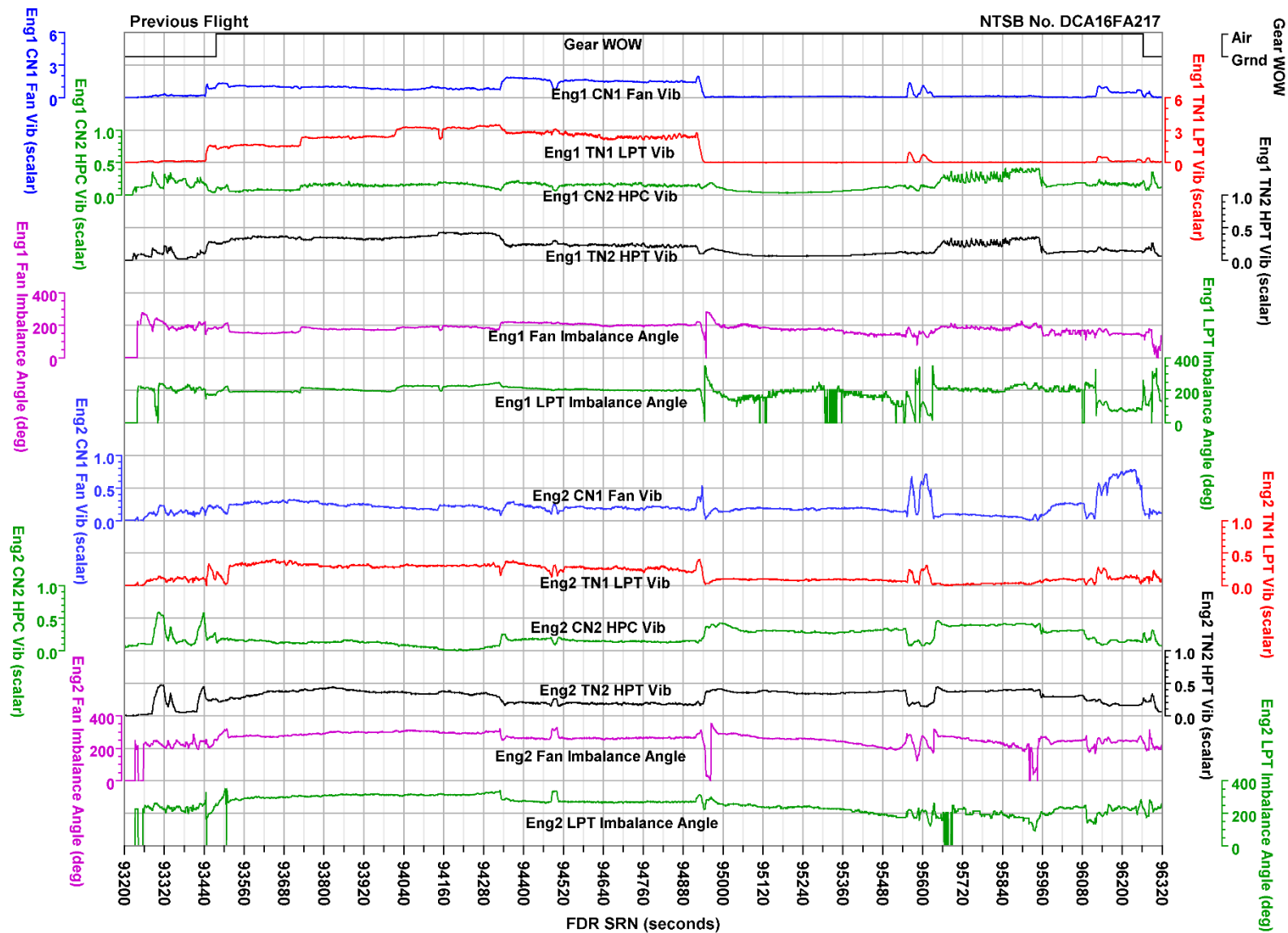
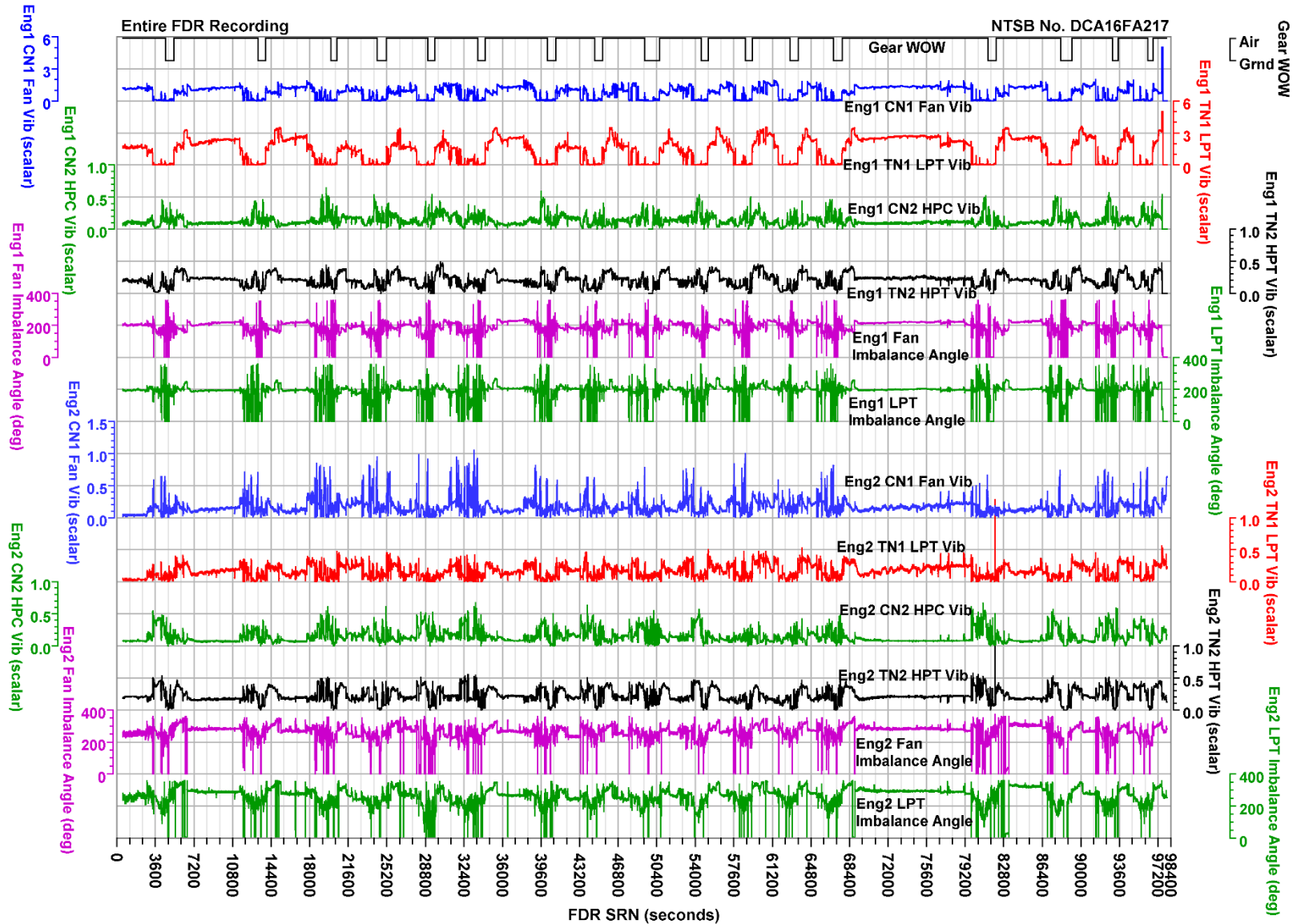


Figure 9. Plot of engine vibration parameters during entire FDR recording.



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APPENDIX A

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

Table A-1. Verified and provided FDR parameters.

Parameter Names	Parameter Descriptions	Units
Accel Lat	Lateral Acceleration	g
Accel Long	Longitudinal Acceleration	g
Accel Vert	Vertical Acceleration	g
Airspeed Comp	Computed Airspeed	kts
Altitude Press	Pressure Altitude	ft
APU Any Fault	Auxiliary Power Unit Any Fault	
APU EGT (T5)	Auxiliary Power Unit Exhaust Gas Temperature	degC
APU Fuel Flow	Auxiliary Power Unit Fuel Flow	pph
APU N1	Auxiliary Power Unit Speed	%RPM
APU Oil Temp	Auxiliary Power Unit Oil Temperature	degC
APU ON	Auxiliary Power Unit On	
Cabin Alt Warn	Cabin Altitude Warning	
Eng# AVM Alert	Engine Airborne Vibration Monitor Alert	
Eng# Bleed Sw	Engine Bleed Switch	
Eng# CN1 Fan Vib	Engine Fan Vibration Magnitude	scalar
Eng# CN2 HPC Vib	Engine High Pressure Compressor Vibration Magnitude	scalar
Eng# Cutoff	Engine Cutoff	
Eng# EGT	Engine Exhaust Gas Temperature	degC
Eng# Fail	Engine Fail	
Eng# Fan Imbalance Angle	Engine Fan Imbalance Angle	deg
Eng# Fire	Engine Fire	
Eng# Flameout Prot Act	Engine Flameout Protection Logic Active	
Eng# Fuel Flow	Engine Fuel Flow	pph
Eng# Idle Select	Engine Idle Select	
Eng# Low Oil Press Caut Msg	Engine Low Oil Pressure Caution Message	
Eng# Low Oil Press Caut-EEC	Engine Low Oil Pressure Caution-Electronic Engine Control	
Eng# LPT Imbalance Angle	Engine Low Pressure Turbine Imbalance Angle	deg
Eng# N1	Engine Fan Speed	%RPM
Eng# N1 Redline	Engine Fan Speed Redline	
Eng# N1 Tach	Engine Fan Speed Tachometer	%RPM
Eng# N2	Engine Core Speed	%RPM
Eng# N2 Redline	Engine Core Speed Redline	
Eng# N2 Tach	Engine Core Speed Tachometer	%RPM
Eng# Oil Press	Engine Oil Pressure	psi
Eng# Oil Press Redline	Engine Oil Pressure Redline	
Eng# Oil Temp	Engine Oil Temperature	degC
Eng# Oil Temp Redline	Engine Oil Temperature Redline	
Eng# TN1 LPT Vib	Engine Low Pressure Turbine Vibration Magnitude	scalar
Eng# TN2 HPT Vib	Engine High Pressure Turbine Vibration Magnitude	scalar
Engine-Out Engaged	Engine Out Engaged	
Gear WOW	Gear Weight on Wheels	
Heading Mag-L	Magnetic Heading – Left	deg
Hyd Sys A Eng1	Hydraulic System A Engine 1	
Hyd Sys B Eng2	Hydraulic System B Engine 2	
Key VHF-1	Microphone Keying-1	
Key VHF-2	Microphone Keying-2	

Parameter Names	Parameter Descriptions	Units
Pitch-L	Pitch Angle – Left	deg
Roll-L	Roll Angle - Left	deg
Time GMT Hrs	Greenwich Meantime Hours	hrs
Time GMT Min	Greenwich Meantime Minutes	min
Time GMT Sec	Greenwich Meantime Seconds	sec

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: For this aircraft, there are 2 engines. In the data plots and tabular data, the '#' ranges from 1 to 2.

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 Abbreviations	Descriptions
%RPM	percent revolutions per minute
deg	degrees
degC	degrees Celsius
Disp	Displayed
Eng	Engaged
ft	feet
Grnd	Ground
hrs	hours
kts	knots
Lo	Low
min	minutes
Min	Minimum
pph	pounds per hour
Press	Pressure
psi	pounds per square inch
Recvr Act	Recover Active
sec	seconds