National Transportation Safety Board
Office of Research and Engineering
Washington, DC 20594

DCA21FA085

FLIGHT DATA RECORDER

Specialist's Factual Report

August 1, 2022

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A. INCIDENT

Location: Broomfield, Colorado
Date: February 20, 2021
Time: 1309 mountain standard time (MST)
Airplane: Boeing 777-222, United Airlines, UA328, N772UA

B. FLIGHT DATA RECORDER SPECIALIST

Specialist: Michael Portman
Aerospace Engineer – Recorder Specialist
National Transportation Safety Board (NTSB)

C. FEDERAL CARRIAGE REQUIREMENTS

The event aircraft, N772UA, was operating under Title 14 *Code of Federal Regulations* (CFR) Part 121. The event aircraft was manufactured in 1994 and was operating such that it was required to be equipped with a Flight Data Recorder (FDR) that recorded, at a minimum, 34 parameters, as cited in 14 CFR Part 121.344(d).

D. DETAILS OF THE INVESTIGATION

An FDR group was not convened. The NTSB Vehicle Recorder Division received the following FDRs:

Recorder Manufacturer/Model:	Honeywell 4700
Part Number:	980-4700-042
Recorder Serial Number:	6543

Recorder Manufacturer/Model:	Optical Quick Access Recorder (OQAR)
Part Number:	29-3130-3-0002
Recorder Serial Number:	Unknown

1.0 Honeywell 4700 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 128 12-bit words of digital information every second. Each grouping of 128 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

128-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-C124a.

1.1 Recorder Condition

The recorder was in good condition and the data were extracted normally from the recorder.

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 35 minutes. The parameters evaluated for the purpose of this report appeared to be in accordance with federal FDR carriage requirements.

1.2.1 Engineering Unit Conversions

The engineering unit 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 1 lists the FDR parameters verified and provided in this report. Additionally, Table 2 describes the unit and discrete state abbreviations used in this report.

1.3 Time Correlation

Correlation of the FDR data from SRN to the event local time, MST, was established by using the recorded Greenwich mean time (GMT) Hours, GMT Minutes, and GMT Seconds and then applying an additional 7 hours offset to change GMT to MST.[2]

Accordingly, the time offset for the event flight data from SRN to local MST is the following: MST = SRN – 146,991. Therefore, for the rest of this report, all times are referenced as MST, not SRN.

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[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).

2.0 OQAR Description, Carriage Requirements, and Recording Description

QARs are typically used in Flight Data Monitoring or Flight Operations Quality Assurance programs. QARs have no Federal Aviation Administration carriage requirements. The aircraft was equipped with a QAR system which recorded flight data in the same format as the FDR, therefore the QAR data were not analyzed for this event.

E. FIGURES AND TABULAR DATA

Figure 1 to Figure 22 contain FDR data recorded during the event on February 20, 2021. All the parameters listed in Table 1 are plotted except Latitude, Longitude, Time GMT Hours, Time GMT Minutes, and Time GMT Seconds.

Figure 1, Figure 2, and Figure 3 show basic parameters during the entire incident flight, during the time surrounding the engine event, and zoomed to show the engine event in detail, respectively.

Figure 4 and Figure 5 show autopilot related parameters during the entire event flight, and during the engine event, respectively.

Figure 6 and Figure 7 show pitch control related parameters during the entire event flight, and during the engine event, respectively.

Figure 8 and Figure 9 show roll control related parameters during the entire event flight, and during the engine event, respectively.

Figure 10 shows hydraulic parameters during the entire event flight.

Figure 11 and Figure 12 show basic engine parameters during the entire event flight, and during the engine event, respectively.

Figure 13 and Figure 14 show engine oil and vibration parameters during the entire event flight, and during the engine event, respectively.

Figure 15 and Figure 16 show miscellaneous engine parameters during the entire event flight, and during the engine event, respectively.

Figure 17 and Figure 18 show target engine thrust parameters during the entire event flight, and during the engine event, respectively.

Figure 19 and Figure 20 show additional miscellaneous engine parameters during the entire event flight, and during the engine event, respectively.

Figure 21 and Figure 22 show commanded engine thrust parameters during the entire event flight, and during the engine event, respectively.

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 summary, the aircraft taxied and subsequently took off from Denver International Airport, Denver, Colorado (DEN), at 13:04:40 with no readily apparent issues. At approximately 13:08:23, at a pressure altitude of 12,110 ft, engine power was slightly increased, consistent with an application of power to increase climb rate. Upon reaching a pressure altitude of approximately 12,570 ft, at 13:08:33, multiple parameters associated with the right-hand engine (engine 2) dropped significantly, including N1, N2, EPR, and fuel flow, while the exhaust gas temperature (EGT) noticeably raised in comparison to engine 1. Shortly thereafter, numerous vibrations were recorded in the right-hand engine, and both engine 2 fire warning parameters activated. After reaching a maximum pressure altitude of 13,456 ft at approximately 13:09:50, the aircraft began a descent down to 9,200 ft, reaching the altitude at 13:13:30 and remaining there until it began its descent towards DEN at 13:23:30.

Fire bottle 2 was discharged at approximately 13:11:47, and fire bottle 1 was discharged at approximately 13:12:36. However, the engine 2 fire warnings remained activated until 13:21:16. Returning to DEN, the aircraft touched down at approximately 13:28:10, and stopped on the runway at 13:29:12. The aircraft remained stationary for the remainder of the recording, which ended at 13:34:11.

The corresponding tabular data used to create Figure 1 to Figure 22, including Latitude, Longitude, 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.

Submitted by:

Michael Portman
Aerospace Engineer – Recorder Specialist

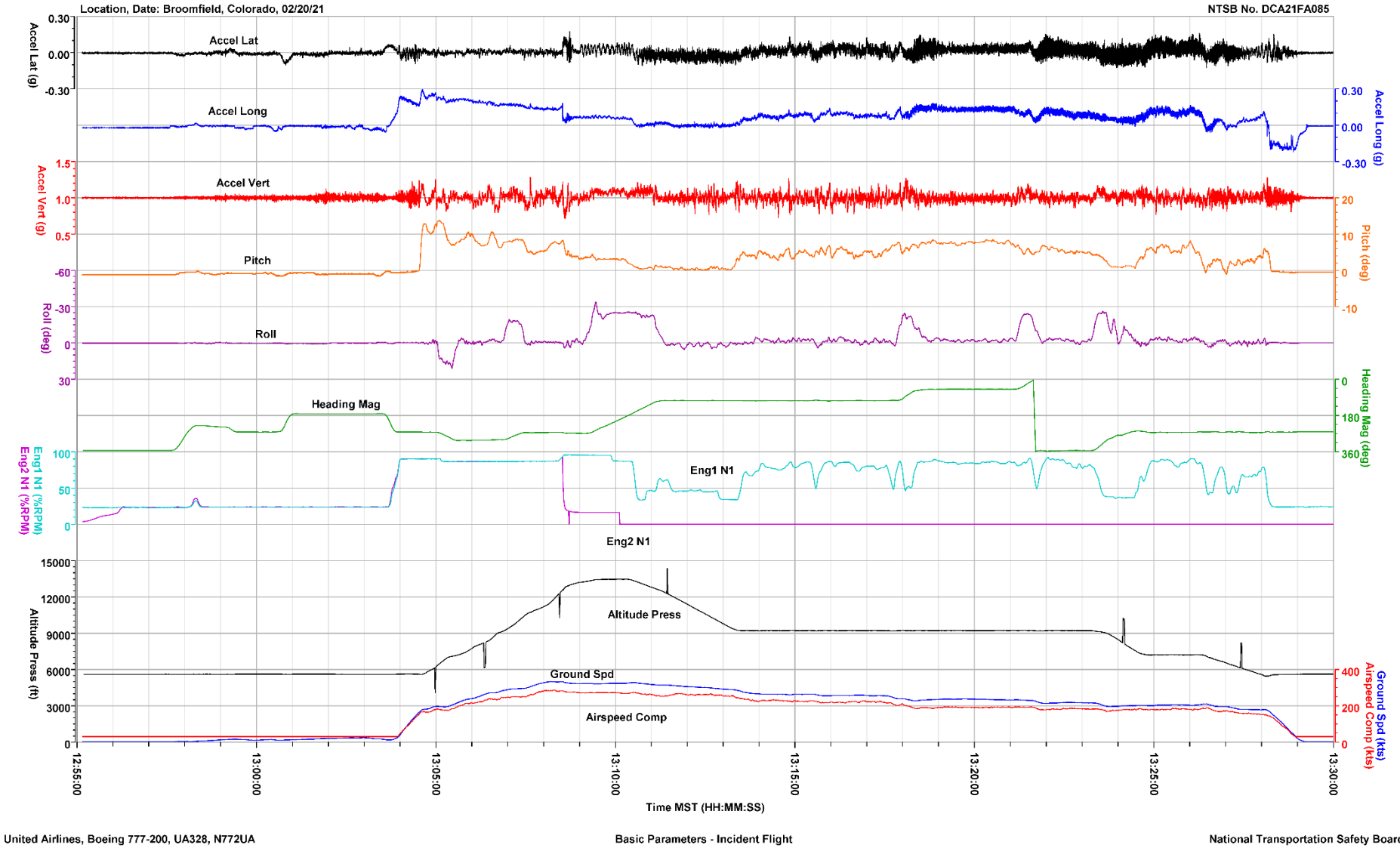

Figure 1. Plot of basic parameters for the entire incident flight.

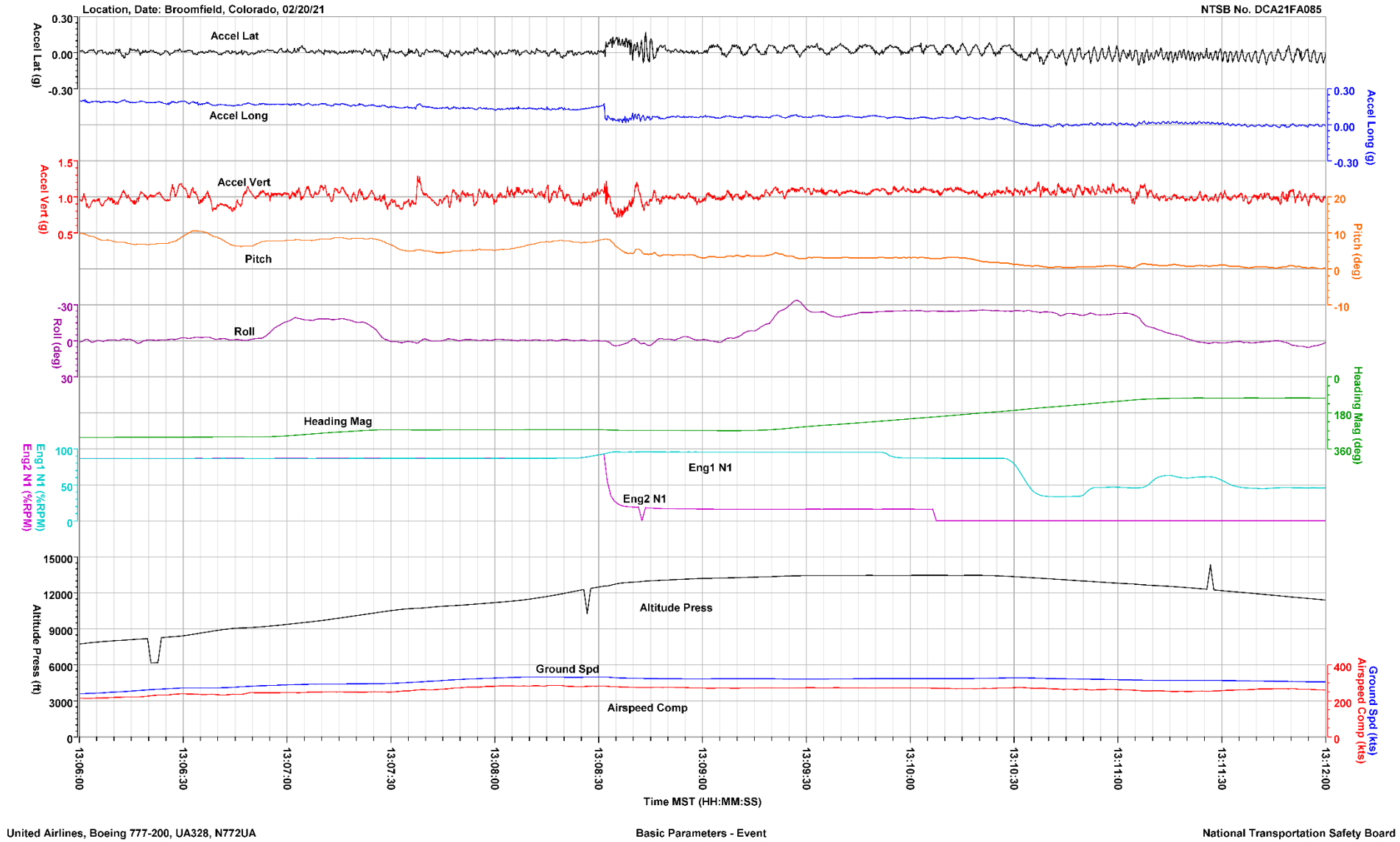

Figure 2. Plot of basic parameters during the engine event.

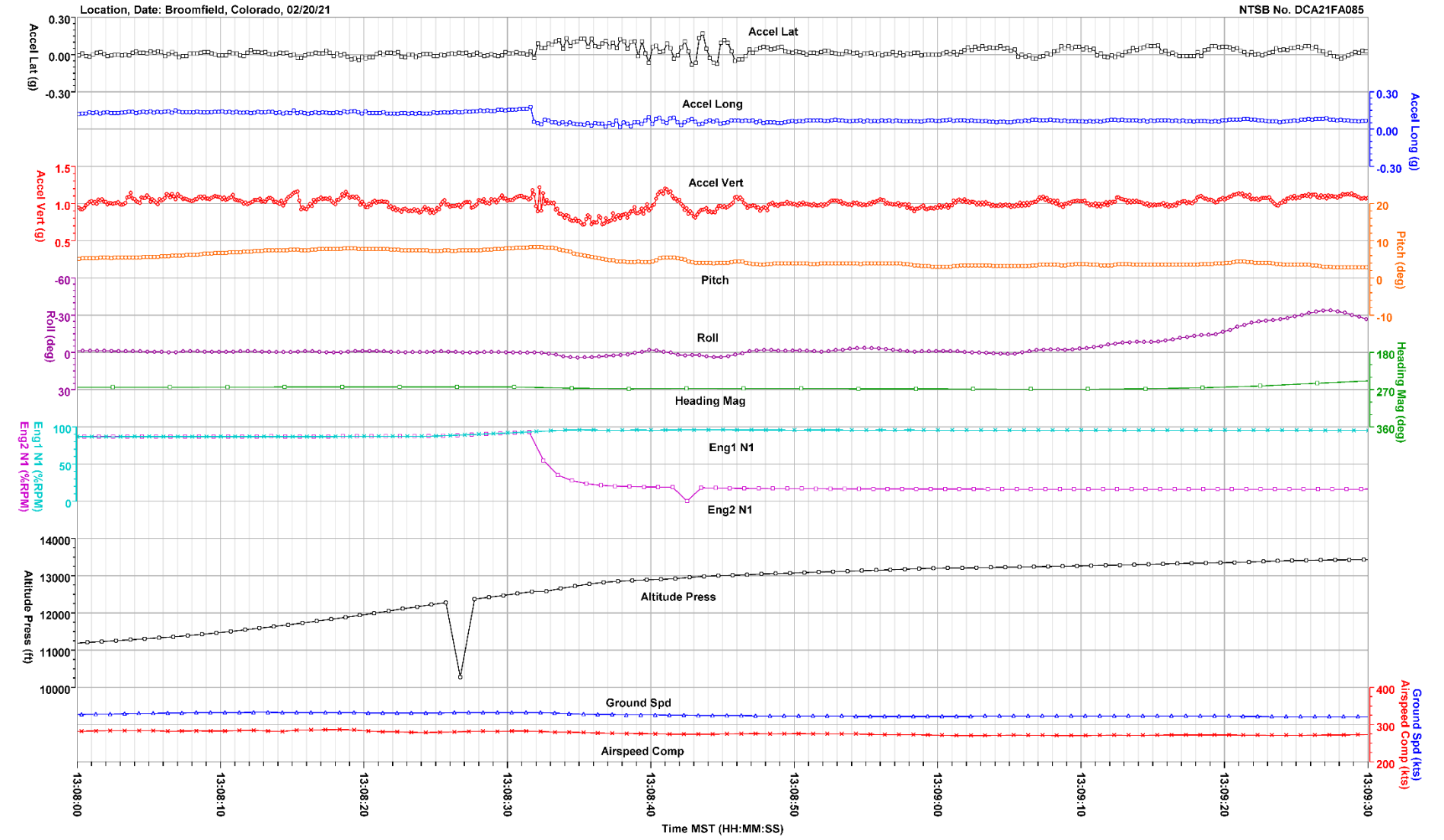

Figure 3. Plot of basic parameters zoomed to show detail of the engine event.

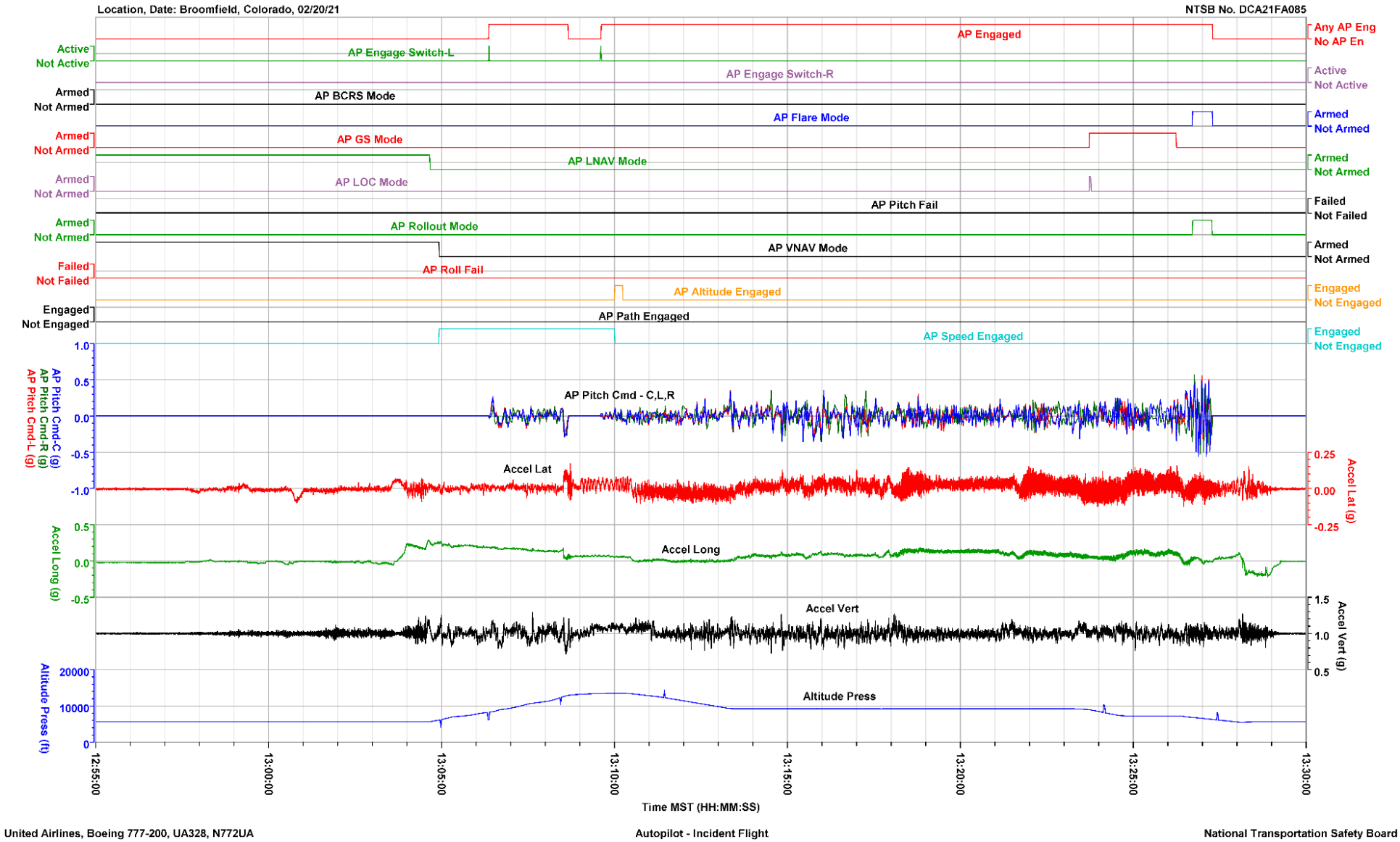

Figure 4. Plot of autopilot related parameters for the entire incident flight.

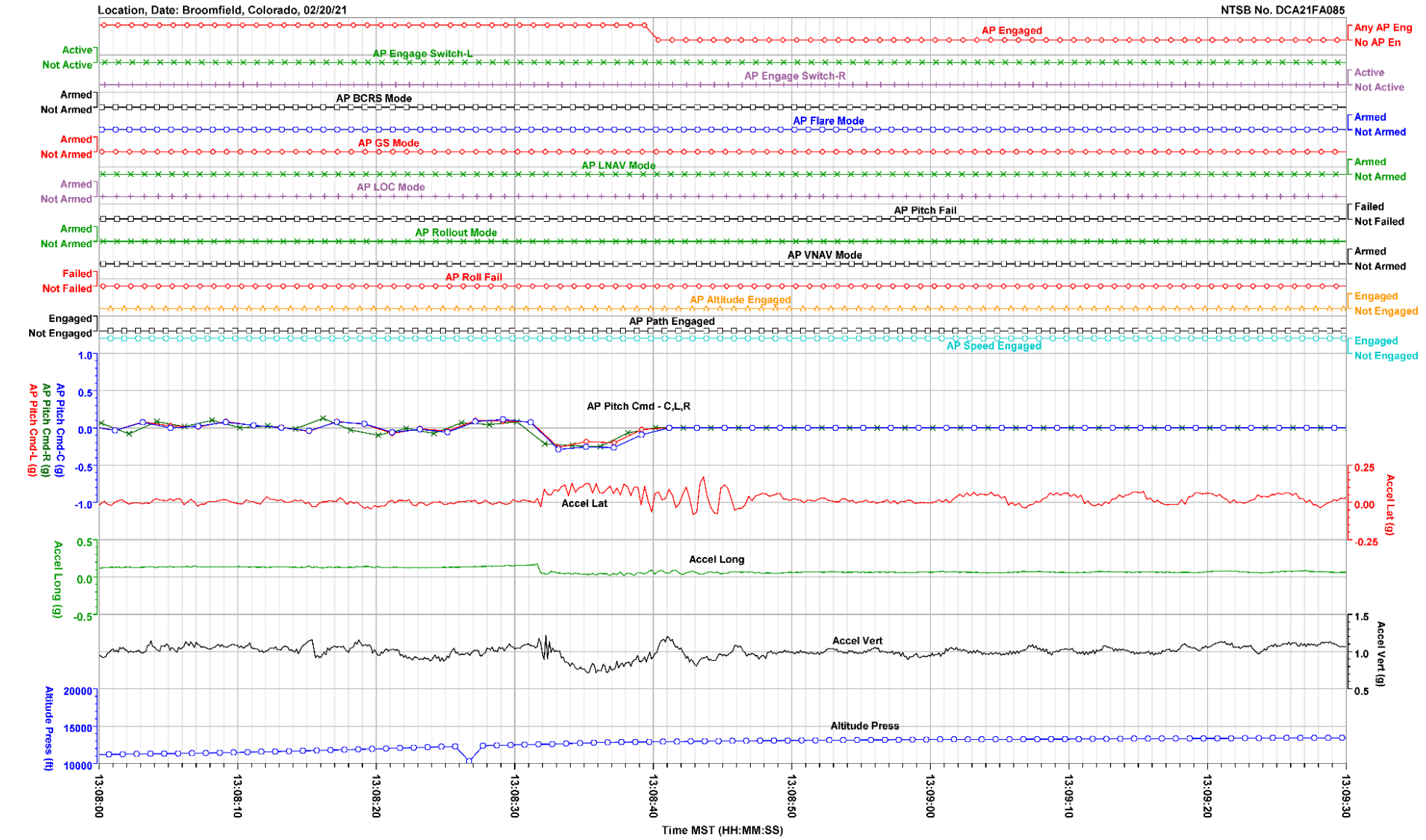

Figure 5. Plot of autopilot related parameters during the engine event.

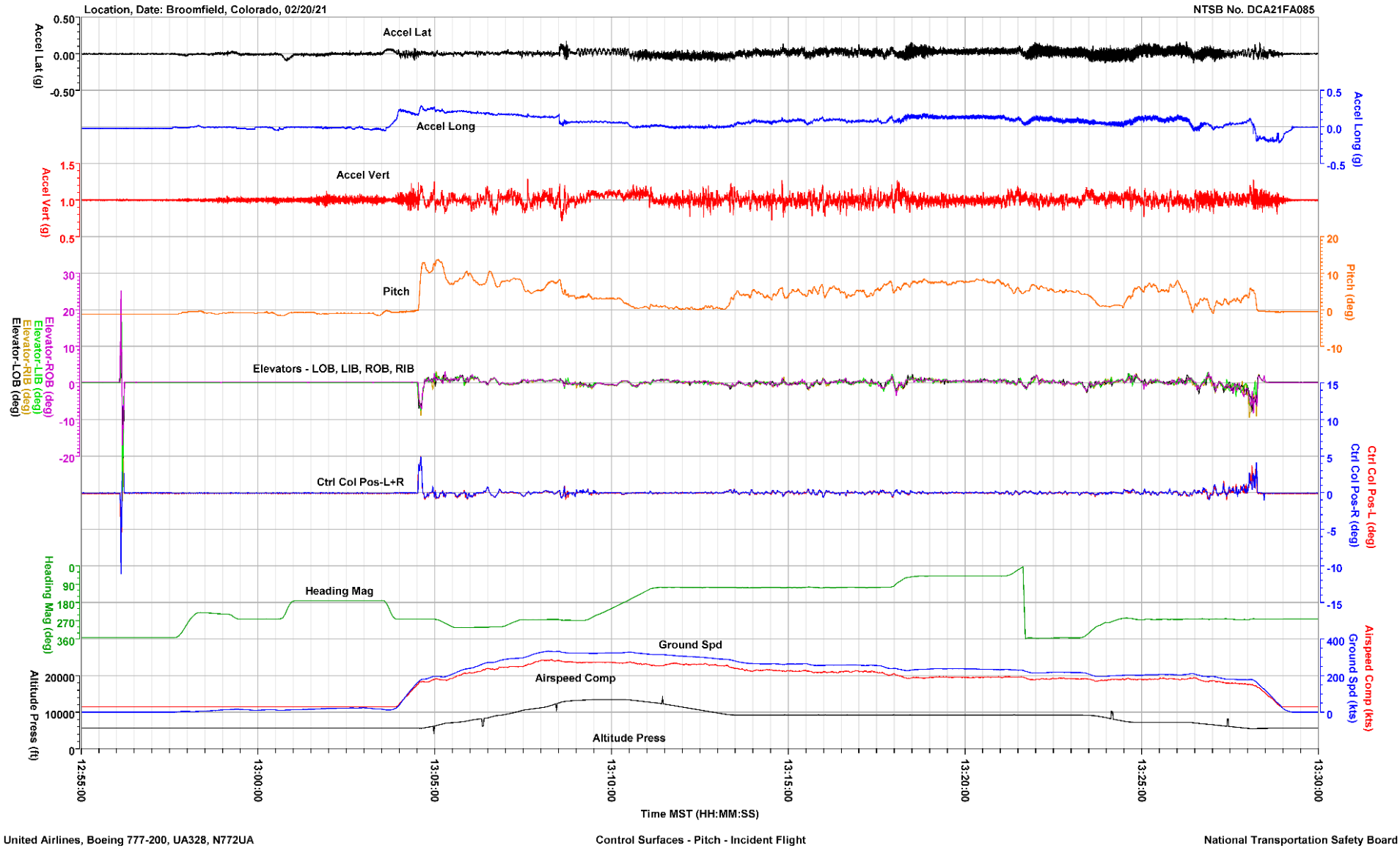

Figure 6. Plot of pitch control parameters for the entire incident flight.

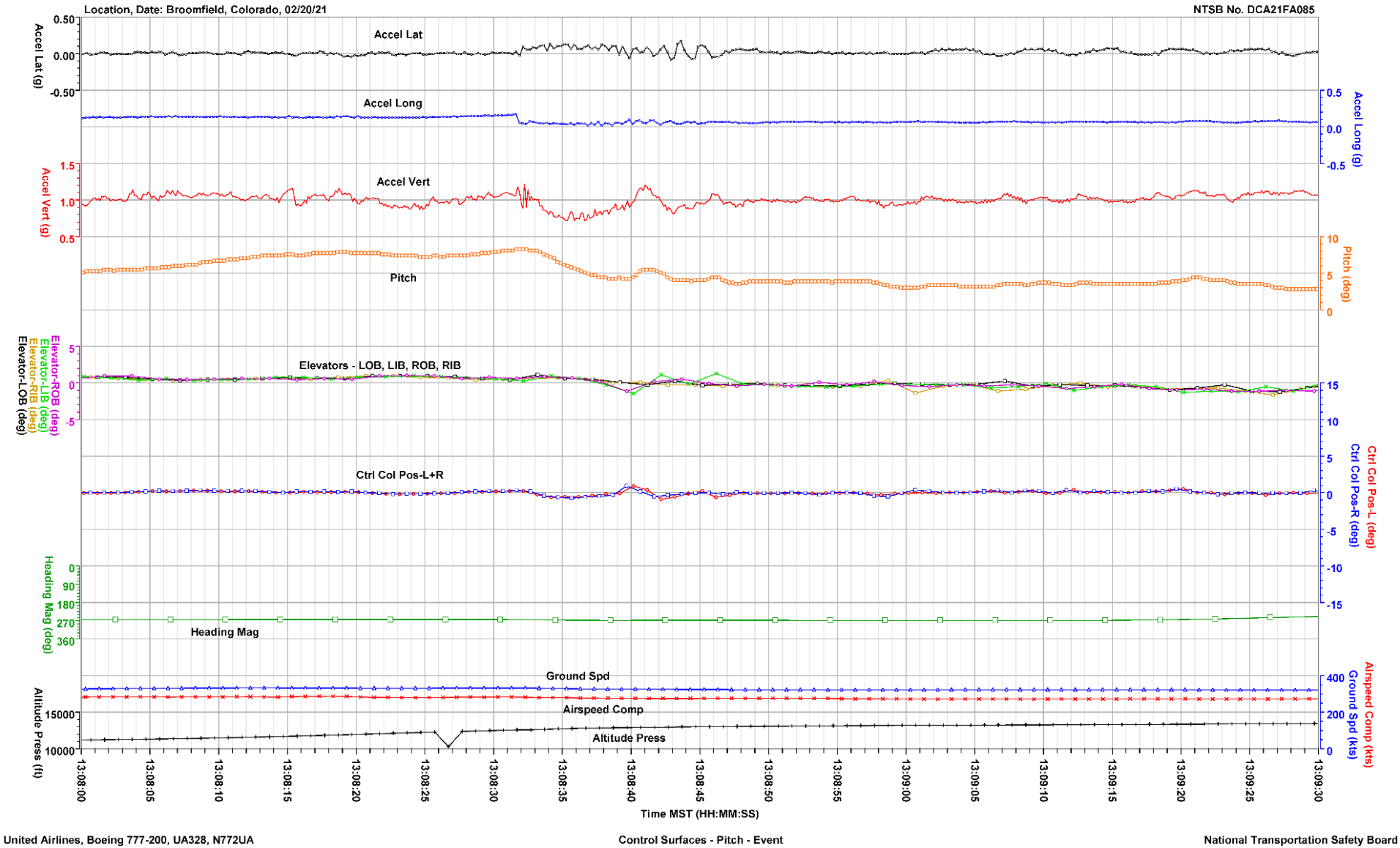

Figure 7. Plot of pitch control parameters during the engine event.

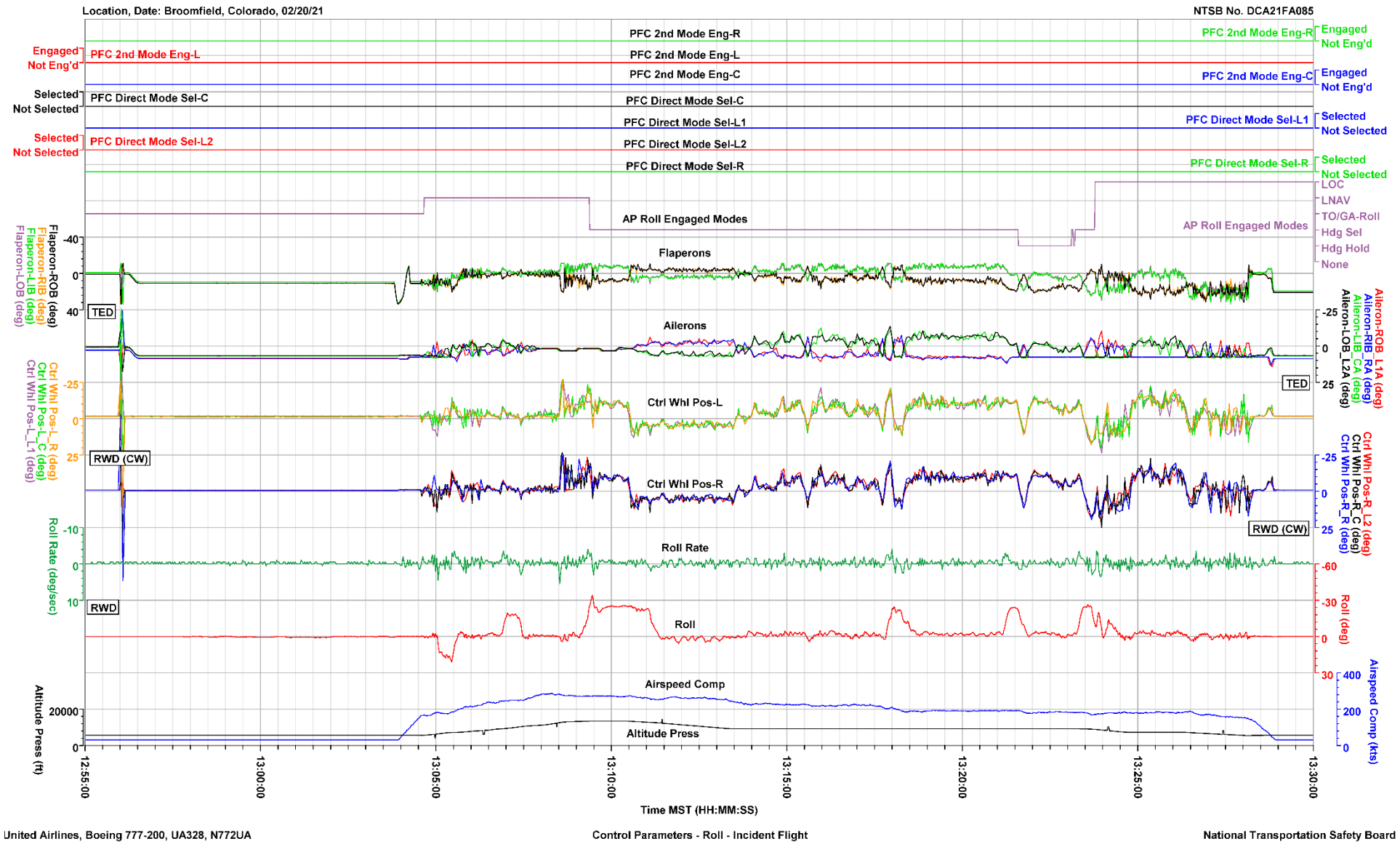

Figure 8. Plot of roll control parameters for the entire incident flight.

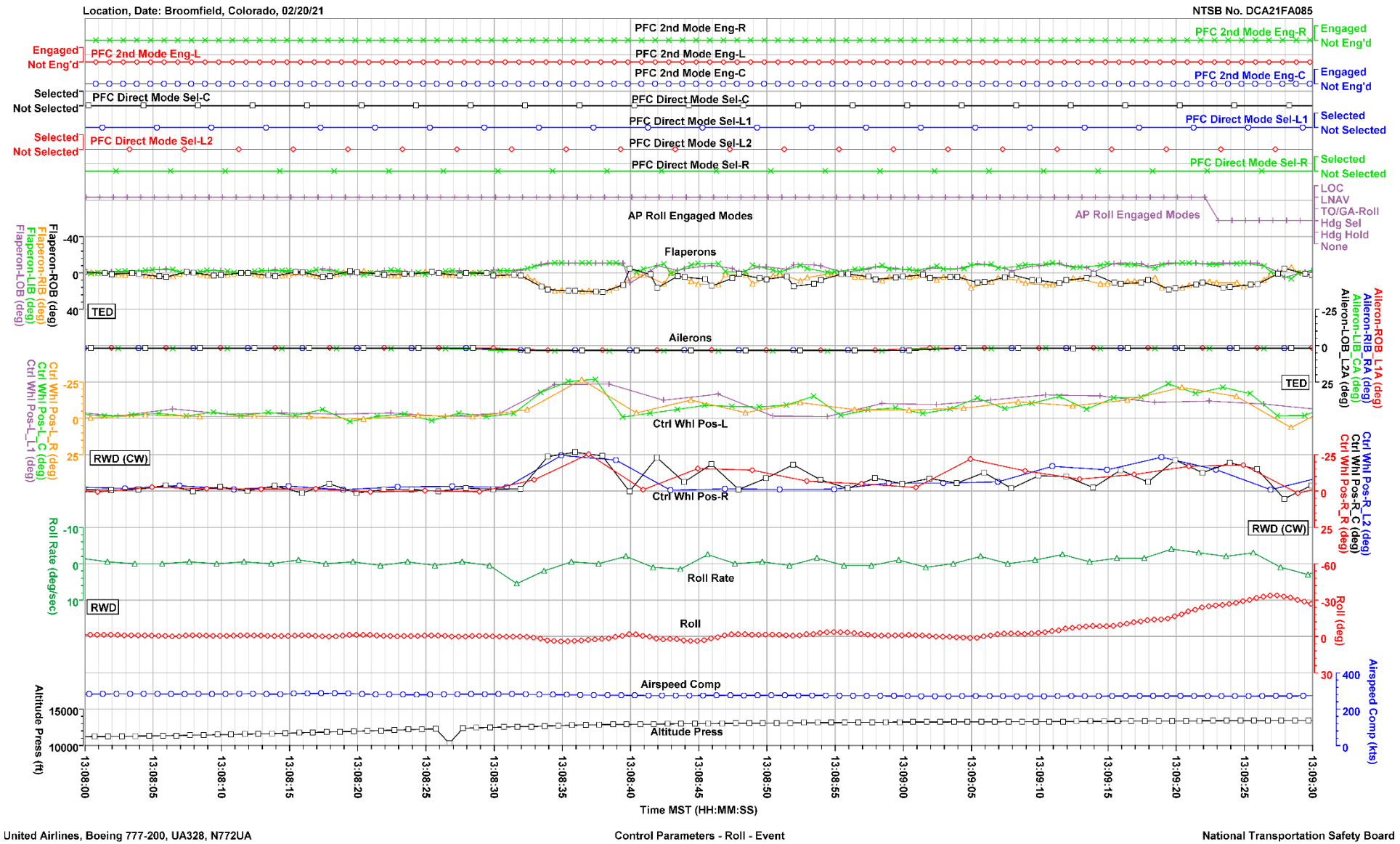

Figure 9. Plot of roll control parameters during the engine event.

Figure 10. Plot of hydraulic parameters for the entire incident flight.

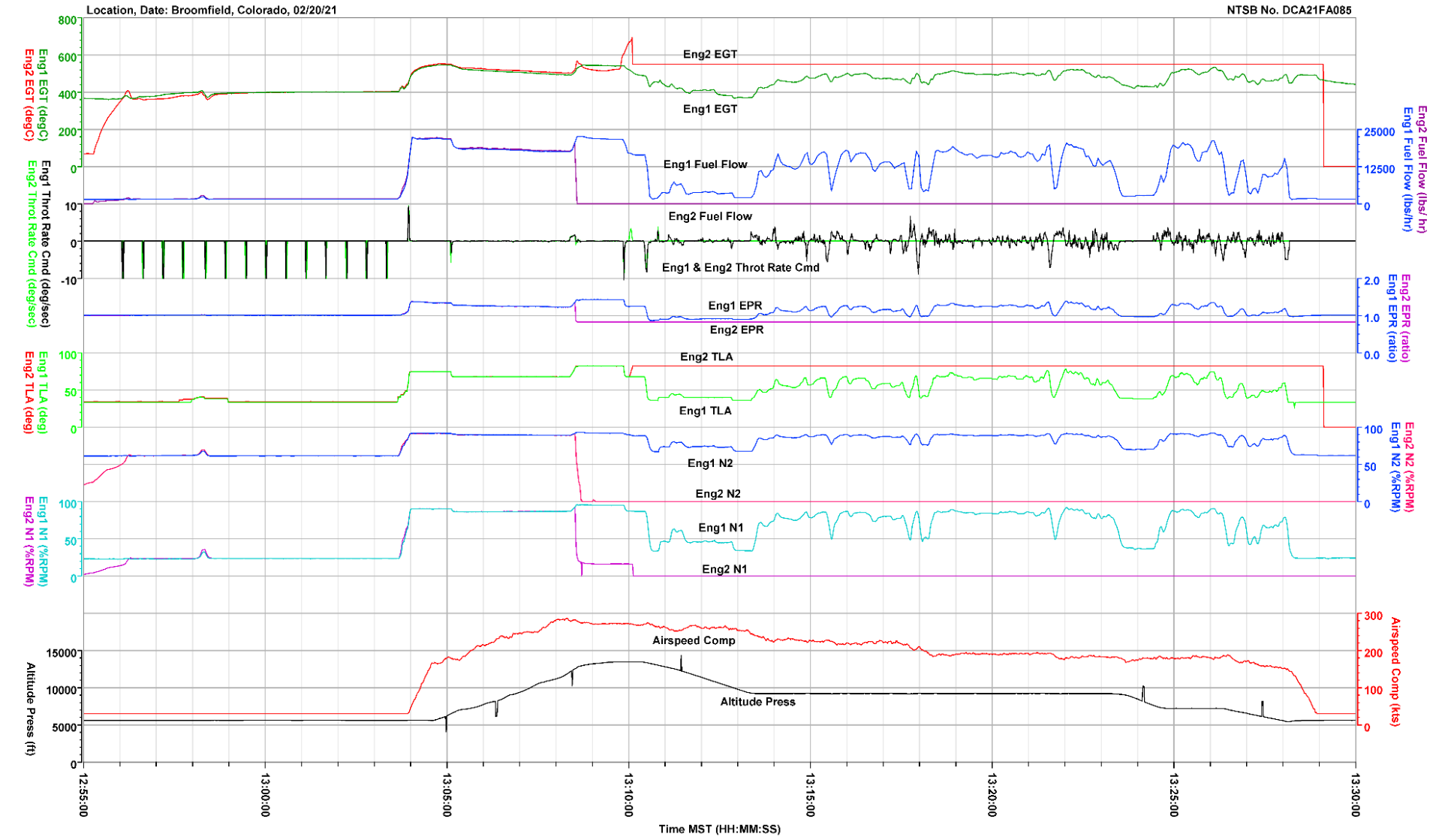

Figure 11. Plot of basic engine parameters for the entire incident flight.

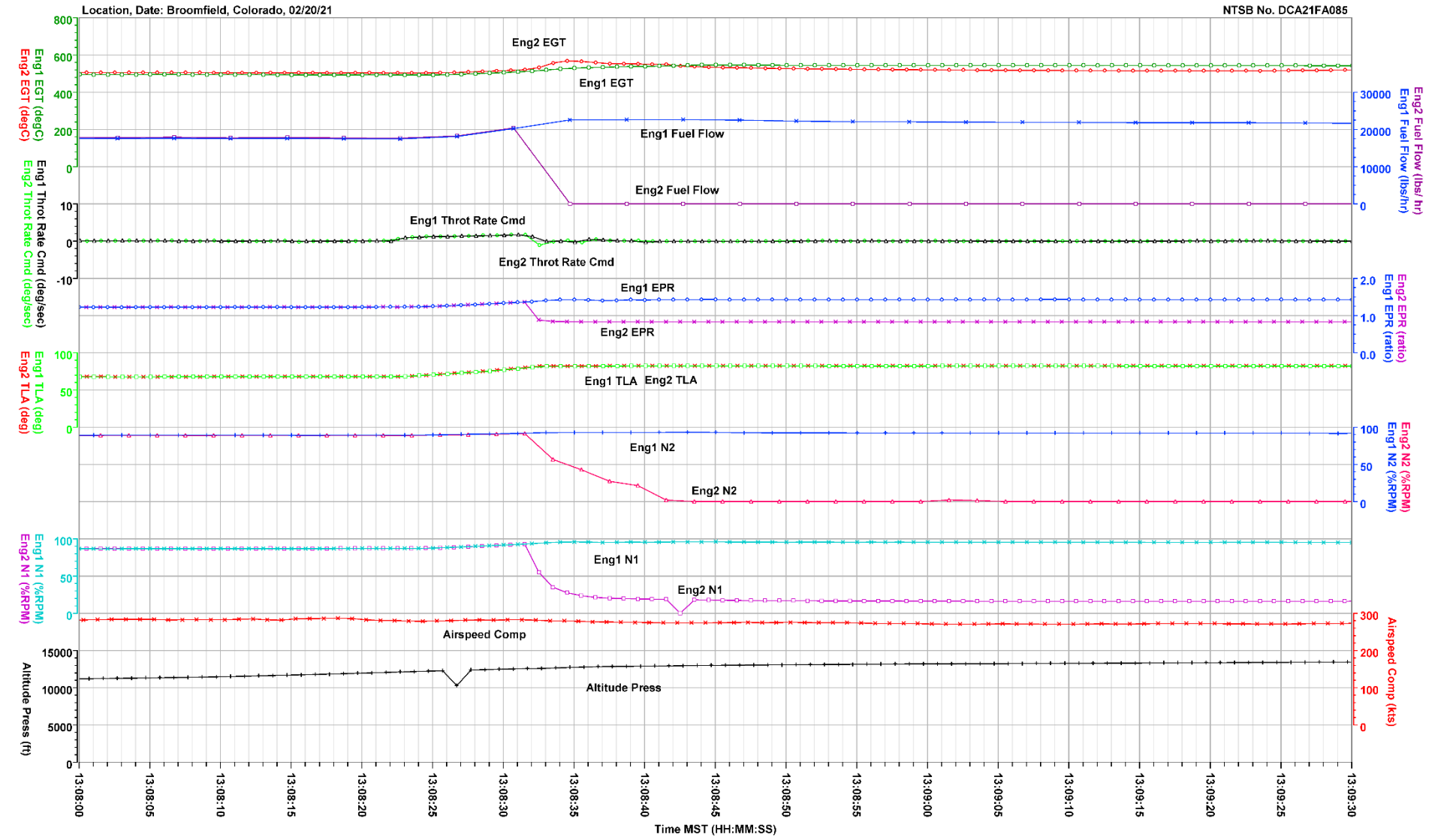

Figure 12. Plot of basic engine parameters during the engine event.

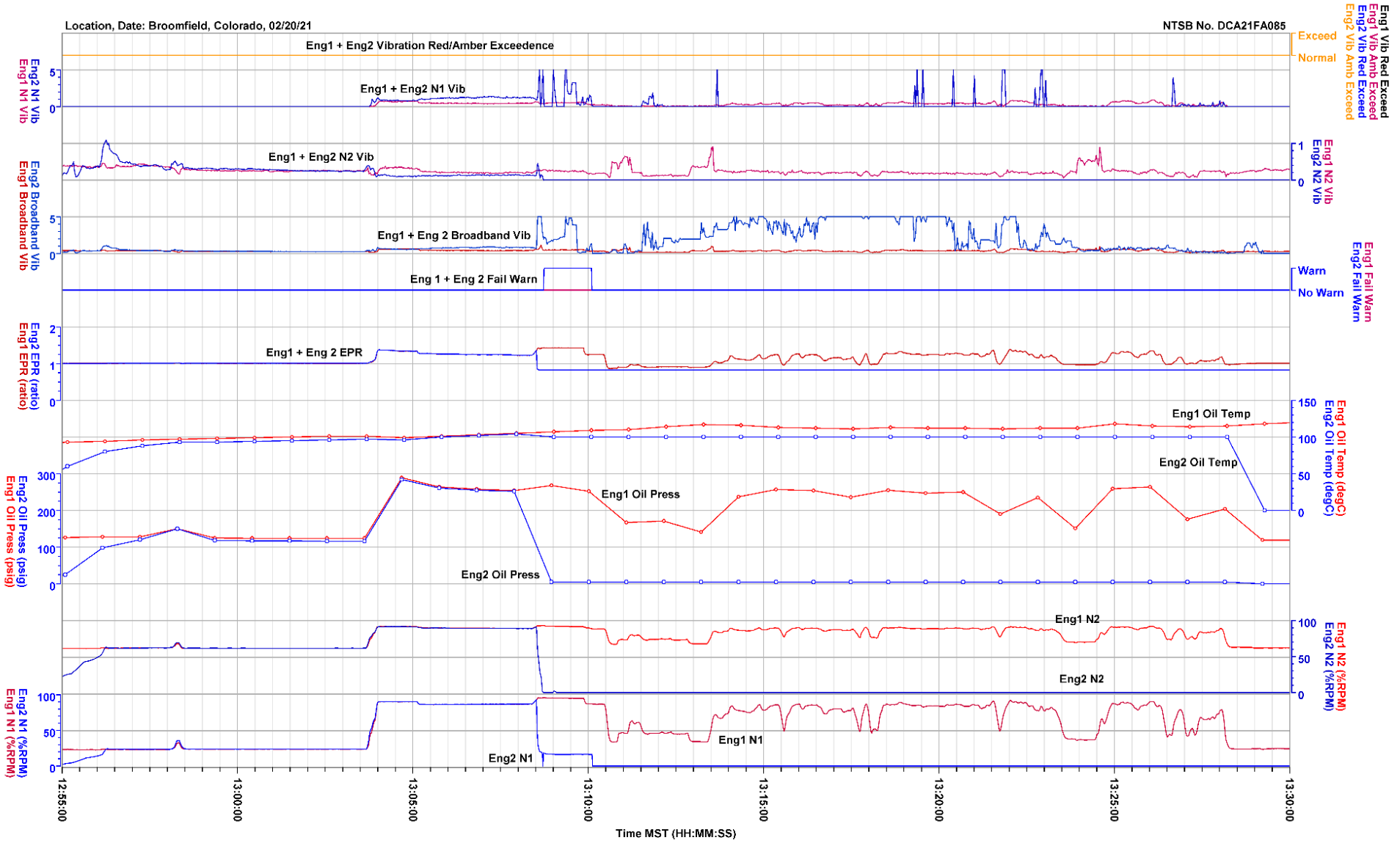

Figure 13. Plot of engine oil and vibration parameters for the entire incident flight.

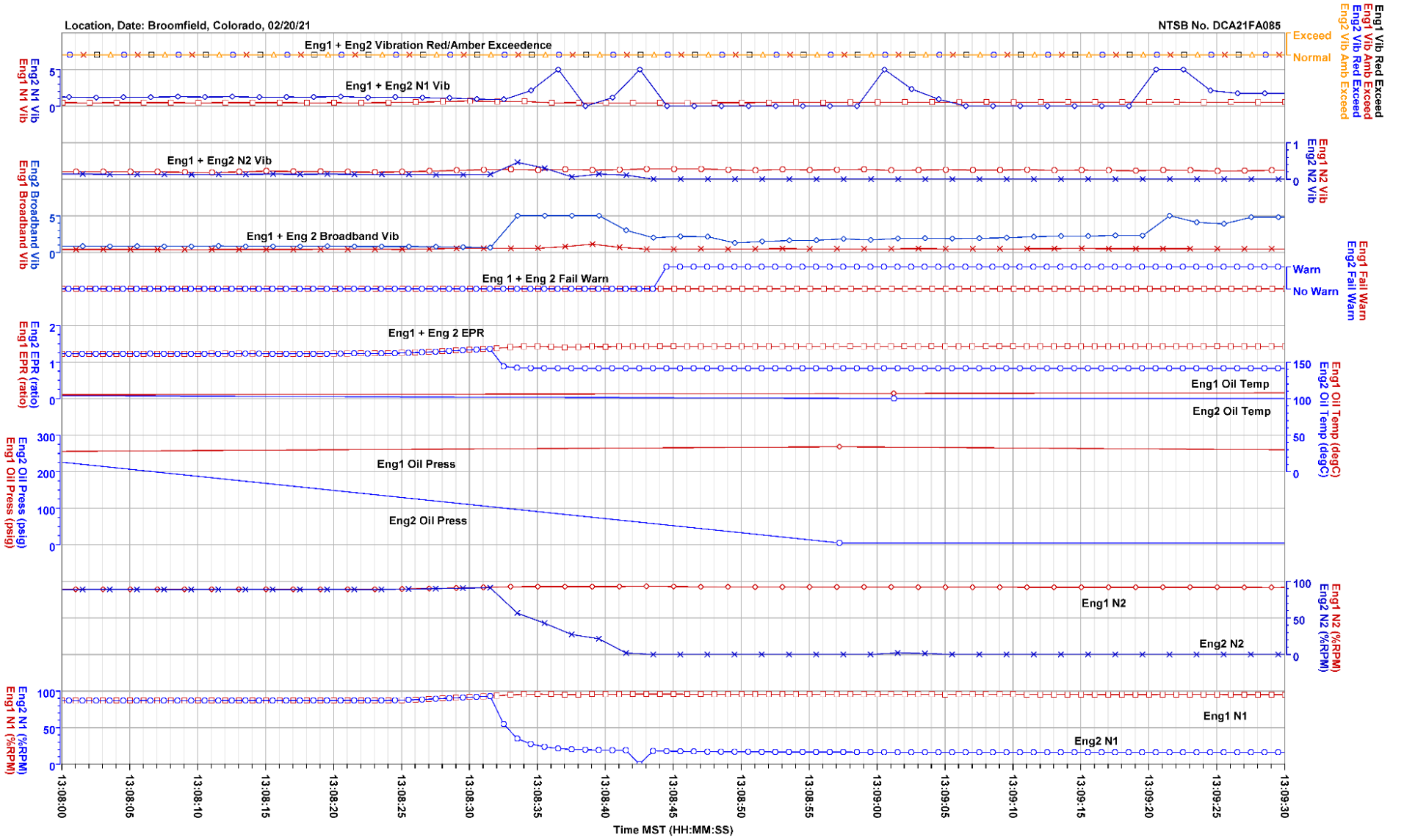

Figure 14. Plot of engine oil and vibration parameters during the engine event.

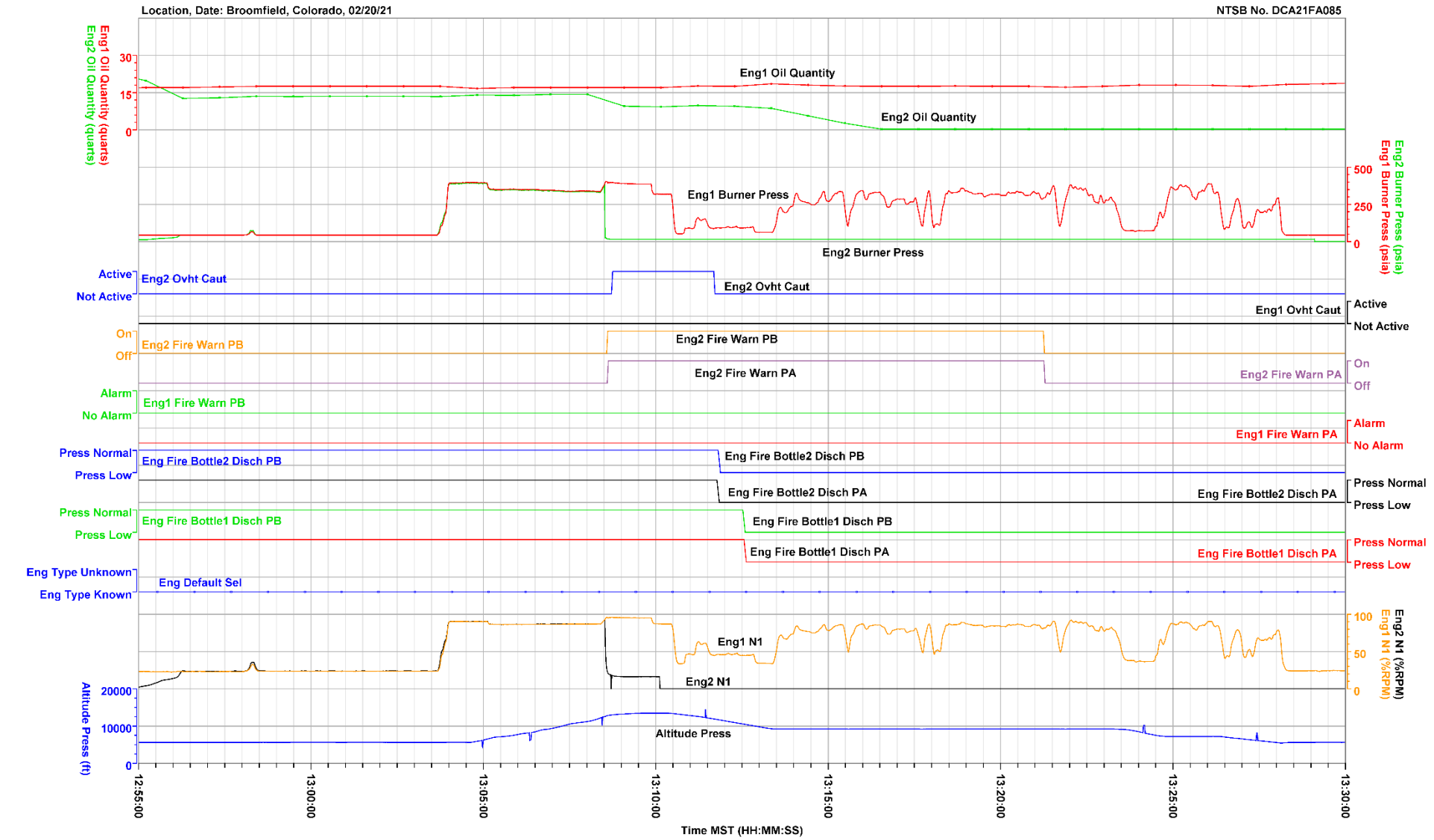

Figure 15. Plot of miscellaneous engine parameters for the entire incident flight.

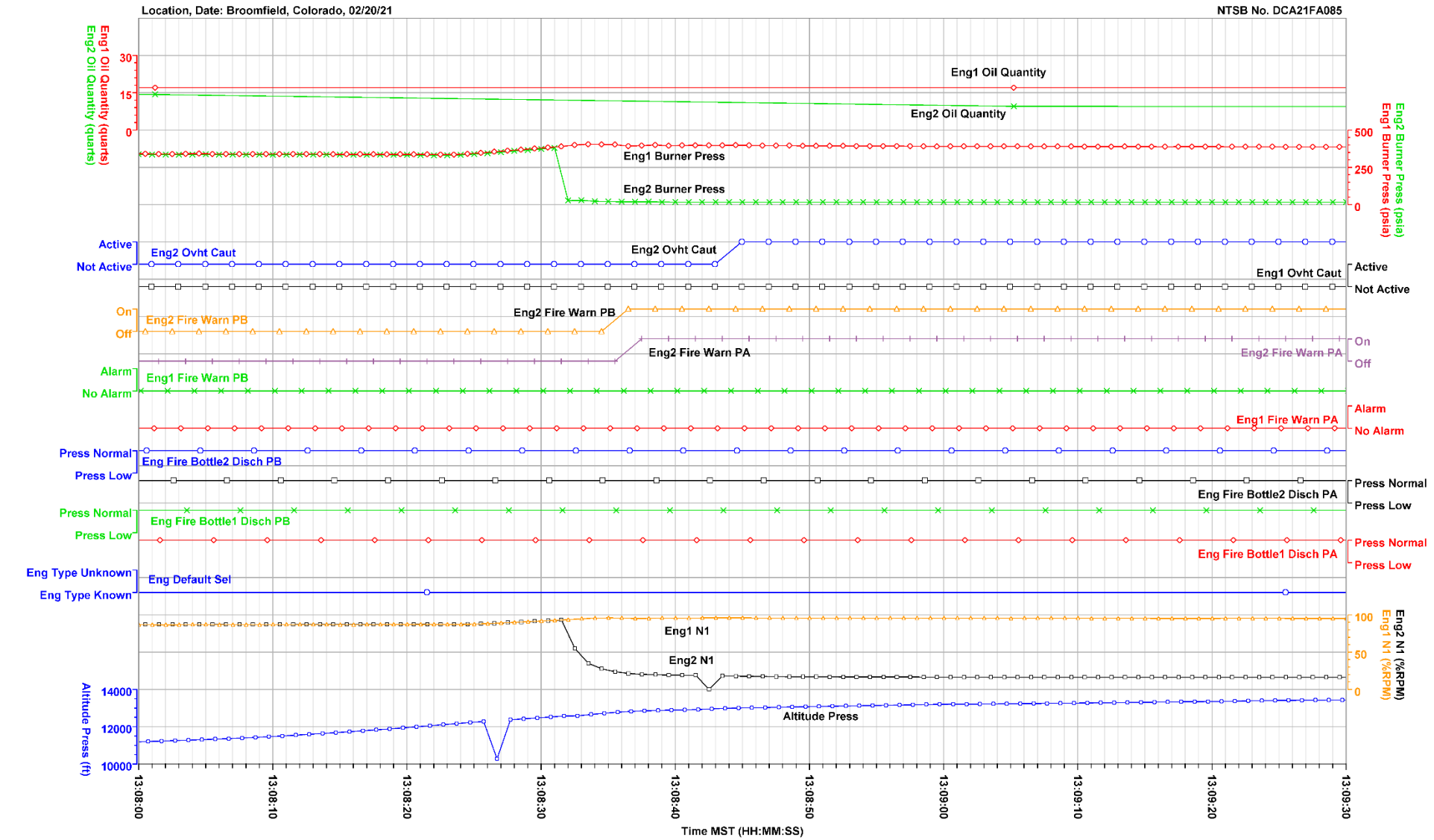

Figure 16. Plot of miscellaneous engine parameters during the engine event.

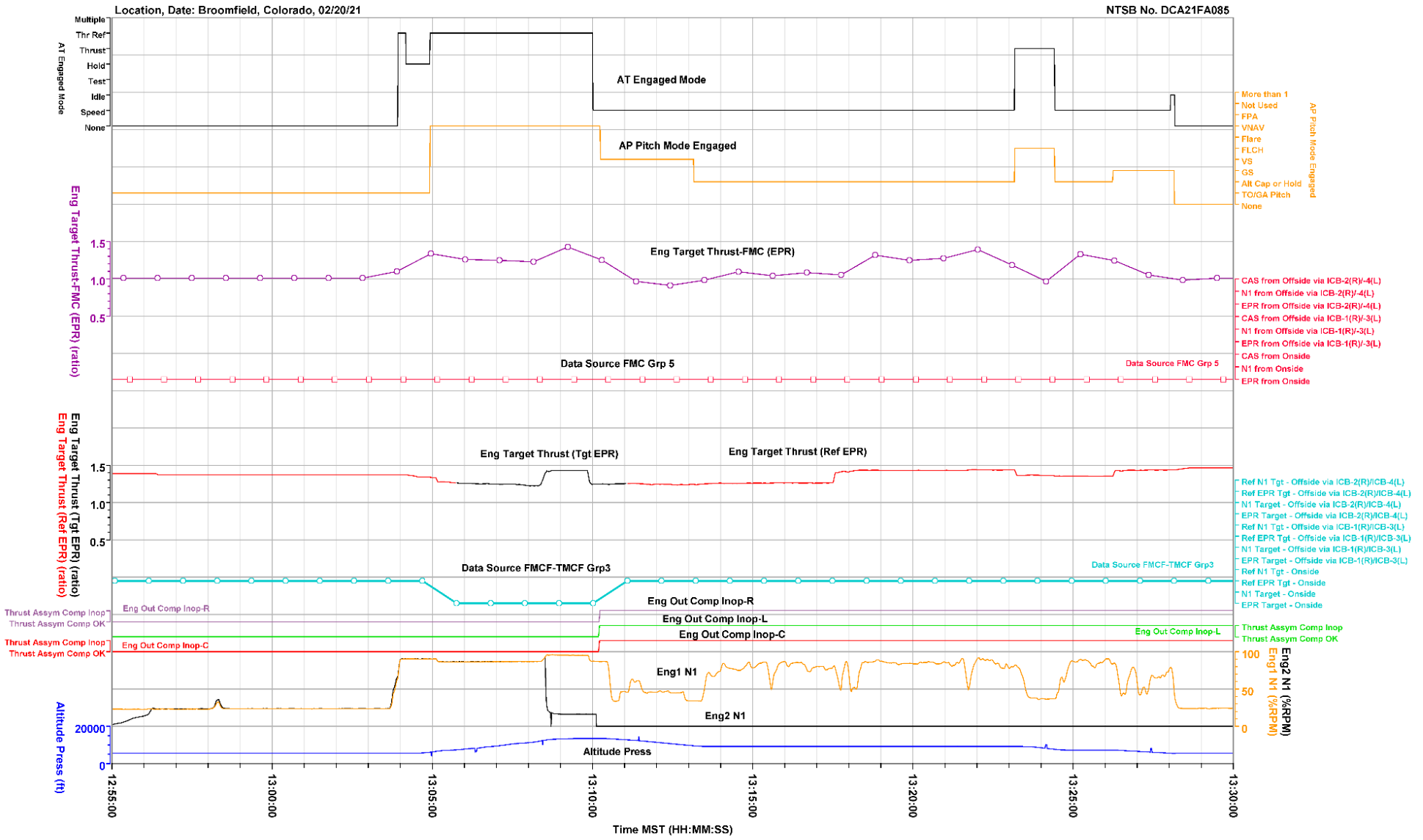

Figure 17. Plot of engine target thrust parameters for the entire incident flight.

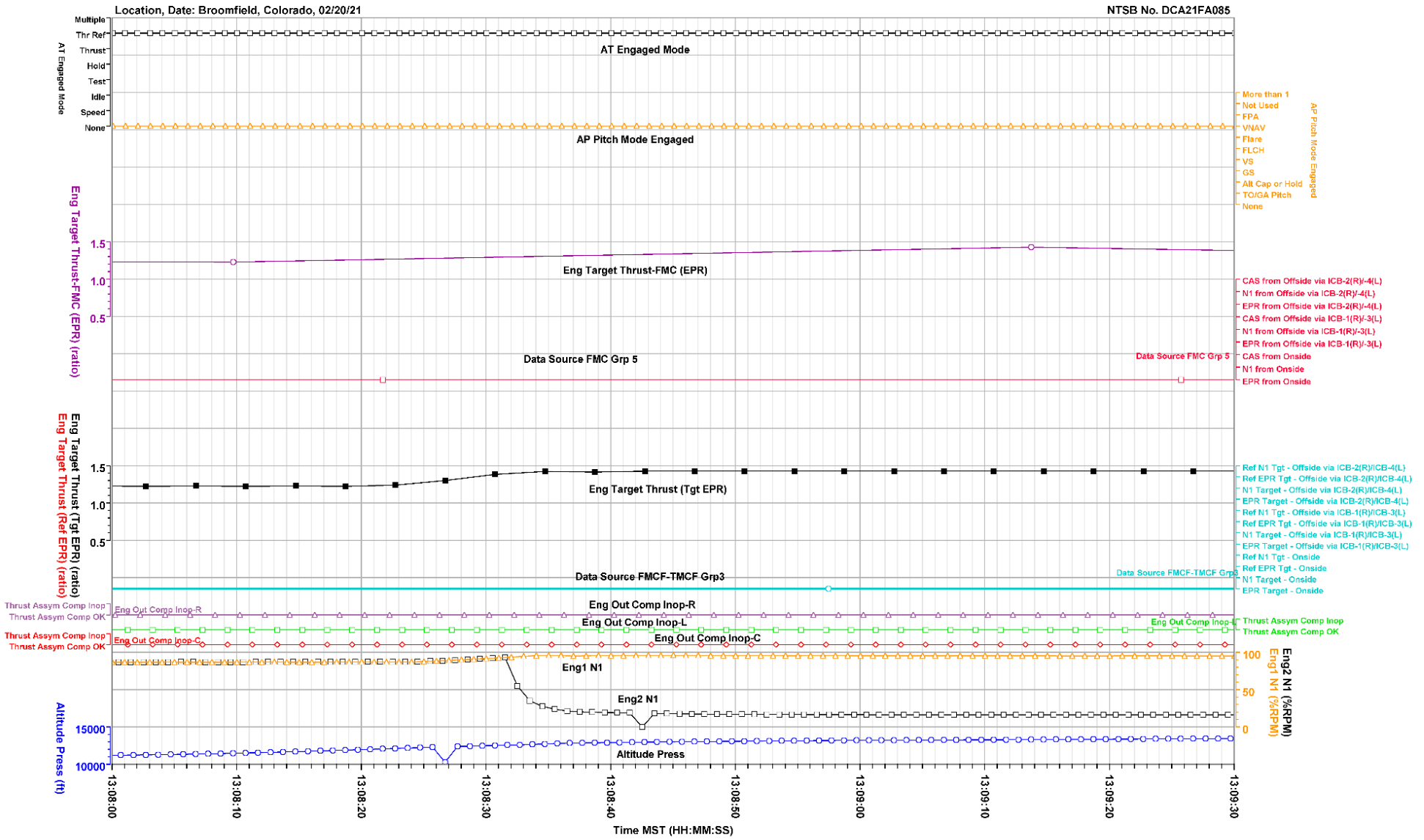

Figure 18. Plot of engine target thrust parameters during the engine event.

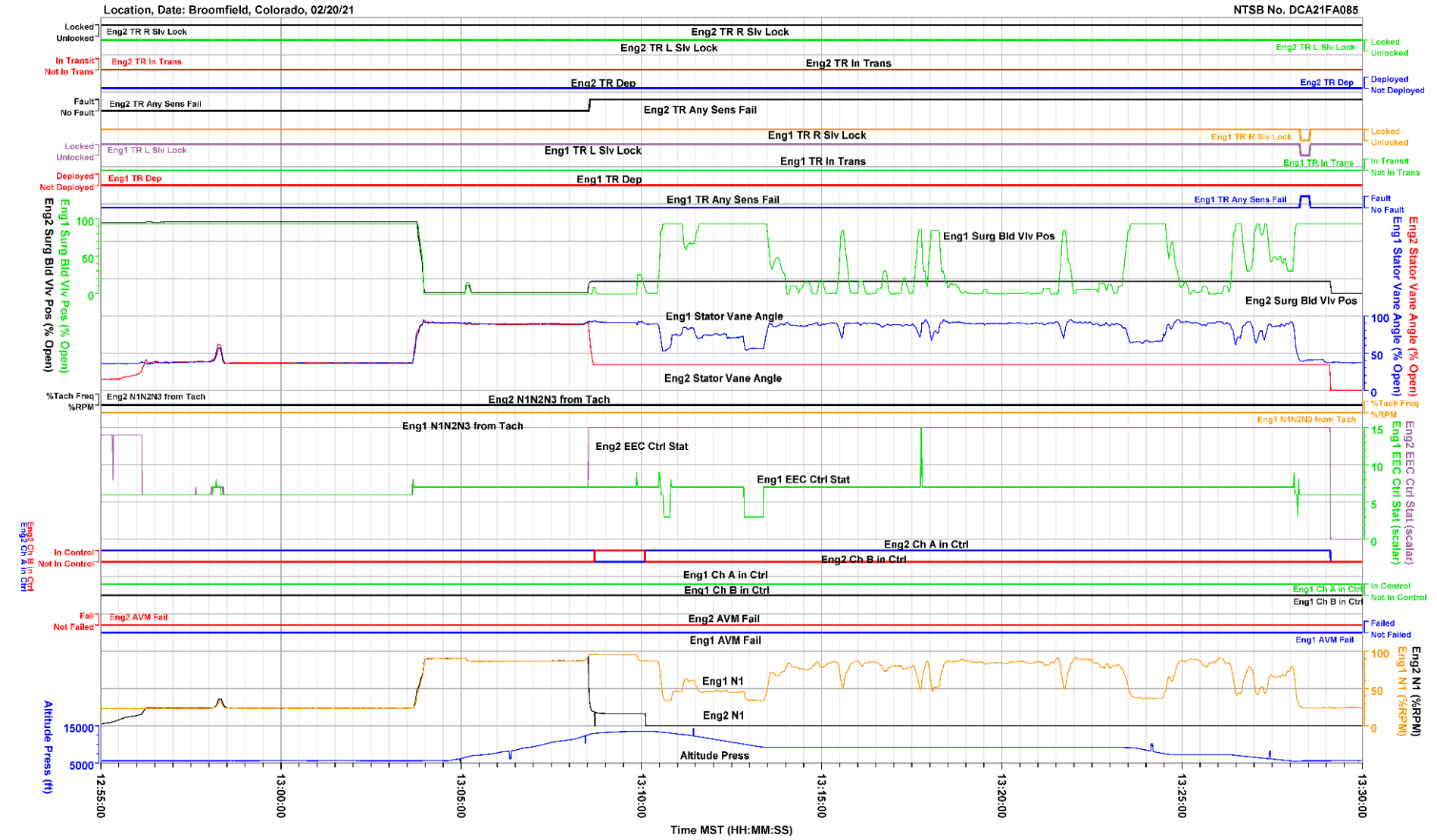

Figure 19. Plot of additional miscellaneous engine parameters for the entire incident flight.

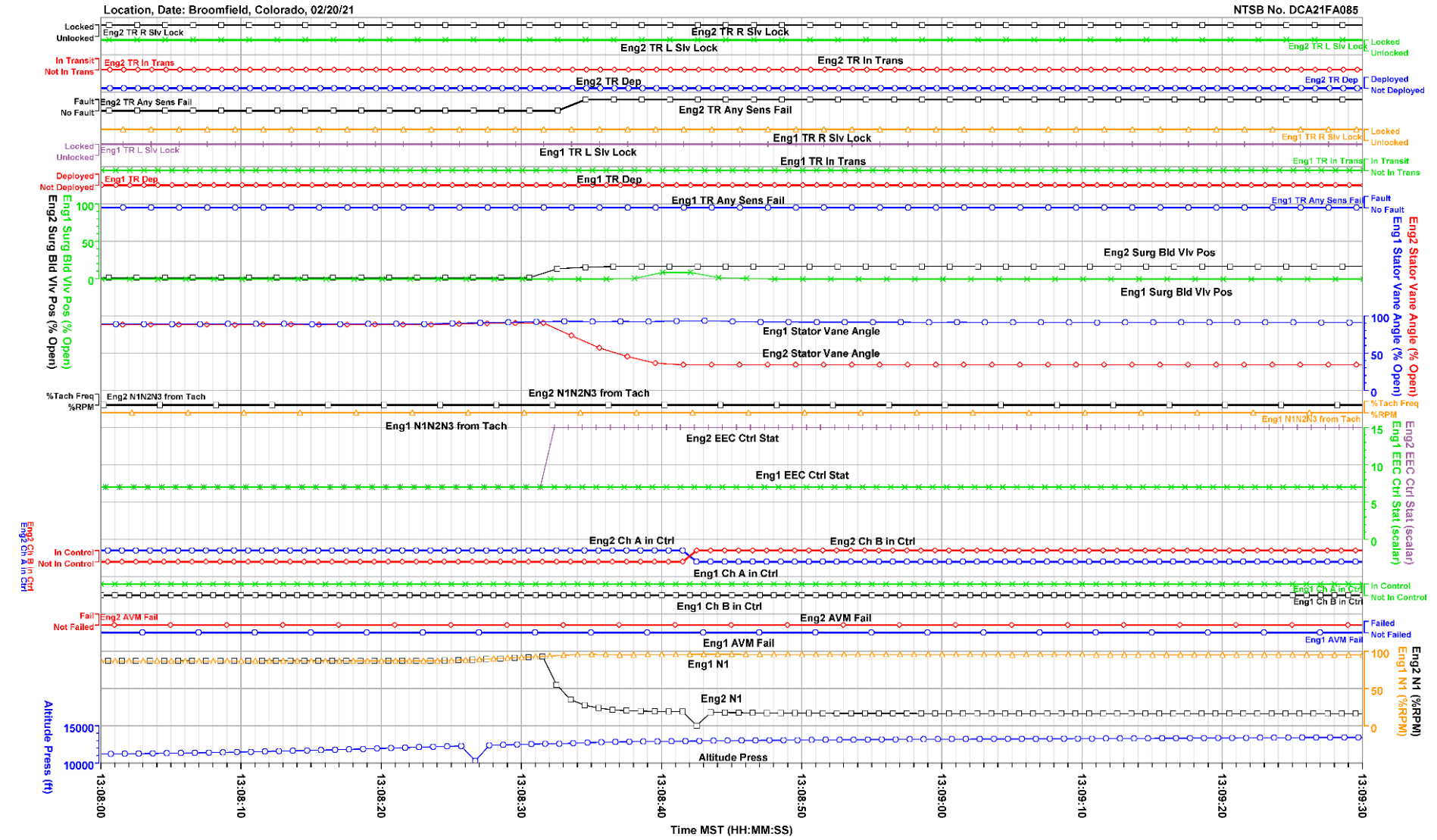

Figure 20. Plot of additional miscellaneous engine parameters during the engine event.

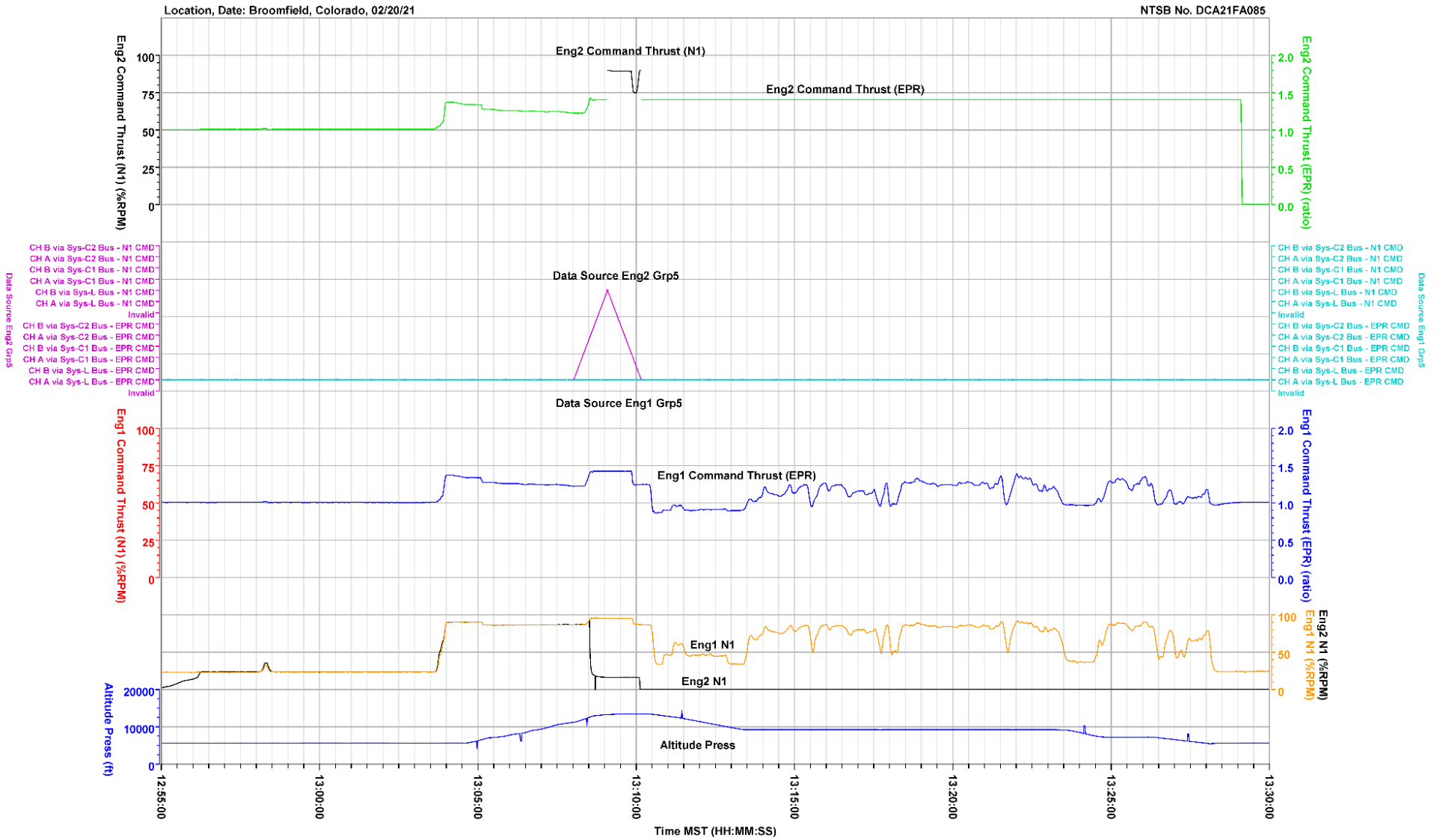

Figure 21. Plot of engine commanded thrust parameters for the entire incident flight.

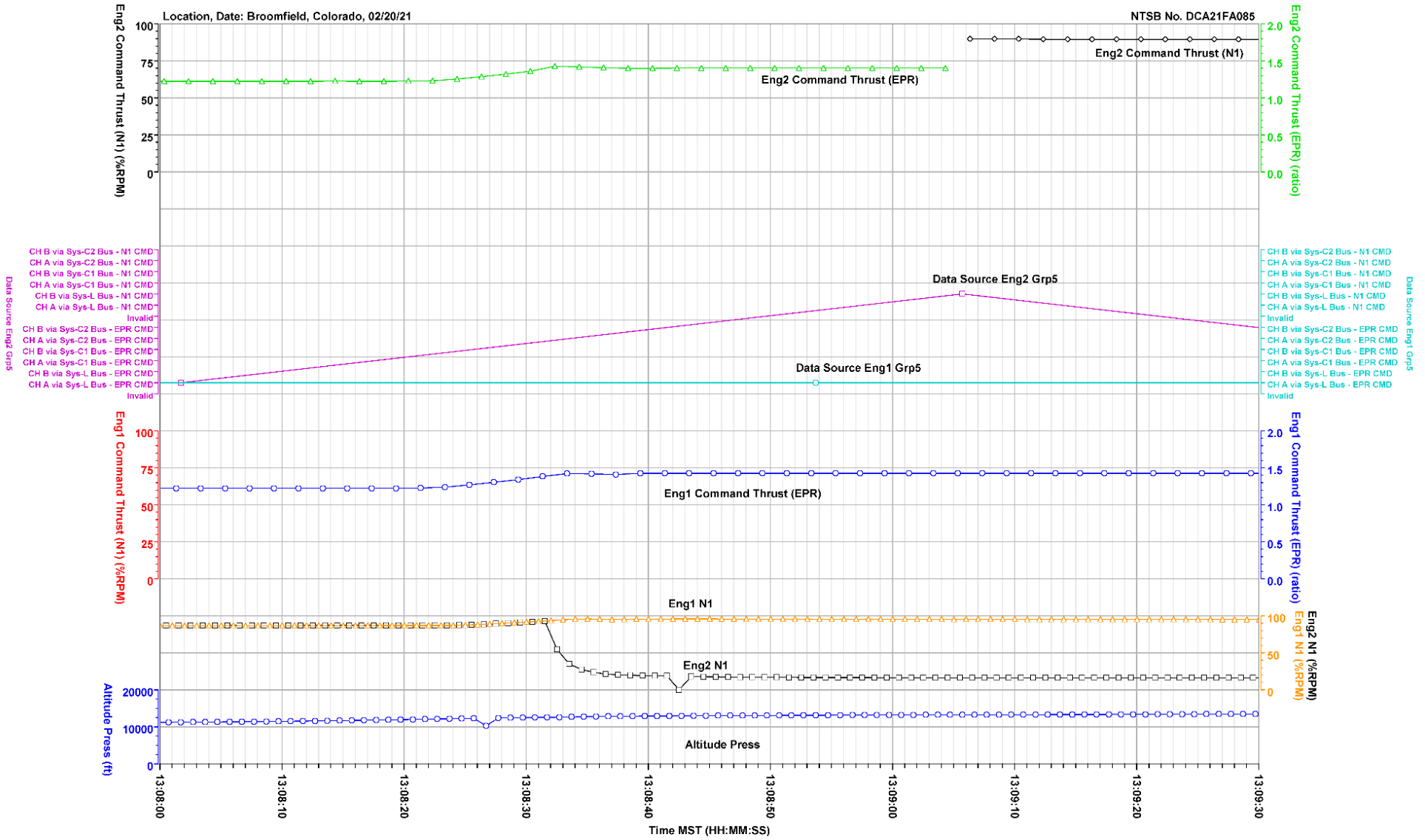

Figure 22. Plot of engine commanded thrust parameters during the engine event.

APPENDIX A. VERIFIED AND PROVIDED PARAMETERS

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

Table 1. Verified and provided FDR parameters

Plot/Table Labels	Parameter Names	Units
Accel Lat	Lateral Load Factor	g
Accel Long	Longitudinal Load Factor	g
Accel Vert	Vertical Load Factor	g
Aileron-LIB	Left Inboard Aileron Position	deg
Aileron-LOB	Left Outboard Aileron Position	deg
Aileron-RIB	Right Inboard Aileron Position	deg
Aileron-ROB	Right Outboard Aileron Position	deg
Airspeed Comp	Computed Airspeed	kts
Altitude Press	Pressure Altitude	ft
AP Altitude Engaged	Autopilot Altitude Mode Engaged	
AP BCRS Mode	Autopilot Back Course Mode	
AP Engage Switch-L	Autopilot Engaged Switch - Left	
AP Engage Switch-R	Autopilot Engaged Switch – Right	
AP Engaged	Autopilot Engaged	
AP Flare Mode	Autopilot Flare Mode	
AP GS Mode	Autopilot Glideslope Mode	
AP LNAV Mode	Autopilot Lateral Navigation Mode	
AP LOC Mode	Autopilot Localizer Mode	
AP Path Engaged	Autopilot Path Engaged	
AP Pitch Cmd-C	Autopilot Pitch Command - Center	g
AP Pitch Cmd-L	Autopilot Pitch Command – Left	g
AP Pitch Cmd-R	Autopilot Pitch Command - Right	g
AP Pitch Fail	Autopilot Pitch Mode Fail	
AP Pitch Mode Engaged	Autopilot Pitch Mode Engaged	
AP Roll Engaged Modes	Autopilot Roll Mode Engaged	
AP Roll Fail	Autopilot Roll Mode Fail	
AP Rollout Mode	Autopilot Rollout Mode	
AP Speed Engaged	Autopilot Speed Mode Engaged	
AP VNAV Mode	Autopilot Vertical Navigation Mode	
AT Engaged Mode	Autothrottle Engaged	
Ctrl Col Pos-L	Control Column Position-Left	deg
Ctrl Col Pos-R	Control Column Position-Right	deg
Ctrl Whl Pos-L_C	Control Wheel Position-Left – Center sensor	deg
Ctrl Whl Pos-L_L1	Control Wheel Position-Left – Left sensor	deg
Ctrl Whl Pos-L_R	Control Wheel Position-Left – Right sensor	deg
Ctrl Whl Pos-R_C	Control Wheel Position-Right – Center sensor	deg
Ctrl Whl Pos-R_L1	Control Wheel Position-Right – Left sensor	deg
Ctrl Whl Pos-R_R	Control Wheel Position-Right – Right sensor	deg
Data Source Eng1 Grp5	Selected Data Source – Engine 1 Data Group 5	
Data Source Eng2 Grp5	Selected Data Source – Engine 2 Data Group 5	

Plot/Table Labels	Parameter Names	Units
Data Source FMC Grp 5	Selected Data Source – Flight Management Computer Data Group 5	
Data Source FMCF-TMCF Grp3	Selected Data Source – Flight Management Computing Function-Thrust Management Computing Function Data Group 3	
Elevator-LIB	Left Inboard Elevator Position	deg
Elevator-LOB	Left Outboard Elevator Position	deg
Elevator-RIB	Right Inboard Elevator Position	deg
Elevator-ROB	Right Outboard Elevator Position	deg
Eng Default Sel	Engine Default Select	
Eng Fire Bottle1 Disch PA	Engine Fire Bottle 1 Pressure Low – Internal Path A	
Eng Fire Bottle1 Disch PB	Engine Fire Bottle 1 Pressure Low – Internal Path B	
Eng Fire Bottle2 Disch PA	Engine Fire Bottle 2 Pressure Low – Internal Path A	
Eng Fire Bottle2 Disch PB	Engine Fire Bottle 2 Pressure Low – Internal Path B	
Eng Out Comp Inop-C	Engine Out Compensation Inoperative – Center	
Eng Out Comp Inop-L	Engine Out Compensation Inoperative – Left	
Eng Out Comp Inop-R	Engine Out Compensation Inoperative – Right	
Eng Target Thrust (Ref EPR)	Engine Target Thrust (Reference EPR)	ratio
Eng Target Thrust (Tgt EPR)	Engine Target Thrust (Target EPR)	ratio
Eng Target Thrust-FMC (EPR)	Flight Management Computer – Engine Target Thrust (Target EPR)	ratio
Eng1 AVM Fail	Engine 1 Airborne Vibration Monitor Fail	
Eng1 Broadband Vib	Engine Vibration – Broadband – Engine 1	
Eng1 Burner Press	Engine 1 Burner Pressure	psi
Eng1 Ch A in Ctrl	Channel A In Control – Engine 1	
Eng1 Ch B in Ctrl	Channel B In Control – Engine 1	
Eng1 Command Thrust (EPR)	Engine 1 Commanded Thrust (EPR)	ratio
Eng1 Command Thrust (N1)	Engine 1 Commanded Thrust (N1)	%
Eng1 EEC Ctrl Stat	EEC Loop In Control Status – Engine 1	
Eng1 EGT	Engine 1 Exhaust Gas Temperature	degC
Eng1 EPR	Engine 1 Engine Pressure Ratio	ratio
Eng1 Fail Warn	Engine 1 Fail Warning	
Eng1 Fire Warn PA	Engine 1 Fire Warning – Internal Path A	
Eng1 Fire Warn PB	Engine 1 Fire Warning – Internal Path B	
Eng1 Fuel Flow	Engine 1 Fuel Flow Ware	lbs/hr
Eng1 N1	Engine 1 Fan Speed	%
Eng1 N1 Vib	Engine 1 N1 Vibration	
Eng1 N1N2N3 from Tach	Engine 1 N1/N2/N3 from Tachometer	
Eng1 N2	Engine 1 Core Speed	%
Eng1 N2 Vib	Engine 1 N2 Vibration	
Eng1 Oil Press	Engine 1 Oil Pressure	psi
Eng1 Oil Quantity	Engine 1 Oil Quantity	quarts
Eng1 Oil Temp	Engine 1 Oil Temperature	degC
Eng1 Ovht Caut	Engine 1 Overheat Caution	
Eng1 Stator Vane Angle	Engine 1 Stator Vane Angle	% Open
Eng1 Surg Bld Vlv Pos	Engine 1 Surge Bleed Valve Position	% Open
Eng1 Throt Rate Cmd	Engine 1 Throttle Rate Command	deg/sec
Eng1 TLA	Engine 1 Thrust Lever Angle	deg
Eng1 TR Any Sens Fail	Engine 1 Thrust Reverser Any Sensor Fail	
Eng1 TR Dep	Engine 1 Thrust Reverser Deployed	

Plot/Table Labels	Parameter Names	Units
Eng1 TR In Trans	Engine 1 Thrust Reverser In Transit	
Eng1 TR L Slv Lock	Engine 1 Thrust Reverser Left Sleeve Locked	
Eng1 TR R Slv Lock	Engine 1 Thrust Reverser Right Sleeve Locked	
Eng1 Vib Amb Exceed	Engine 1 Vibration Amber Exceedance	
Eng1 Vib Red Exceed	Engine 1 Vibration Red Exceedance	
Eng2 AVM Fail	Engine 2 Airborne Vibration Monitor Fail	
Eng2 Broadband Vib	Engine Vibration – Broadband – Engine 2	
Eng2 Burner Press	Engine 2 Burner Pressure	psi
Eng2 Ch A in Ctrl	Channel A In Control – Engine 2	
Eng2 Ch B in Ctrl	Channel B In Control – Engine 2	
Eng2 Command Thrust (EPR)	Engine 2 Commanded Thrust (EPR)	ratio
Eng2 Command Thrust (N1)	Engine 2 Commanded Thrust (N1)	%
Eng2 EEC Ctrl Stat	EEC Loop In Control Status – Engine 2	
Eng2 EGT	Engine 2 Exhaust Gas Temperature	degC
Eng2 EPR	Engine 2 Engine Pressure Ratio	ratio
Eng2 Fail Warn	Engine 2 Fail Warning	
Eng2 Fire Warn PA	Engine 2 Fire Warning – Internal Path A	
Eng2 Fire Warn PB	Engine 2 Fire Warning – Internal Path B	
Eng2 Fuel Flow	Engine 2 Fuel Flow Ware	lbs/hr
Eng2 N1	Engine 2 Fan Speed	%
Eng2 N1 Vib	Engine 2 N1 Vibration	
Eng2 N1N2N3 from Tach	Engine 2 N1/N2/N3 from Tachometer	
Eng2 N2	Engine 2 Core Speed	%
Eng2 N2 Vib	Engine 2 N2 Vibration	
Eng2 Oil Press	Engine 2 Oil Pressure	psi
Eng2 Oil Quantity	Engine 2 Oil Quantity	quarts
Eng2 Oil Temp	Engine 2 Oil Temperature	degC
Eng2 Ovht Caut	Engine 2 Overheat Caution	
Eng2 Stator Vane Angle	Engine 2 Stator Vane Angle	% Open
Eng2 Surg Bld Vlv Pos	Engine 2 Surge Bleed Valve Position	% Open
Eng2 Throt Rate Cmd	Engine 2 Throttle Rate Command	deg/sec
Eng2 TLA	Engine 2 Thrust Lever Angle	deg
Eng2 TR Any Sens Fail	Engine 2 Thrust Reverser Any Sensor Fail	
Eng2 TR Dep	Engine 2 Thrust Reverser Deployed	
Eng2 TR In Trans	Engine 2 Thrust Reverser In Transit	
Eng2 TR L Slv Lock	Engine 2 Thrust Reverser Left Sleeve Locked	
Eng2 TR R Slv Lock	Engine 2 Thrust Reverser Right Sleeve Locked	
Eng2 Vib Amb Exceed	Engine 2 Vibration Amber Exceedance	
Eng2 Vib Red Exceed	Engine 2 Vibration Red Exceedance	
Flaperon-LIB	Flaperon Position – Left Inboard	deg
Flaperon-LOB	Flaperon Position – Left Outboard	deg
Flaperon-RIB	Flaperon Position – Right Inboard	deg
Flaperon-ROB	Flaperon Position – Right Outboard	deg
Ground Spd	Ground Speed	kts
Heading Mag	Magnetic Heading	deg
Hyd Press-C	Hydraulic Pressure – Center	psi
Hyd Press-L	Hydraulic Pressure – Left	psi
Hyd Press-R	Hydraulic Pressure – Right	psi
Hyd Res Qty-C	Hydraulic Reservoir Quantity – Center	%
Hyd Res Qty-L	Hydraulic Reservoir Quantity – Left	%

Plot/Table Labels	Parameter Names	Units
Hyd Res Qty-R	Hydraulic Reservoir Quantity – Right	%
Latitude FMC	Latitude Coordinate – Flight Management Computer	deg
Longitude FMC	Longitude Coordinate – Flight Management Computer	deg
PFC 2nd Mode Eng-C	PFC Secondary Mode Engage Status – Center	
PFC 2nd Mode Eng-L	PFC Secondary Mode Engage Status – Left	
PFC 2nd Mode Eng-R	PFC Secondary Mode Engage Status – Right	
PFC Direct Mode Sel-C	PFC Disconnect Switch Position – Center ACE	
PFC Direct Mode Sel-L1	PFC Disconnect Switch Position – Left 1 ACE	
PFC Direct Mode Sel-L2	PFC Disconnect Switch Position – Left 2 ACE	
PFC Direct Mode Sel-R	PFC Disconnect Switch Position – Right ACE	
Pitch	Pitch Angle	deg
Roll	Roll Angle	deg
Roll Rate	Roll Rate	deg/sec
Time GMT Hrs	Greenwich Mean Time Hours	hrs
Time GMT Min	Greenwich Mean Time Minutes	min
Time GMT Sec	Greenwich Mean Time Seconds	sec
Warn Lo Hyd Press-C1	Hydraulic Low Pressure Warning – Center 1	
Warn Lo Hyd Press-C2	Hydraulic Low Pressure Warning – Center 2	
Warn Lo Hyd Press-L	Hydraulic Low Pressure Warning – Left	
Warn Lo Hyd Press-R	Hydraulic Low Pressure Warning – Right	

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 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 2. Unit and discrete state abbreviations

Unit and Discrete State Abbreviations	Descriptions
%	percent
%rpm	percent revolutions per minute
AP	autopilot
CH	channel
CMD	command
CW	clockwise
deg	degrees
degC	degrees Celsius
deg/sec	degrees per second
Eng	Engaged/Engine
EPR	engine pressure ratio
FLCH	flight level change
ft	feet
g	unit of gravitation acceleration
GS	glideslope
hrs	hours
in	inches
inHg	inches of Mercury
kts	knots

Unit and Discrete State Abbreviations	Descriptions
lbs/hr	pounds per hour
min	minutes
nm	nautical miles
press	pressure
psi	pounds per square inch
psia	pounds per square inch absolute
RWD	right wing down
sec	seconds
sys	system
TED	trailing edge down
VNAV	vertical navigation