

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

December 3, 2018

Flight Data Recorder

Specialist's Factual Report
By Greg Smith

1. EVENT SUMMARY

Location: Honolulu, Hawaii
Date: February 13, 2018
Aircraft: Boeing 777
Registration: N773UA
Operator: United Airlines
NTSB Number: DCA18IA092

On February 13, 2018, about 1200 Hawaiian standard time (HST),¹ a Boeing 777-222 airplane, N773UA, operated by United Airlines as flight 1175, experienced an in-flight separation of a fan blade as well as the inlet duct and fan cowls of the Number 2 (right) engine, a Pratt & Whitney (P&W) PW4077, during cruise flight enroute to the Daniel K. Inouye International Airport (HNL), Honolulu, Hawaii. While the airplane was in level cruise flight at flight level (FL) 360,² the flight crew heard a loud bang that was followed by a violent shaking of the airplane that was followed by warnings of a compressor stall.³ The flight crew shut down the engine, declared an emergency, and proceeded to HNL for a single-engine landing without further incident, landing at about 1237 HST. The 364 passengers,⁴ 2 pilots, and 8 flight attendants on board deplaned normally at the gate and there were no injuries. The airplane was operating as a regularly scheduled flight in accordance with the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 from the San Francisco International Airport (SFO), San Francisco, California to HNL.

2. FLIGHT DATA RECORDER GROUP

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

3. FDR Carriage Requirements

The event aircraft, N773UA, was manufactured in August 1994 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).

¹ 1200 HST is 2200 universal coordinated time (UTC).

² FL 360 is 36,000 feet mean seal level based on an altimeter setting of 29.92 inches of mercury (Hg).

³ A compressor stall is an interruption of airflow through the engine that can be caused by damaged airfoils in the compressor or turbine, deterioration, airplane pitch or yaw movements, or throttle movements, and are typified by loud bangs and/or flames from the inlet and/or tailpipe.

⁴ One of the people listed as a passenger was a United Airlines 777 first officer who was occupying a flight deck jumpseat.

4. DETAILS OF FDR INVESTIGATION

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

Recorder Manufacturer/Model: **Honeywell 4700 128 wps**
Recorder Serial Number: **4656**

4.1. Honeywell 4700 128 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 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-C124.

4.1.1. Recorder Condition

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

4.1.2. Recording Description

The FDR recording contained approximately 54.4 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 5 hours. The parameters evaluated for 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 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=+).⁵

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

⁵ 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 = +.

4.1.3.1. Pressure Altitude

This FDR records pressure altitude, which is based on a standard altimeter setting of 29.92 inches of mercury (in Hg). The 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.

The methodology used to record pressure altitude splits each 18-bit sample into a 7-bit most significant part (MSP) and an 11-bit least significant part (LSP) due to the 12-bit word limitation inherent to the format of the data structure. The MSP (2048 ft resolution) is stored at a rate of one sample every four seconds and the LSP (1 ft resolution) is stored at a rate of one sample every second. These separate MSP and LSP parameters are then combined by the ground-based analysis software to determine the complete recorded pressure altitude. When the pressure altitude passes through a multiple of the MSP resolution during a subframe in which the MSP is not recorded, an artifact, which appears as a spike, is created because the MSP of the data is lagging behind the LSP. These artifacts have not been corrected in the plotted or tabular data.

4.1.3.2. Target/Commanded Thrust Parameters

There are four engine related parameters in the Boeing documentation that have somewhat complicated conversion algorithms that must be considered when analyzing the information provided by these parameters. For these parameters, the conversion algorithms change based on the selected source of the data and the raw counts from one source yield invalid converted data if the conversion from a different source is used. To account for this, each Boeing parameter was expanded into multiple parameters so that the proper conversion could be programmed for each source. Table 1 gives the mapping of NTSB parameter names to Boeing documentation parameter names.

Table 1. Boeing-NTSB parameter name mapping

Boeing Doc Name	NTSB Name	Descriptive name
ENG_TARGET_THRUST	Eng Target Thrust (Ref EPR)	Engine Thrust Target (Reference Mode EPR Target)
	Eng Target Thrust (Ref N1)	Engine Thrust Target (Reference Mode N1 Target)
	Eng Target Thrust (Tgt EPR)	Engine Thrust Target (Target EPR)
	Eng Target Thrust (Tgt N1)	Engine Thrust Target (N1 Target)
FMC_ENG_TARGET_THRUST	Eng Target Thrust-FMC(EPR)	FMC Engine Thrust Target (Target EPR)
	Eng Target Thrust-FMC(N1)	FMC Engine Thrust Target (Target N1)
	Eng Target Thrust-FMC(Spd)	FMC Engine Thrust Target (Target Speed)
L_ENG_COMMANDED_THRUST	Eng1 Command Thrust (EPR)	Commanded Thrust (EPR) - Left Engine
	Eng1 Command Thrust (N1)	Commanded Thrust (N1) - Left Engine
R_ENG_COMMANDED_THRUST	Eng2 Command Thrust (EPR)	Commanded Thrust (EPR) - Right Engine
	Eng2 Command Thrust (N1)	Commanded Thrust (N1) - Right Engine

Additionally, the sources changed during the incident flight meaning that the conversion must dynamically change based on the source being used. The documentation indicates which source indicator parameter is used for each of the engine thrust parameters. However, the sample rate and/or timing of the source parameter samples do not match those of the data parameters so the transitions for changes in source are not always indicated at the correct time (or at all, if the source changes back quickly) resulting in spikes and fluctuations as the raw counts recorded change from one source to another. Table 2 provides the Boeing and NTSB names of the source indicator parameters and their related data parameters.

Table 2. Source Indicator - Parameter Mapping

Boeing Doc Name	NTSB Name	Related Data Parameters
DAT_SRC_FMC_TMC_PG3	Data Source FMCF-TMCF Grp3	Eng Target Thrust (Ref EPR/Ref N1/Tgt EPR/Tgt N1)
DAT_SRC_FMC_PG5 ⁶	Data Source FMC Grp5	Eng Target Thrust-FMC (EPR/N1/Spd)
DAT_SRC_L_ENG_PG5	Data Source Eng1 Grp5	Eng1 Command Thrust (EPR/N1)
DAT_SRC_R_ENG_PG5	Data Source Eng2 Grp5	Eng2 Command Thrust (EPR/N1)

For the Eng Target Thrust and Eng1 Command Thrust parameters, a validation algorithm was added to the conversions to mark the data for a given sub-parameter (Ref EPR/Ref N1/Tgt EPR/Tgt N1 and EPR/N1) as invalid when the source did not indicate that the data came from the appropriate source. This allowed most invalid samples for those parameters be removed from the plots and tabular data.

The other parameters change sources frequently enough that it was deemed appropriate to output all the data for each of the sub-parameters so that the end user would not have to back out an incorrect conversion and apply the correct one if an engineering analysis of the data indicated that a sample was converted based on an incorrect source indication. However, this means that **a significant amount of known incorrect data is included in the tabular data for these parameters and it is the responsibility of the end user to ensure that they are using the correct sub-parameter data in any follow-on analysis.** These parameters, along with their data source parameters, are shown in figures 11 to 16.

Conversion information and more detailed descriptions for these parameters can be found in Boeing document number D247W018-8 revision C.

⁶ There is a typographical error in the documentation for FMC_ENG_TARGET_THRUST. One paragraph references DAT_SRC_FMC_TMC_PG3 as the indicator of the source but other locations call out DAT_SRC_FMC_PG5. DAT_SRC_FMC_PG5 has a decoding definition that contains CAS, which also matches the FMC_ENG_TARGET_THRUST definition.

4.2. Time Correlation

Correlation of the FDR data from SRN to the event local time, HST, was established by using the recorded Time GMT⁷ hours, Time GMT Minutes, and Time GMT Seconds and then applying an additional 10 hours offset to change GMT to HST.

Accordingly, the time offset for the event flight data from SRN to local HST is the following: $HST = SRN - 148,887$. Therefore, for the rest of this report, all times are referenced as HST, not SRN. The event occurred at approximately 11:58:27 HST.

4.3. FDR Plots and Corresponding Tabular Data

Figures 1 to 31 are plots showing selected parameters from the FDR data recorded during the February 13, 2018 event. Most of the plots are grouped into sets of parameters which are plotted for three different time ranges from the incident flight. The time ranges are:

- Incident Flight – covers the complete incident flight from 07:15 HST to the end of the recording (just before 13:03 HST);
- Last 50 Minutes – covers the last 50 minutes of the flight from 11:50 HST to 12:40 HST (approximately 1 minute after landing);
- Event – covers the 3 minutes surrounding the event from 11:57 HST to 12:00 HST.

Figures 1 to 3 show a basic parameter set which includes aircraft accelerations (lateral, longitudinal and vertical), attitude (pitch and roll), heading, air and ground speeds, engine fan speeds (N1), and altitude.

Figures 4 to 6 show a basic set of engine parameters which includes aircraft altitude and airspeed for reference as well as engine fan speeds (N1), core speeds (N2), throttle lever angles (TLA), engine pressure ratios (EPR), throttle rate commands, fuel flows, and exhaust gas temperatures.

Figures 7 to 9 show a set of additional engine parameters related to engine oil, vibrations and warnings which includes N1 and N2 (for reference); oil temperature and pressure; engine vibration parameters (3 per engine: broadband, N1 and n2); and vibration exceedance and engine failure cautions and warnings.

Figure 10 shows a set of parameters which indicate the data sources for various engine parameters. Details of which engine parameters are related to each data source parameter can be found in Boeing document number D247W018-8 revision C. None of the engine data sources in this set indicated invalid data although several did show indications of a change in source after the event. This set of parameters is only shown for the Incident Flight time frame.

Figures 11 to 13 show the set of engine target thrust parameters and their related data source parameters as well as: N1 speeds and altitude for reference; asymmetric thrust compensation status; and those autopilot (AP) and autothrottle (AT) engagement mode

⁷ GMT is Greenwich Mean Time which is also known as Coordinated Universal Time (UTC).

parameters whose state would indicate an impact on the target thrust parameters source selection. See section 4.1.3.2 for a discussion of the parameter/data source relationship. These figures are annotated to indicate when a specific child parameter should be valid. Neither of the data source parameters shown in these figures indicates that any N1 sources were used during the incident flight. Therefore, the traces for Eng Target Thrust -FMC (N1), Eng Target Thrust (Tgt N1) and Eng Target Thrust (Ref N1) are not shown on the plots.

Figures 14 to 16 show each engine's commanded thrust parameters and their respective data source parameters as well as the N1 speeds and altitude for reference. The Eng1 Command Thrust (N1) was invalid and not plotted because its data source parameter remained on an EPR source for the duration of the incident flight. The engine 2 commanded thrust parameter toggled between EPR and N1 sources during the incident flight after the event as discussed in section 4.1.3.2. The large variation in sample rates discussed above can be seen in figures 15 and 16. The rapid toggling between values seen between 12:17 HST and the end of the flight may include artifacts introduced by the data source switching but, due to the low sample rate of the data source parameter, an indication of every source switch may not have been captured.

Figures 17 to 19 show a set of miscellaneous engine related parameters including oil quantities, burner pressures, overheat cautions, fire warnings, fire bottle status and engine type selection status as well as the N1 speeds and altitude for reference.

Figures 20 to 22 show a second set of miscellaneous engine related parameters including thrust reverser status and sensor failures, engine surge bleed valve positions, stator vane angles, engine speed (N1/N2) source indicators, electronic engine control (EEC) status and channel selections as well as the N1 speeds and altitude for reference.

Figures 23 to 25 show a set of parameters related to controlling the pitch of the aircraft including the 3 accelerations, pitch attitude, control column positions, elevator surface position, heading, altitude and ground and air speeds.

Figures 26 to 28 show a set of parameters related to controlling the roll of the aircraft including the primary flight control (PFC) secondary and direct mode status, AP roll mode engaged, roll attitude, roll rate, control wheel positions, aileron surface positions, flaperon surface positions, altitude and airspeed.

Figures 29 to 31 show a set of parameters related to the autopilot including mode selections, engagement status, engagement switch activation and failures as well as altitude and the 3 accelerations for reference.

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 corresponding tabular data used to create figures 1 to 31, as well as that for the other parameters listed in table A-1, are provided in electronic comma separated value (*.csv) format as attachment 1 to this report.

Figure 1. Basic parameter set for the incident flight timeframe.

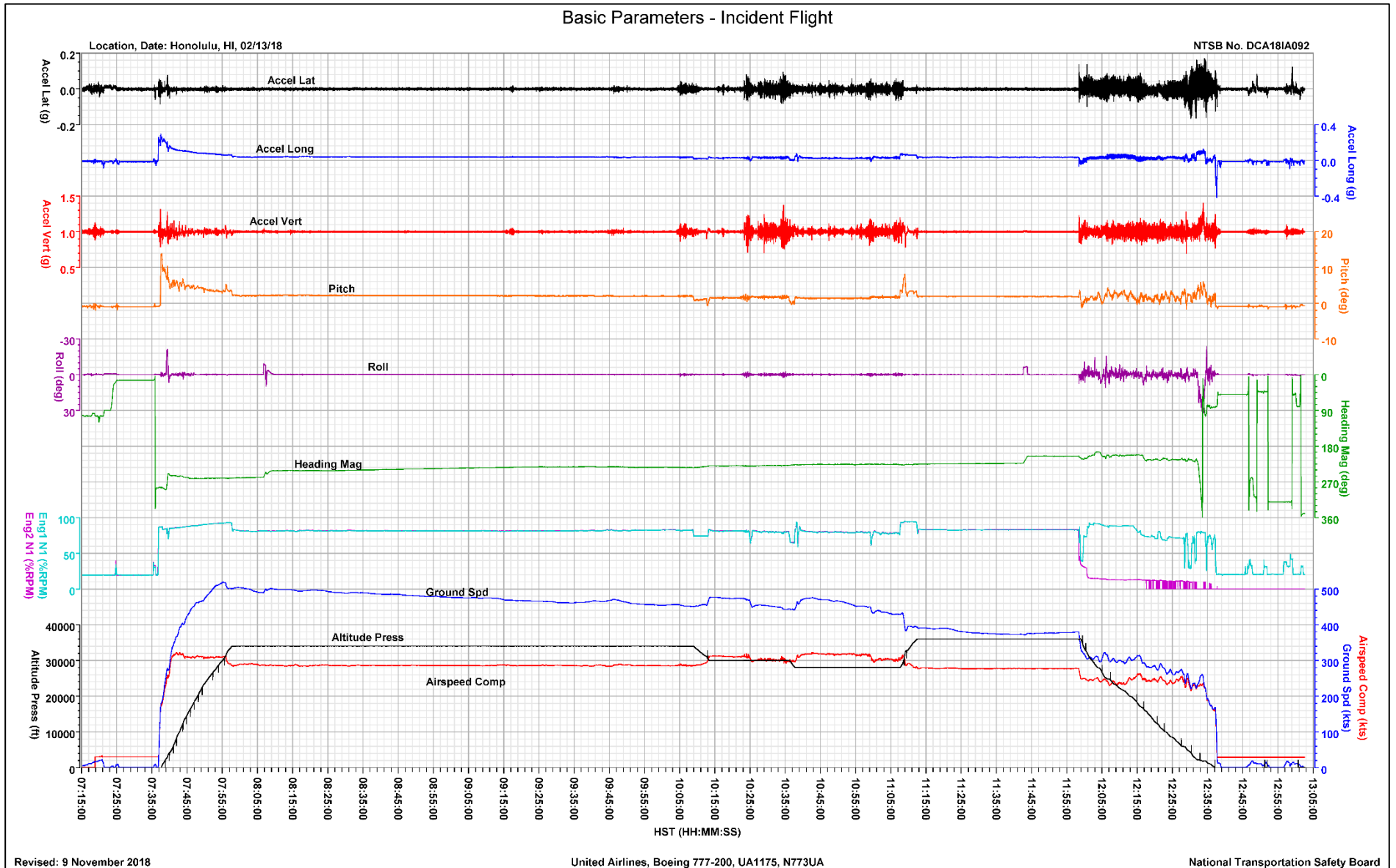


Figure 2. Basic parameter set for the last 50 minutes of the flight.

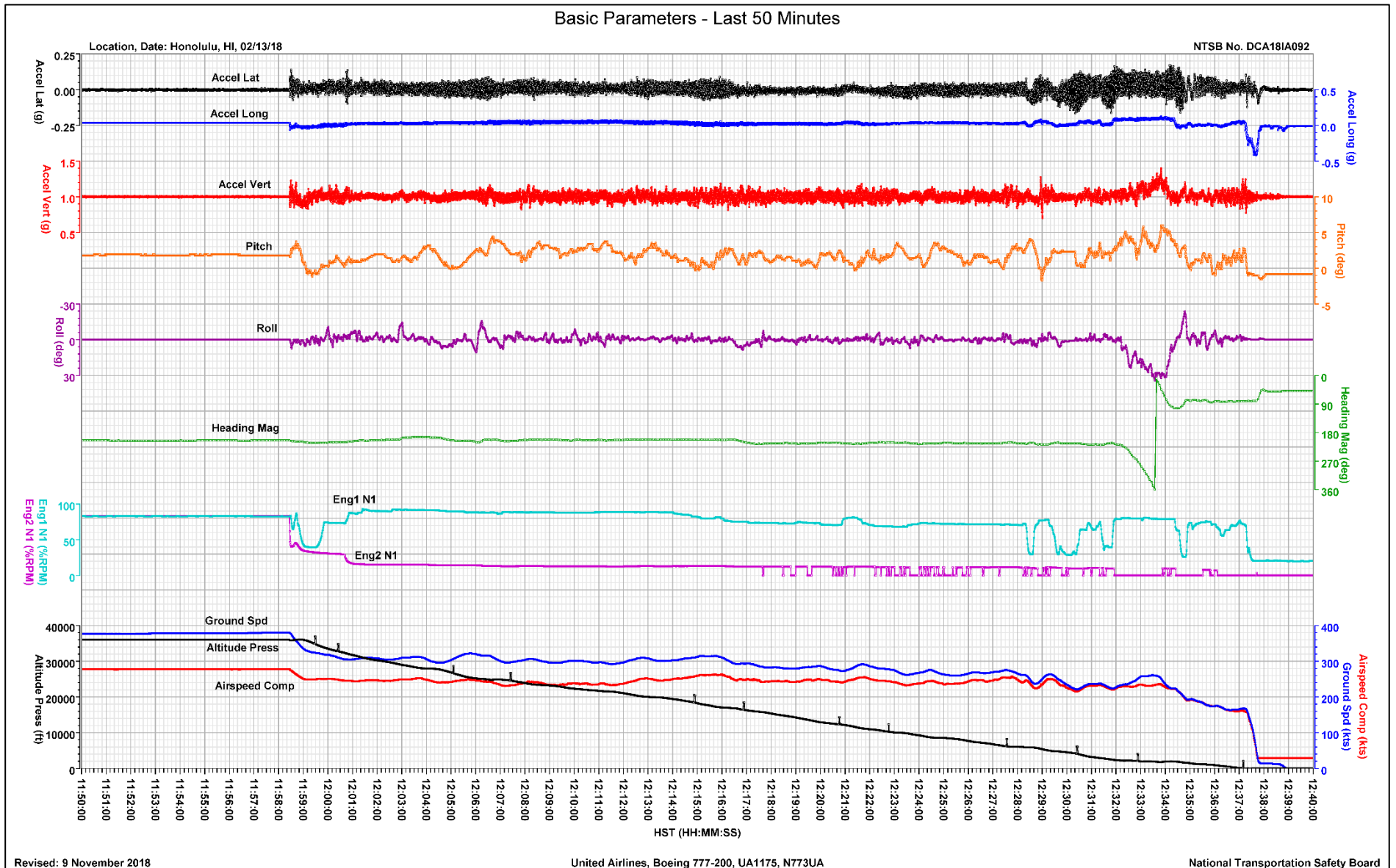


Figure 3. Basic parameter set for the three minutes around the event.

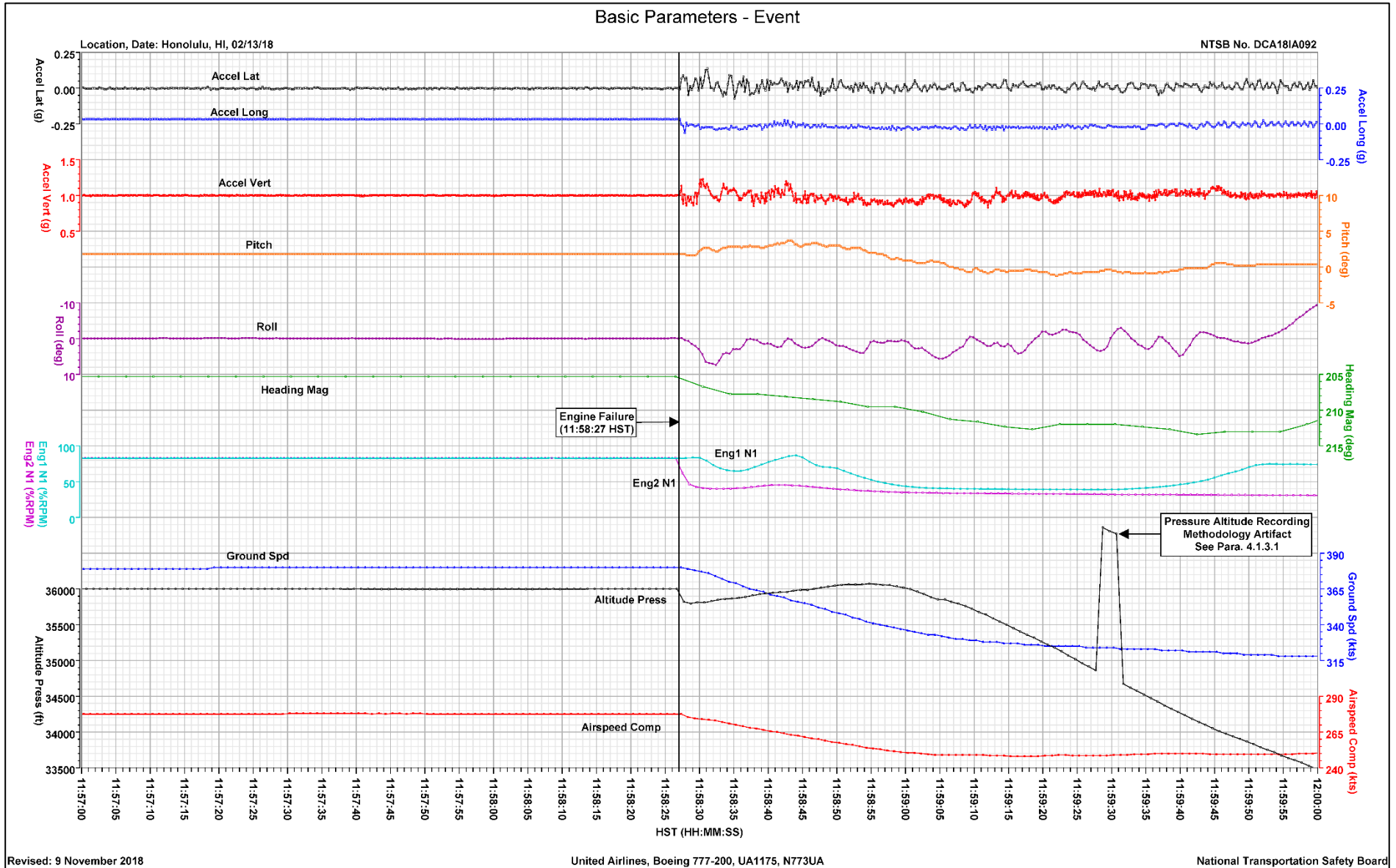


Figure 4. Basic engine parameter set for the incident flight timeframe.

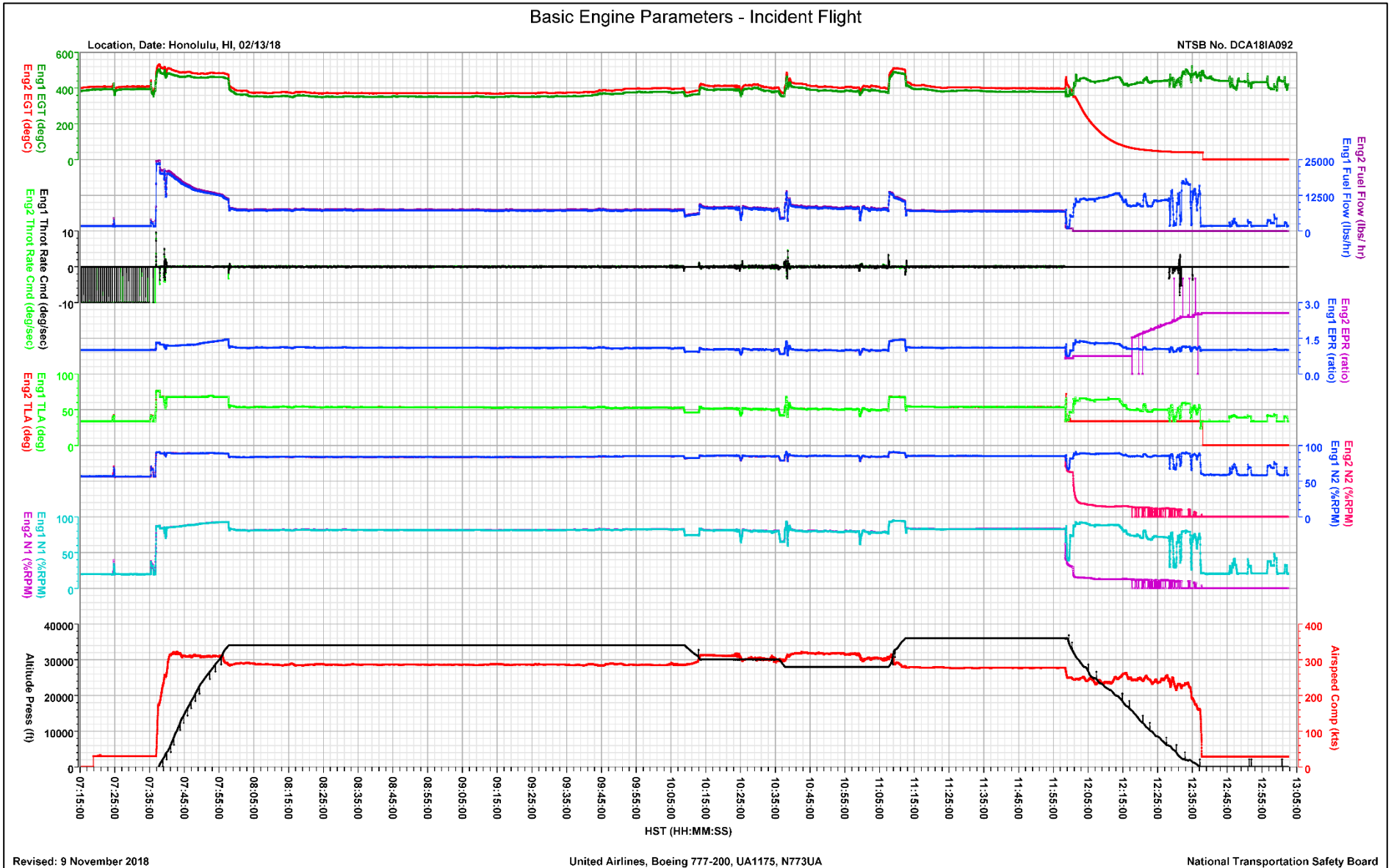


Figure 5. Basic engine parameter set for the last 50 minutes of the flight.

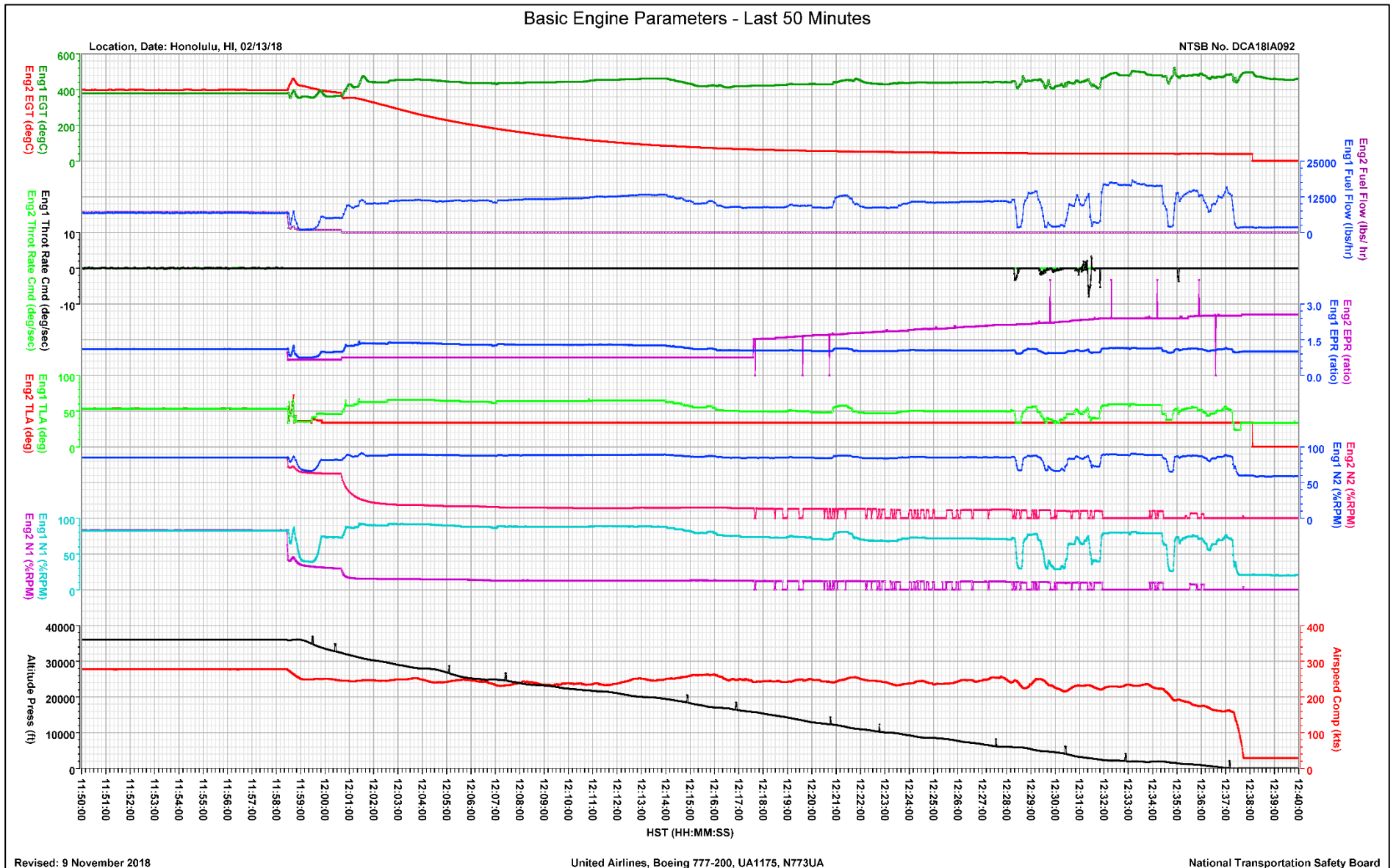


Figure 6. Basic engine parameter set for the three minutes around the event.

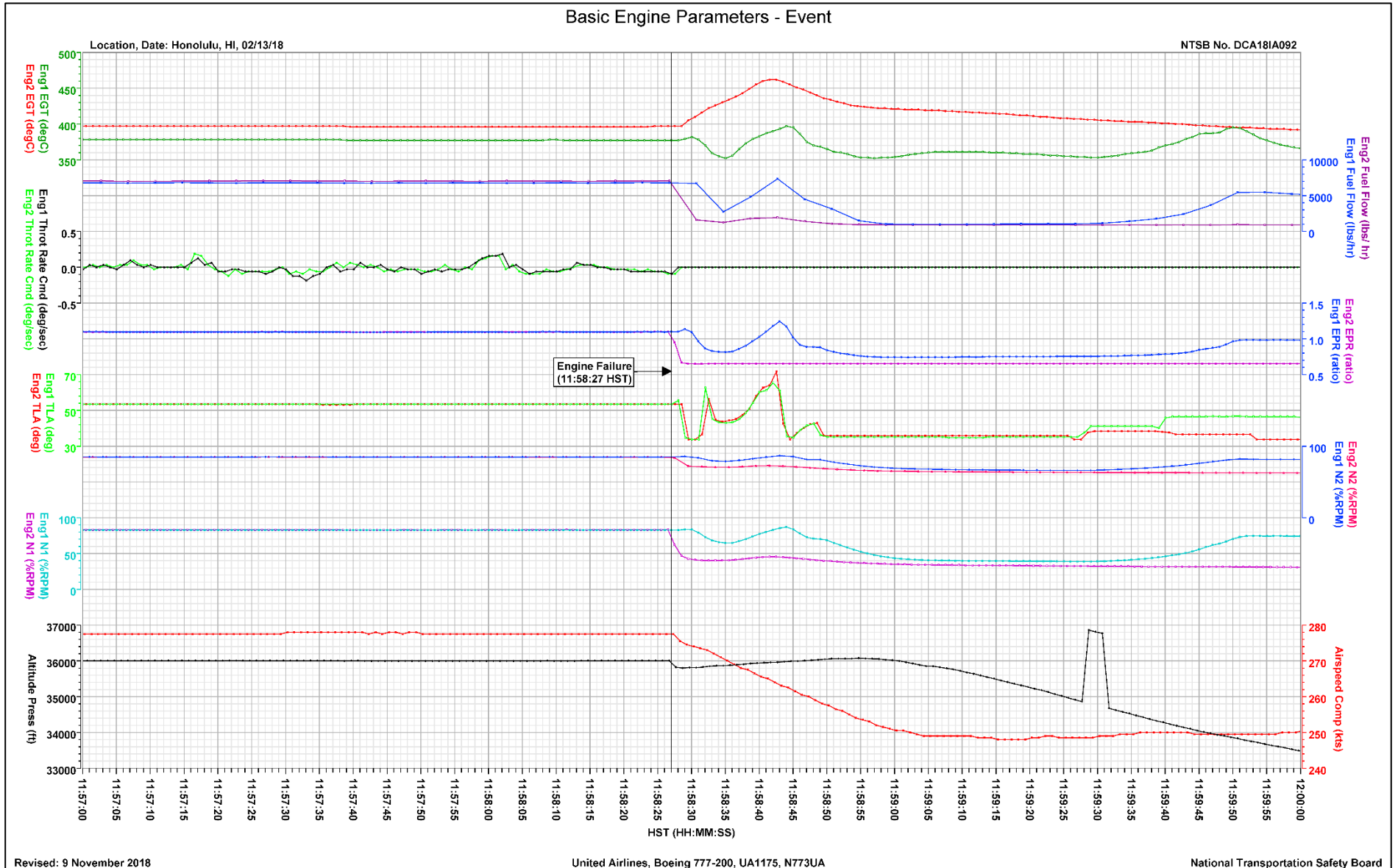


Figure 7. Engine oil and vibration parameter set for the incident flight timeframe.

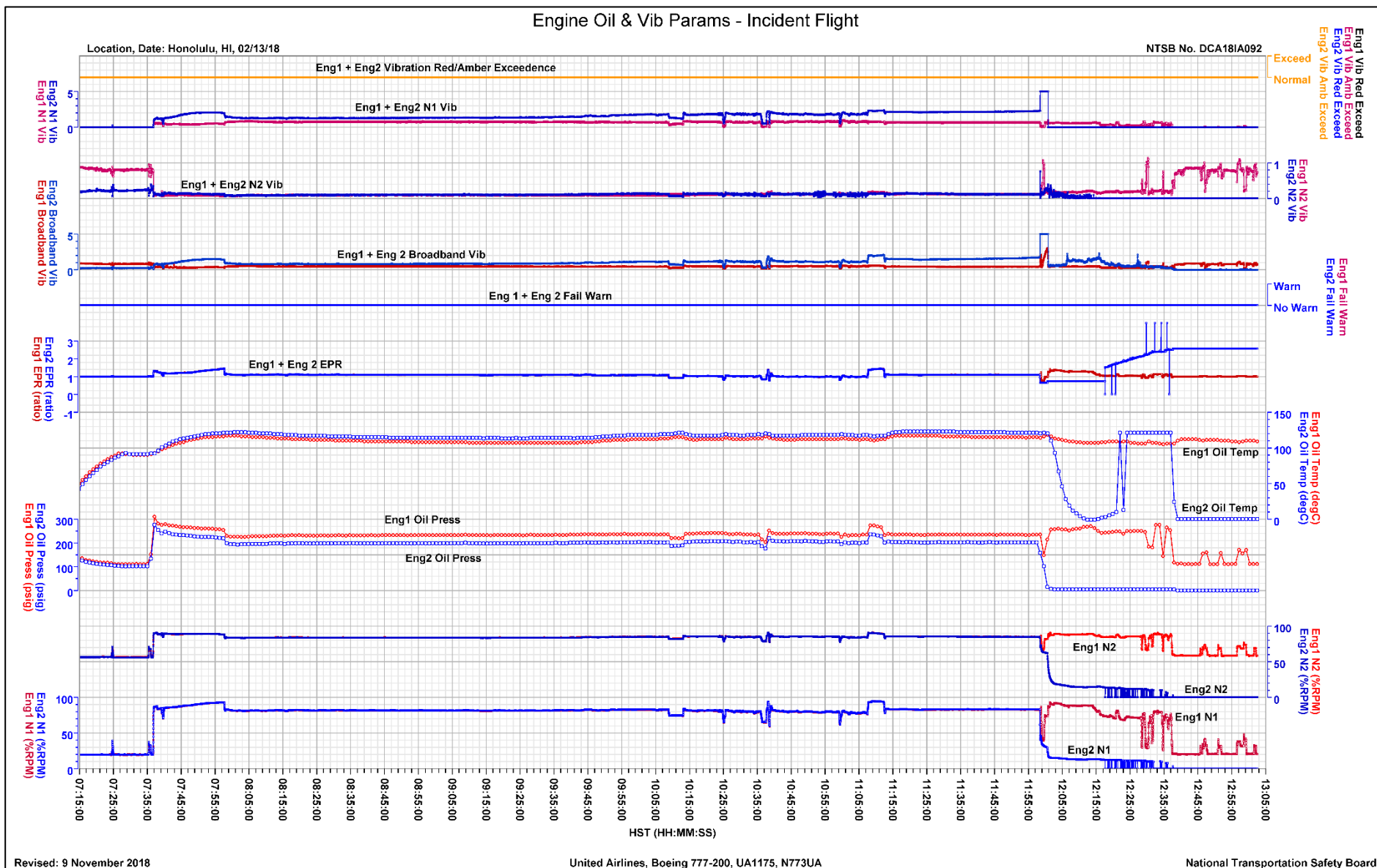


Figure 8. Engine oil and vibration parameter set for the last 50 minutes of the flight.

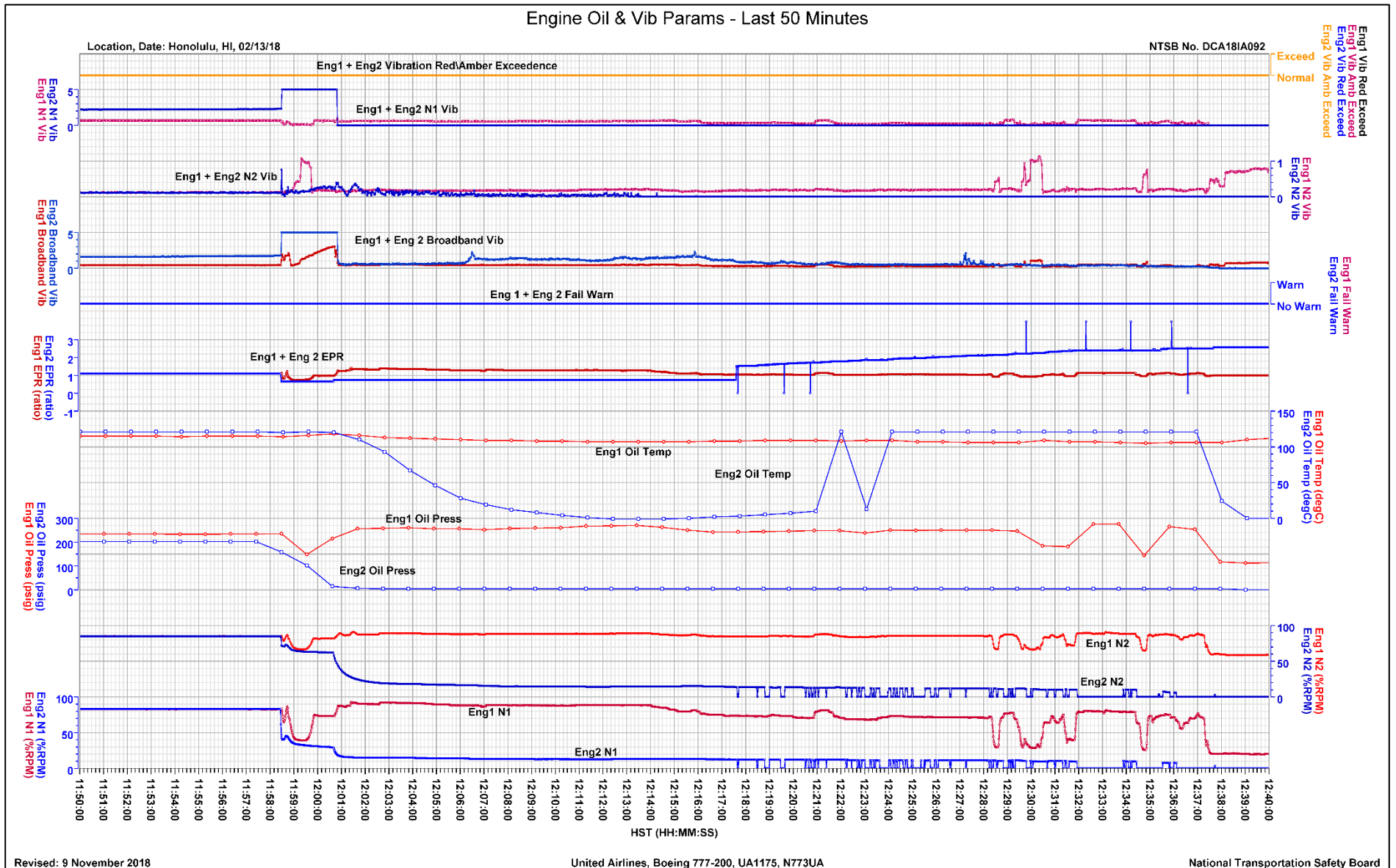


Figure 9. Engine oil and vibration parameter set for the three minutes around the event.

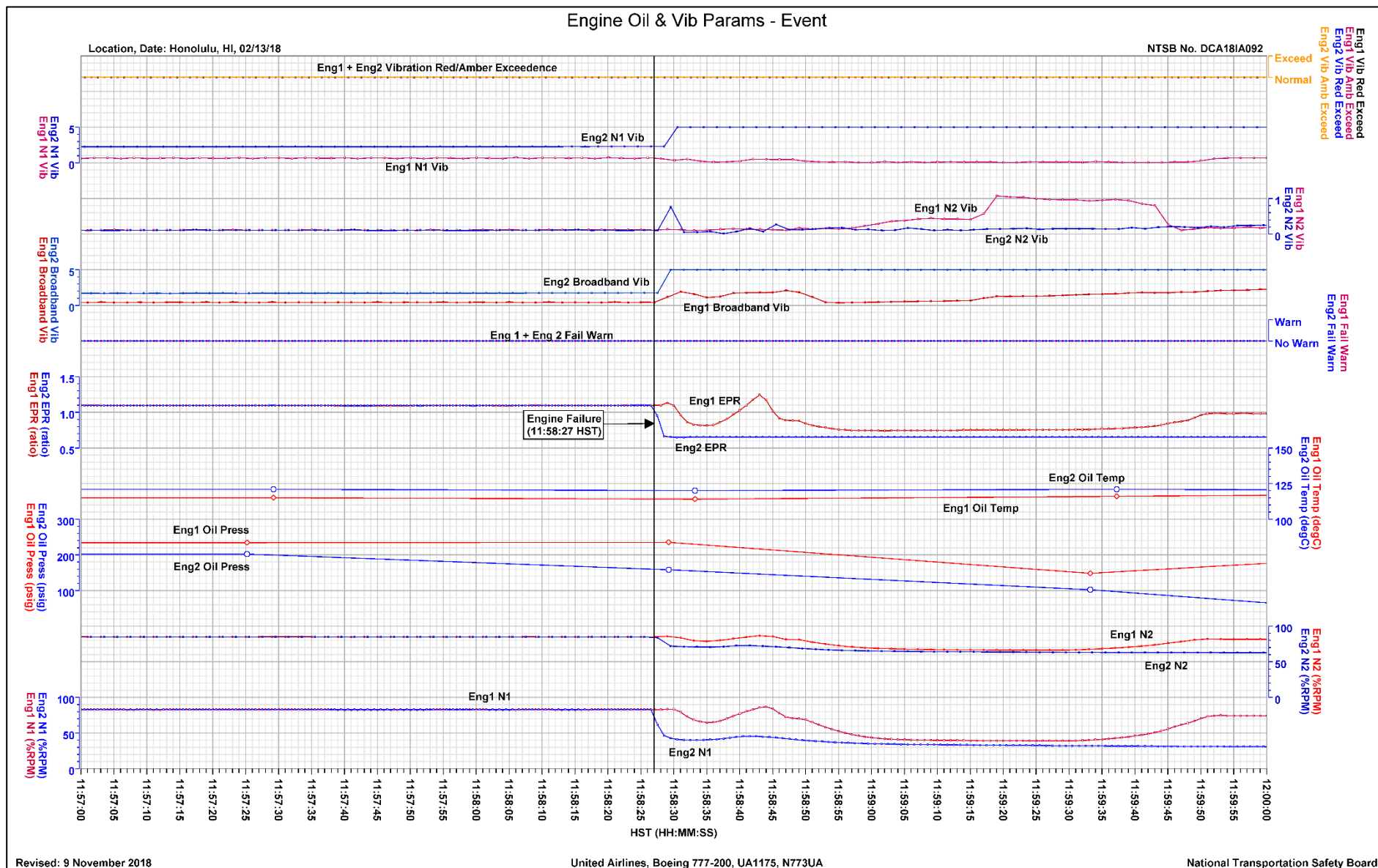


Figure 10. Engine parameter data source parameter set for the incident flight timeframe.

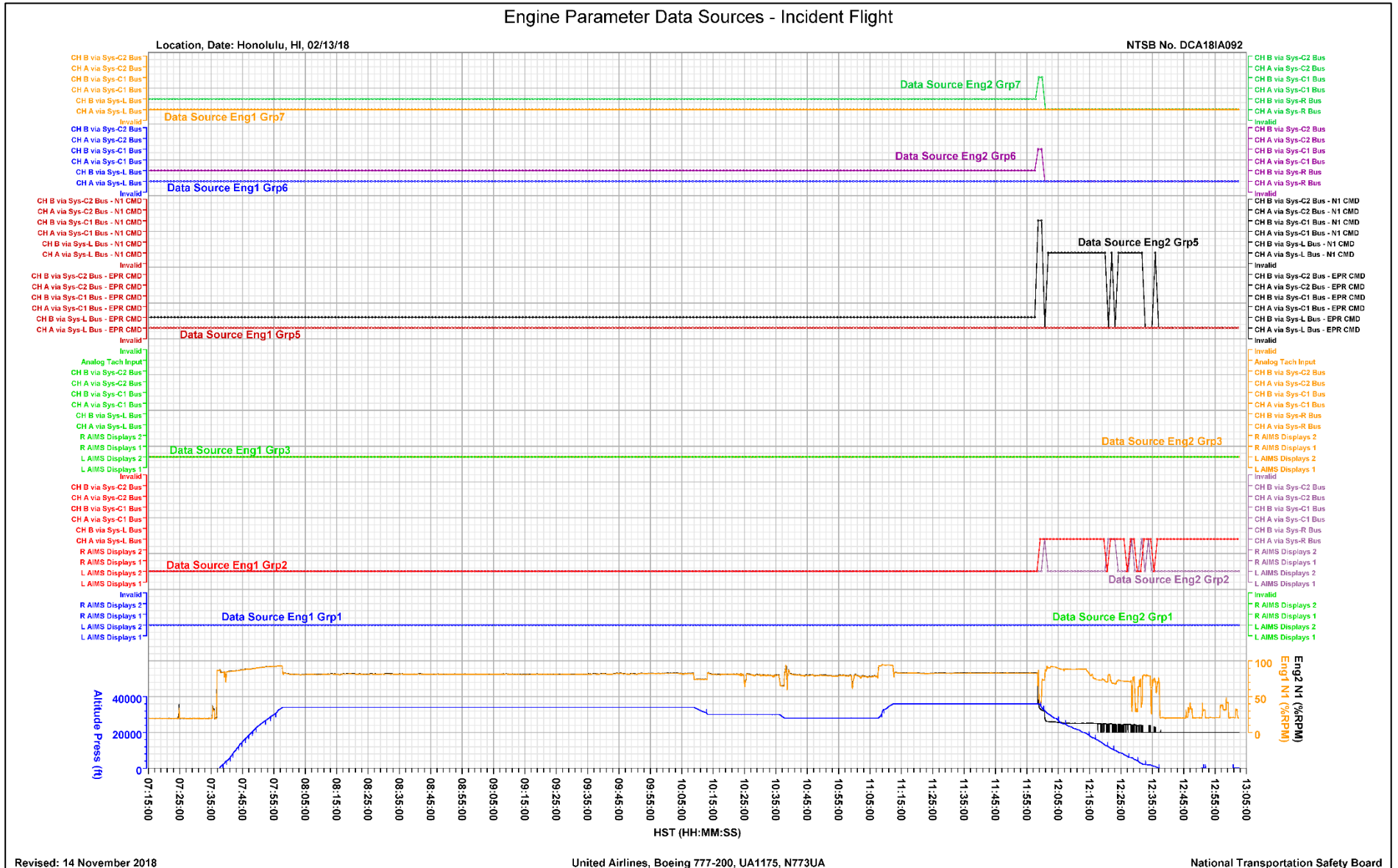


Figure 11. Engine target thrust parameter set for the incident flight timeframe.

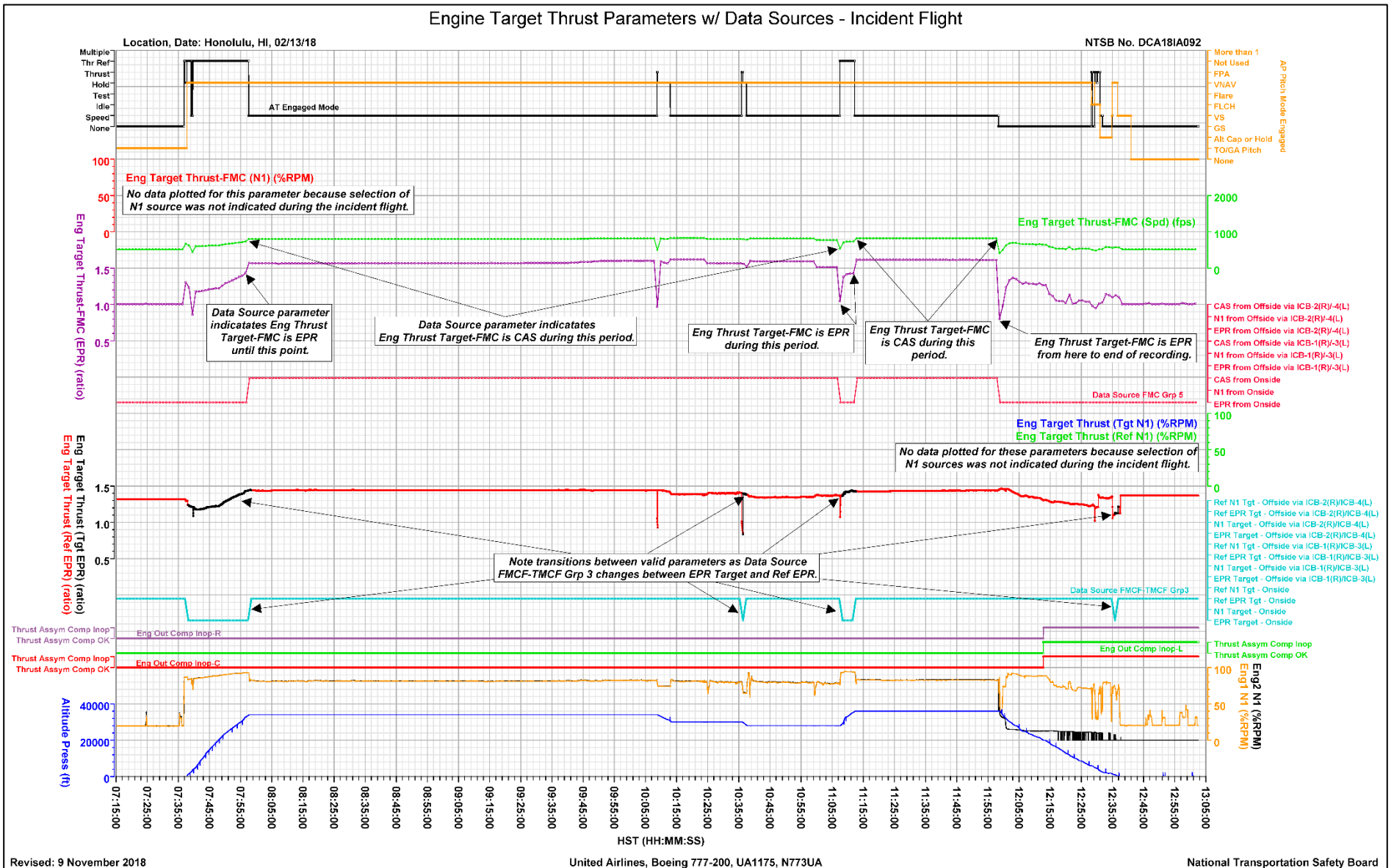


Figure 12. Engine target thrust parameter set for the last 50 minutes of the flight.

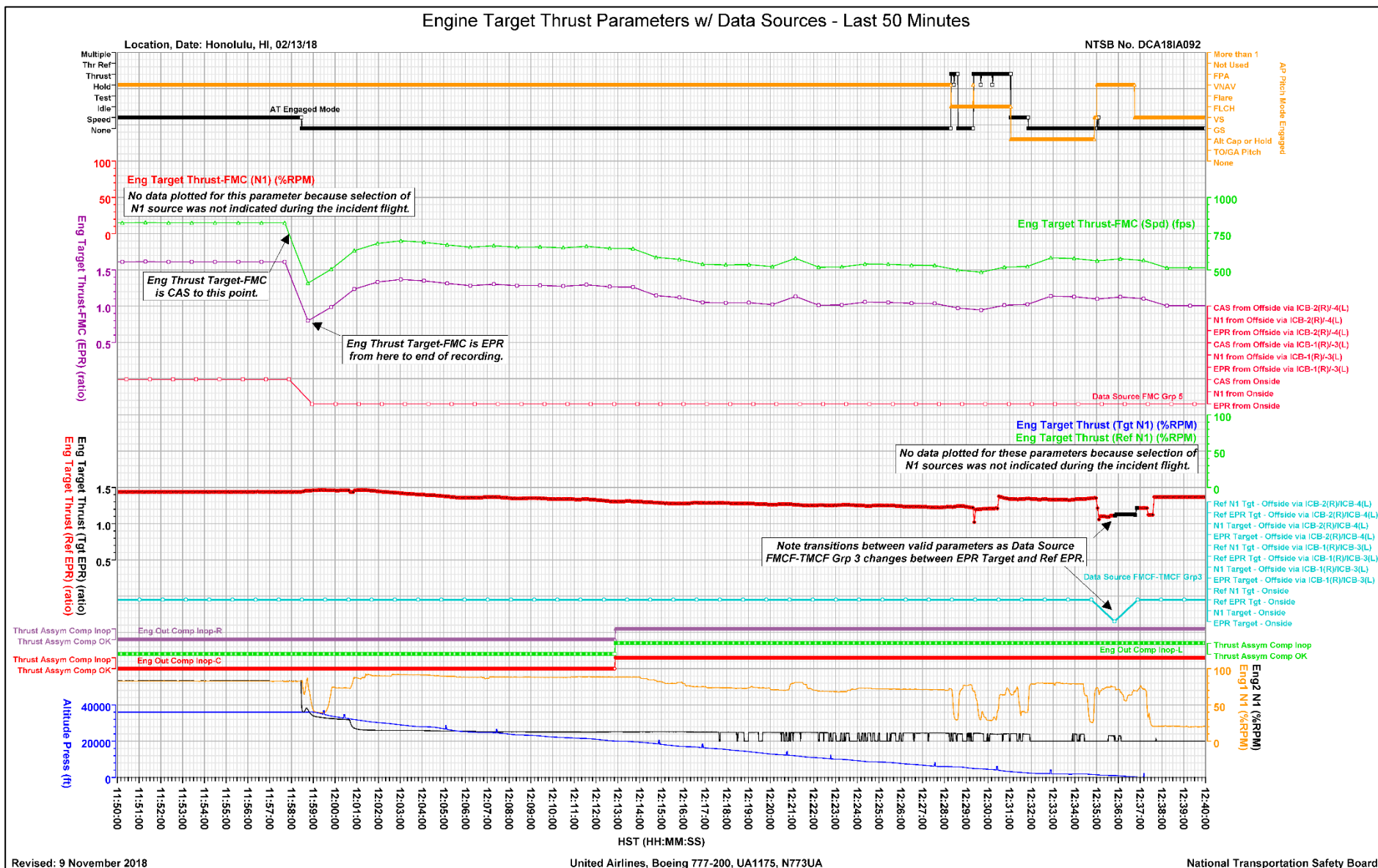


Figure 13. Engine target thrust parameter set for the three minutes around the event.

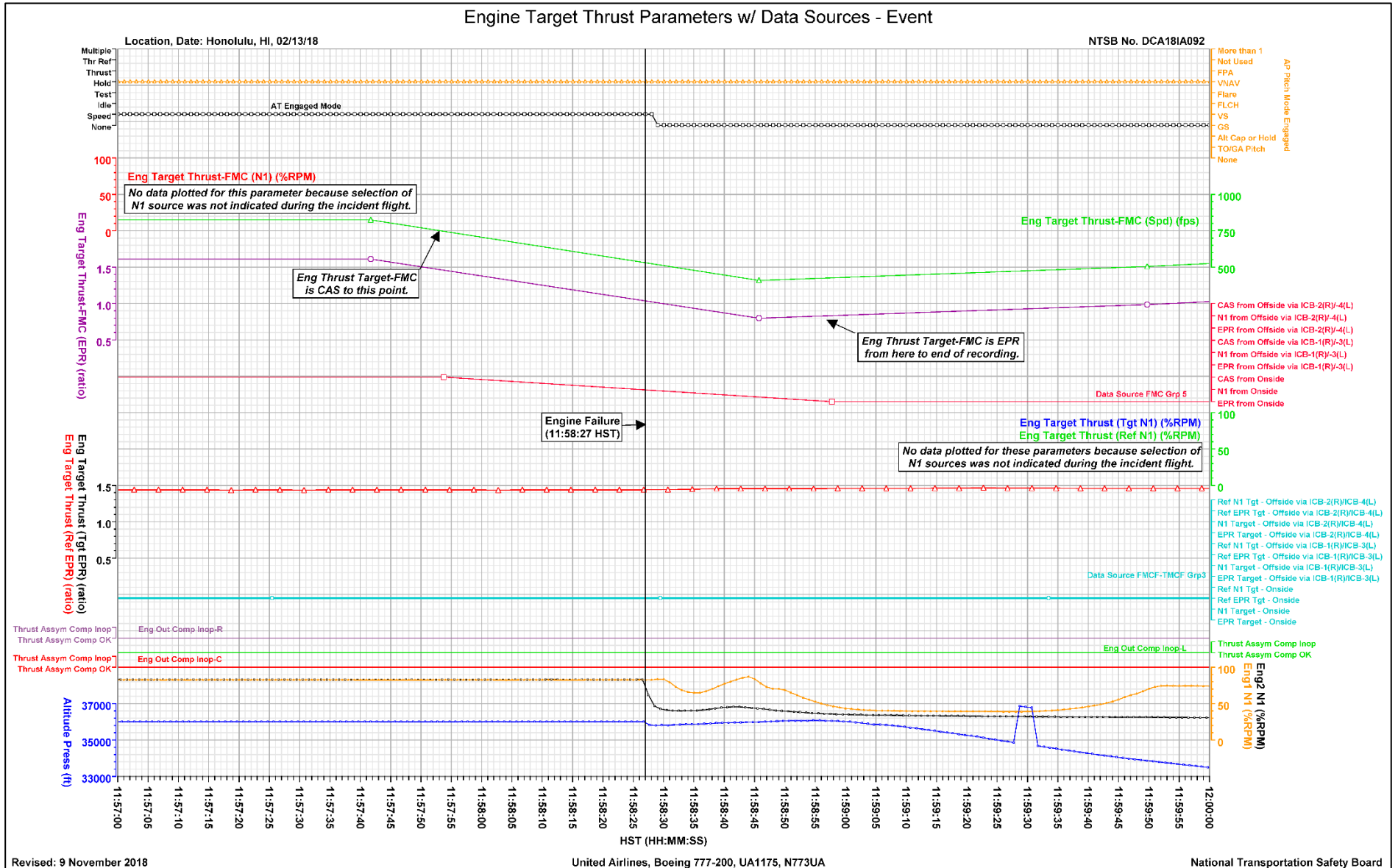


Figure 14. Engine commanded thrust parameter set for the incident flight timeframe.

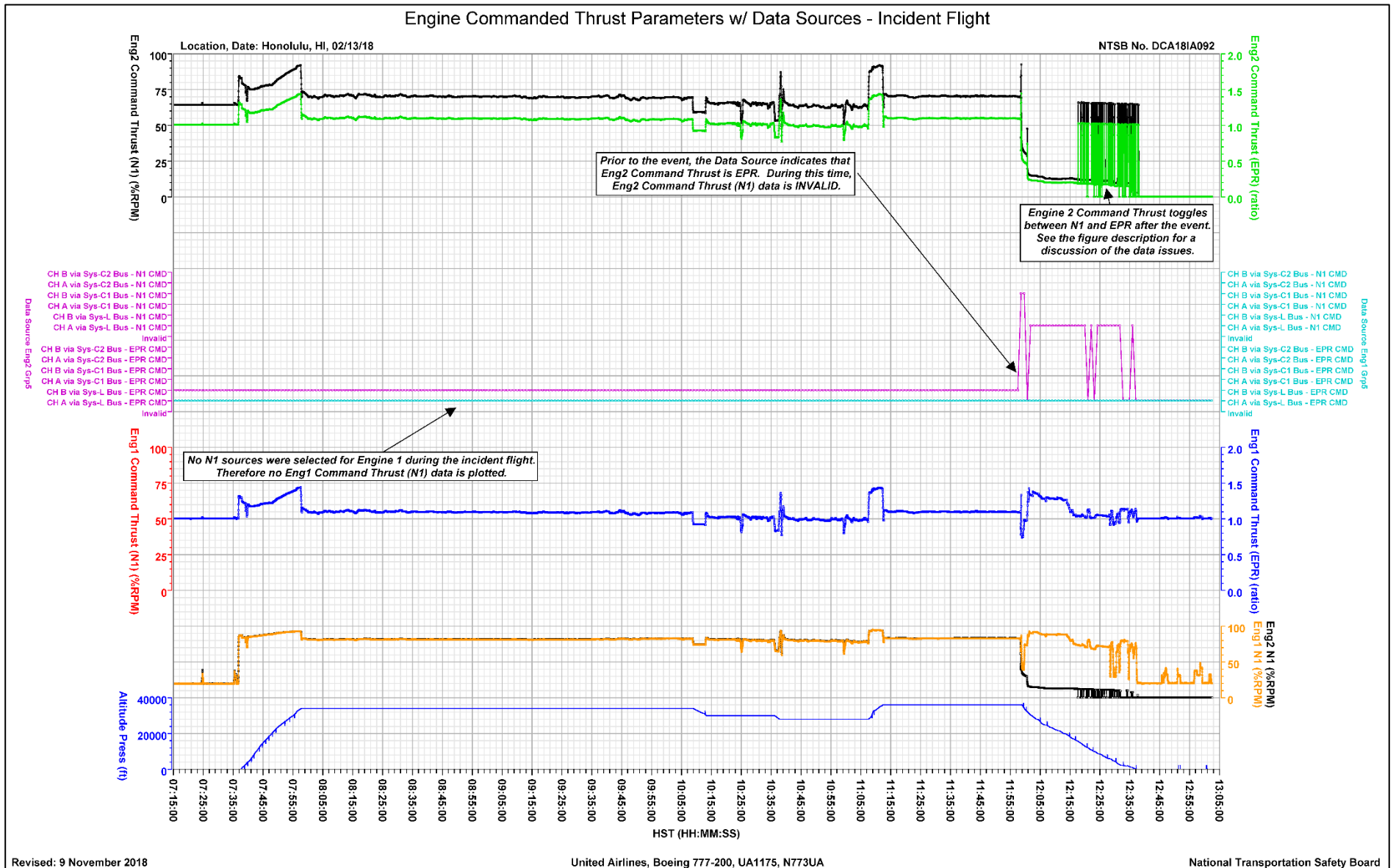


Figure 15. Engine commanded thrust parameter set for the last 50 minutes of the flight.

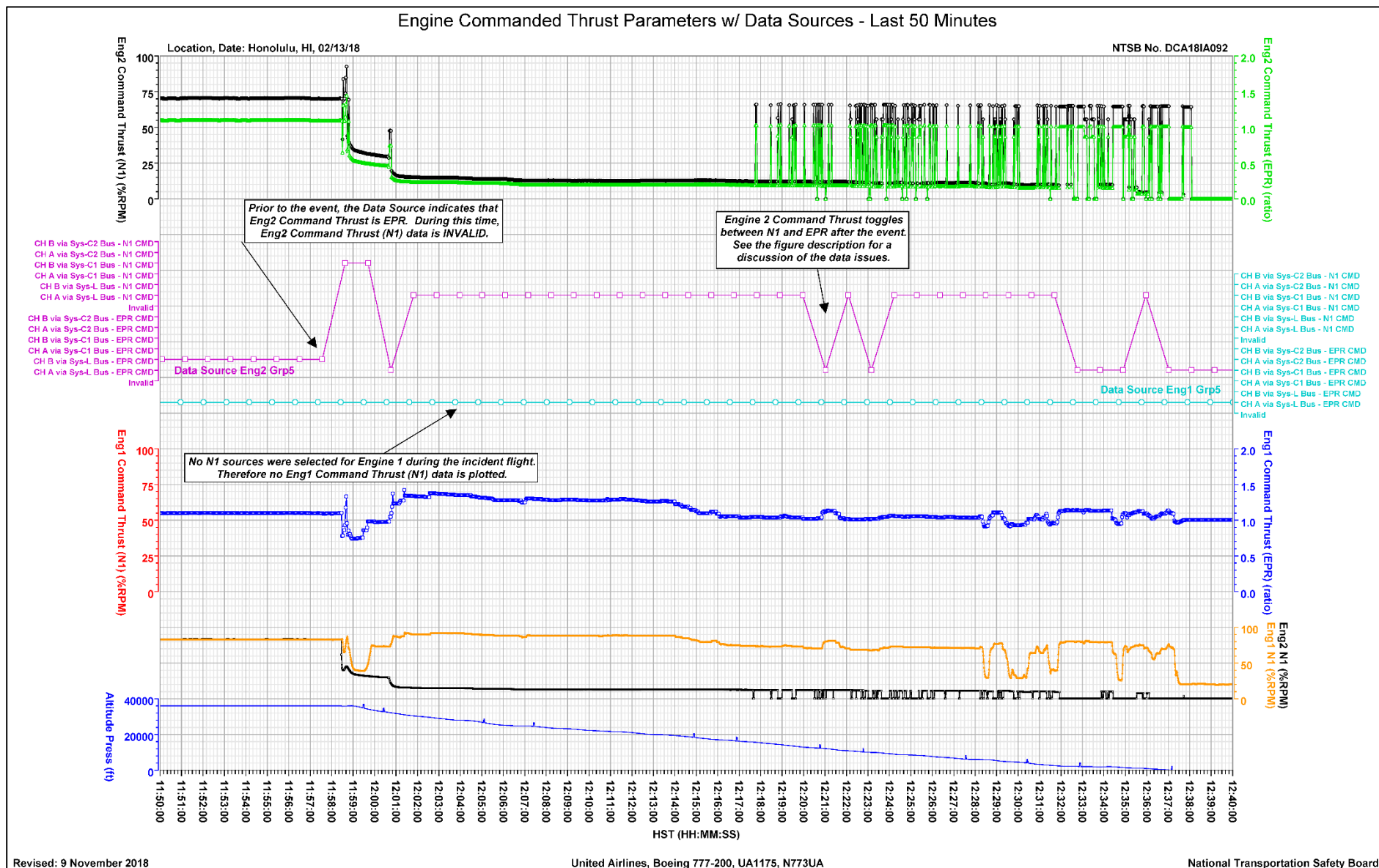


Figure 16. Engine commanded thrust parameter set for the three minutes around the event.

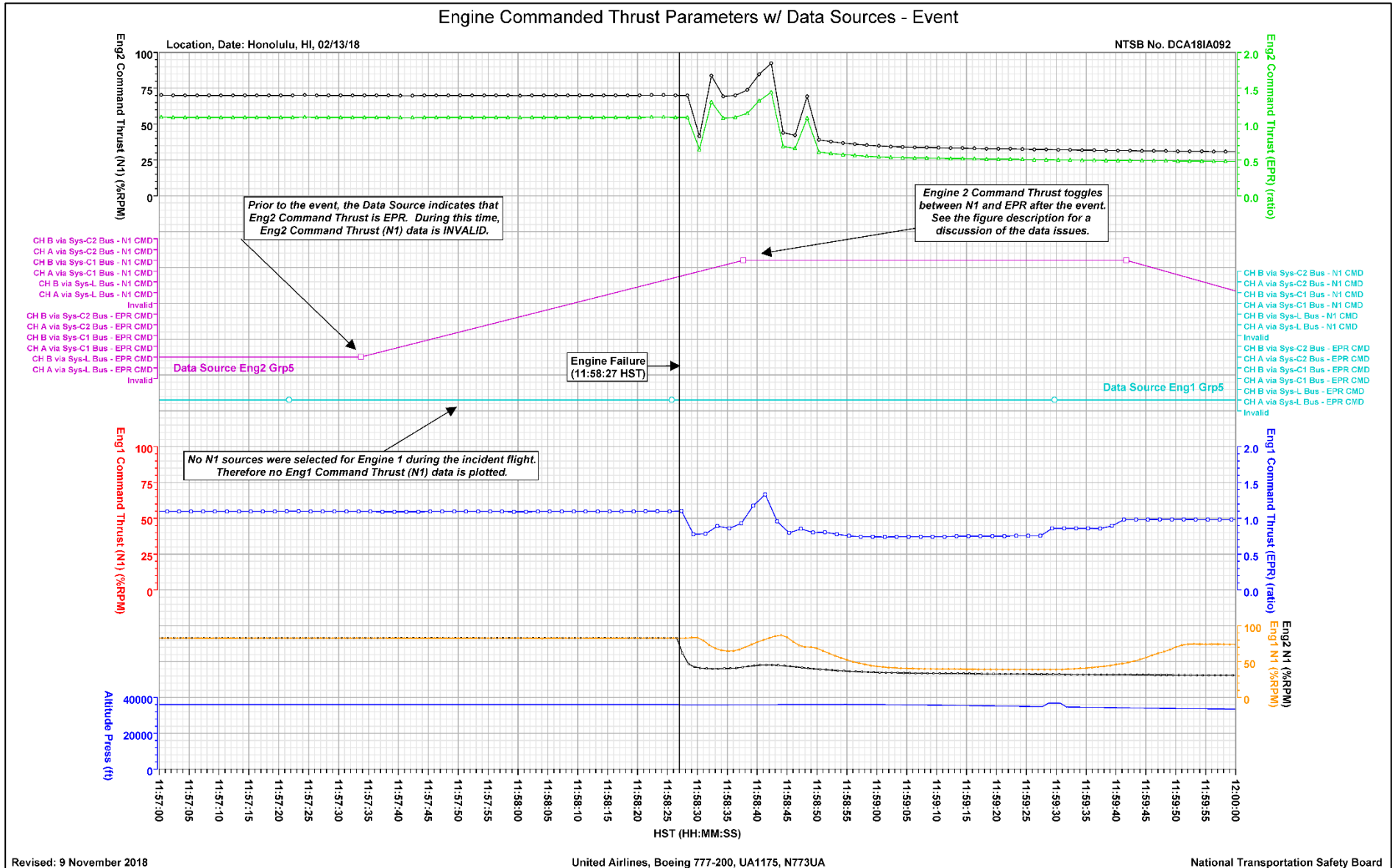


Figure 17. Miscellaneous engine parameter set 1 for the incident flight timeframe.

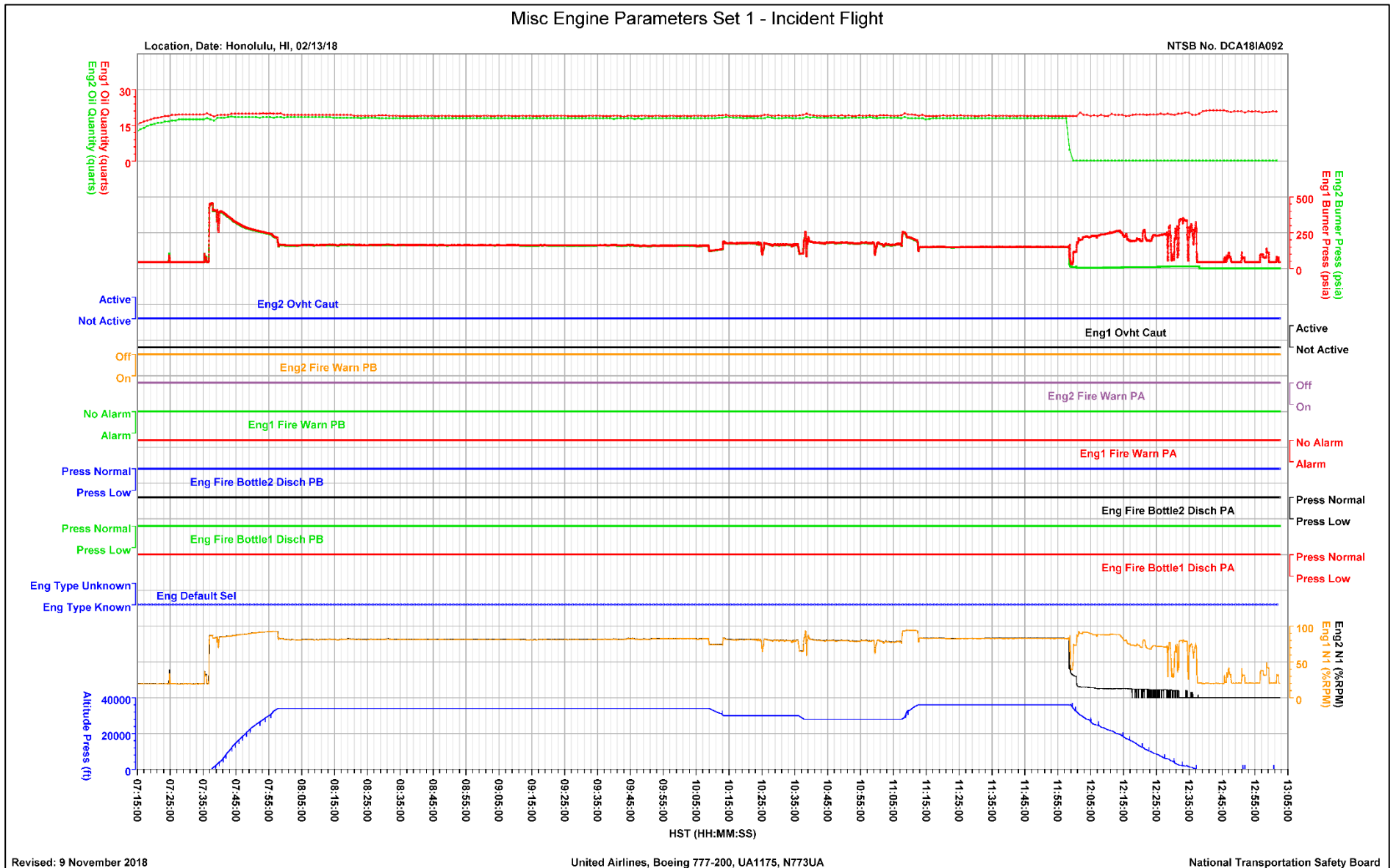


Figure 18. Miscellaneous engine parameter set 1 for the last 50 minutes of the flight.

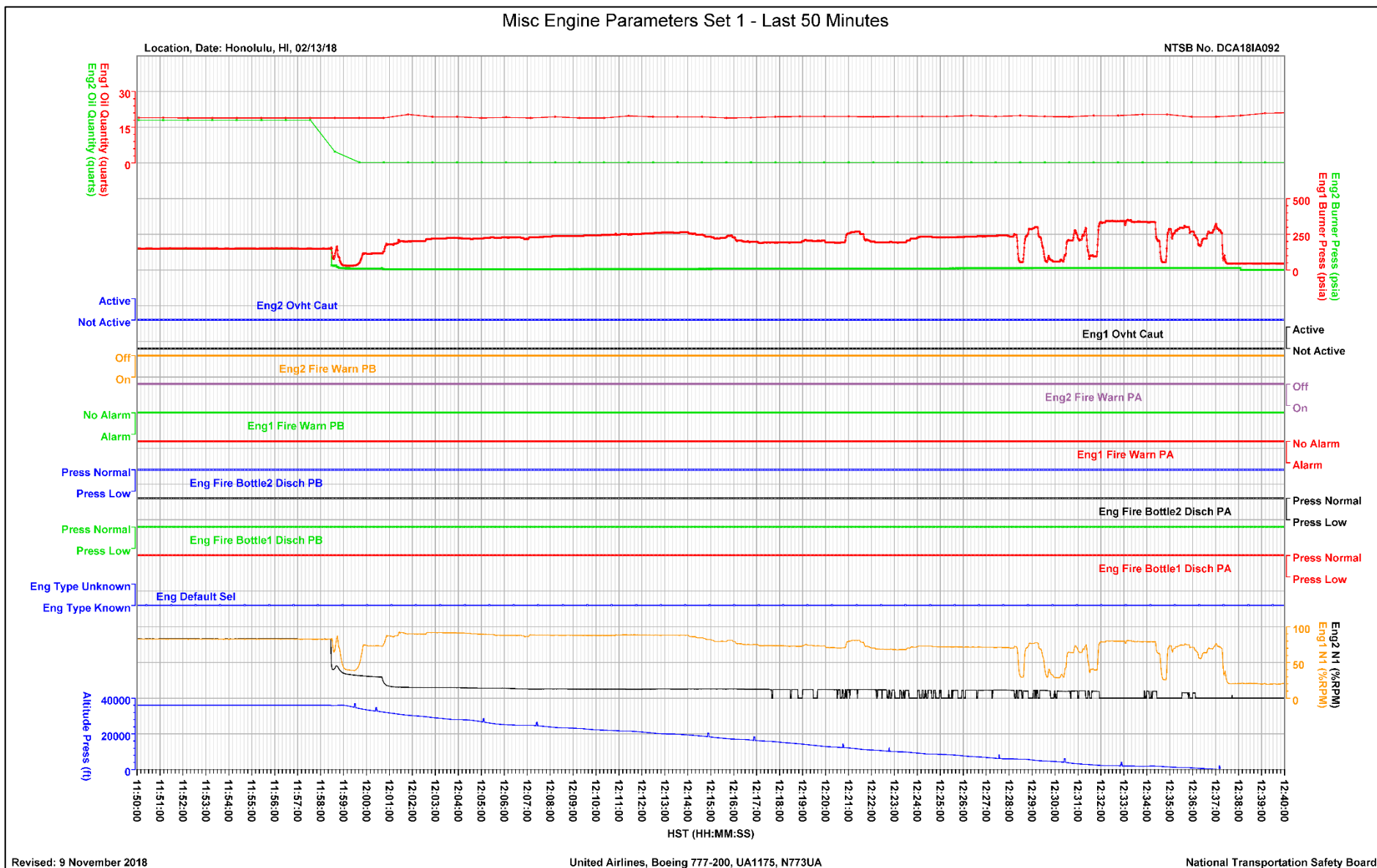


Figure 19. Miscellaneous engine parameter set 1 for the three minutes around the event.

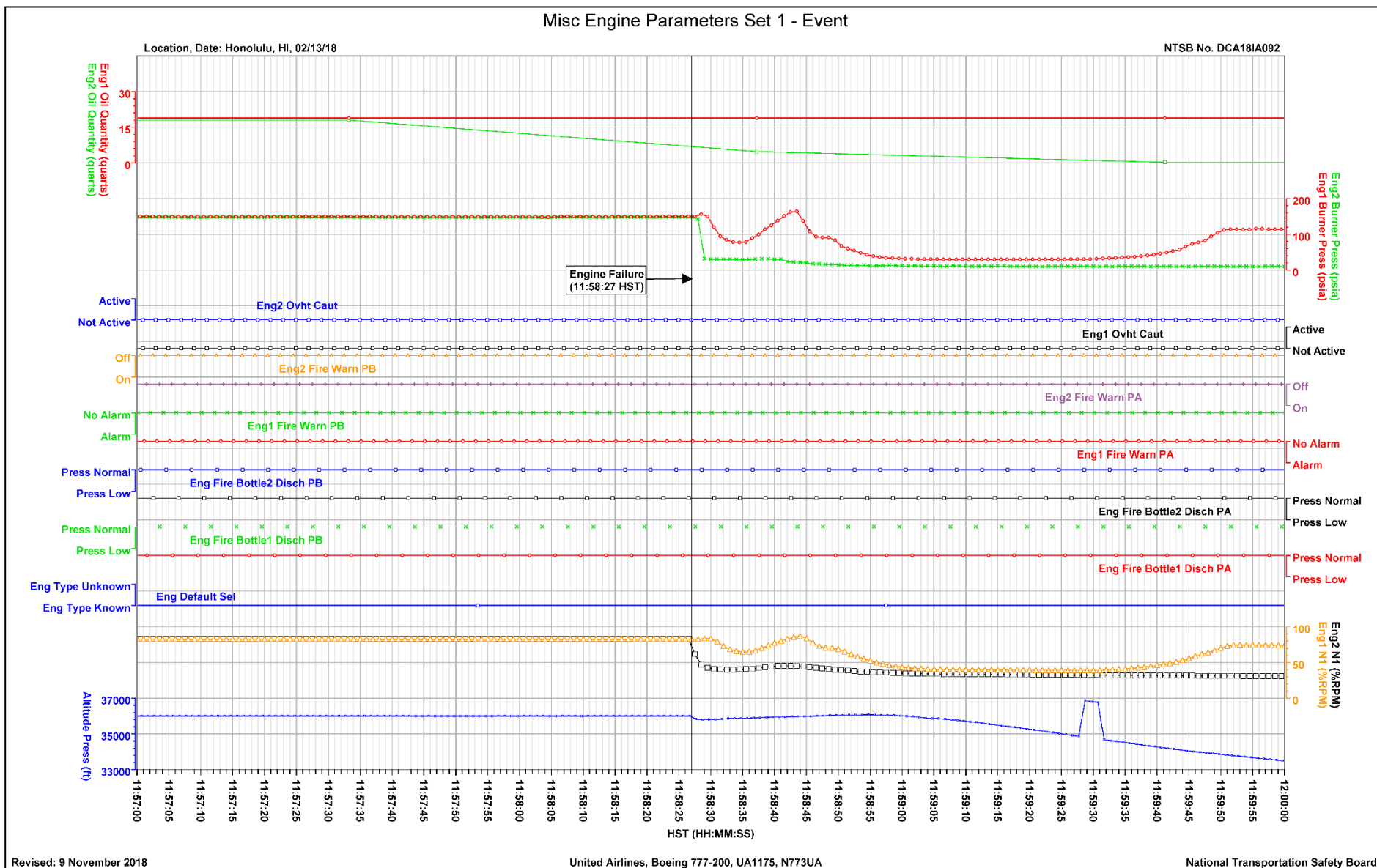


Figure 20. Miscellaneous engine parameter set 2 for the incident flight timeframe.

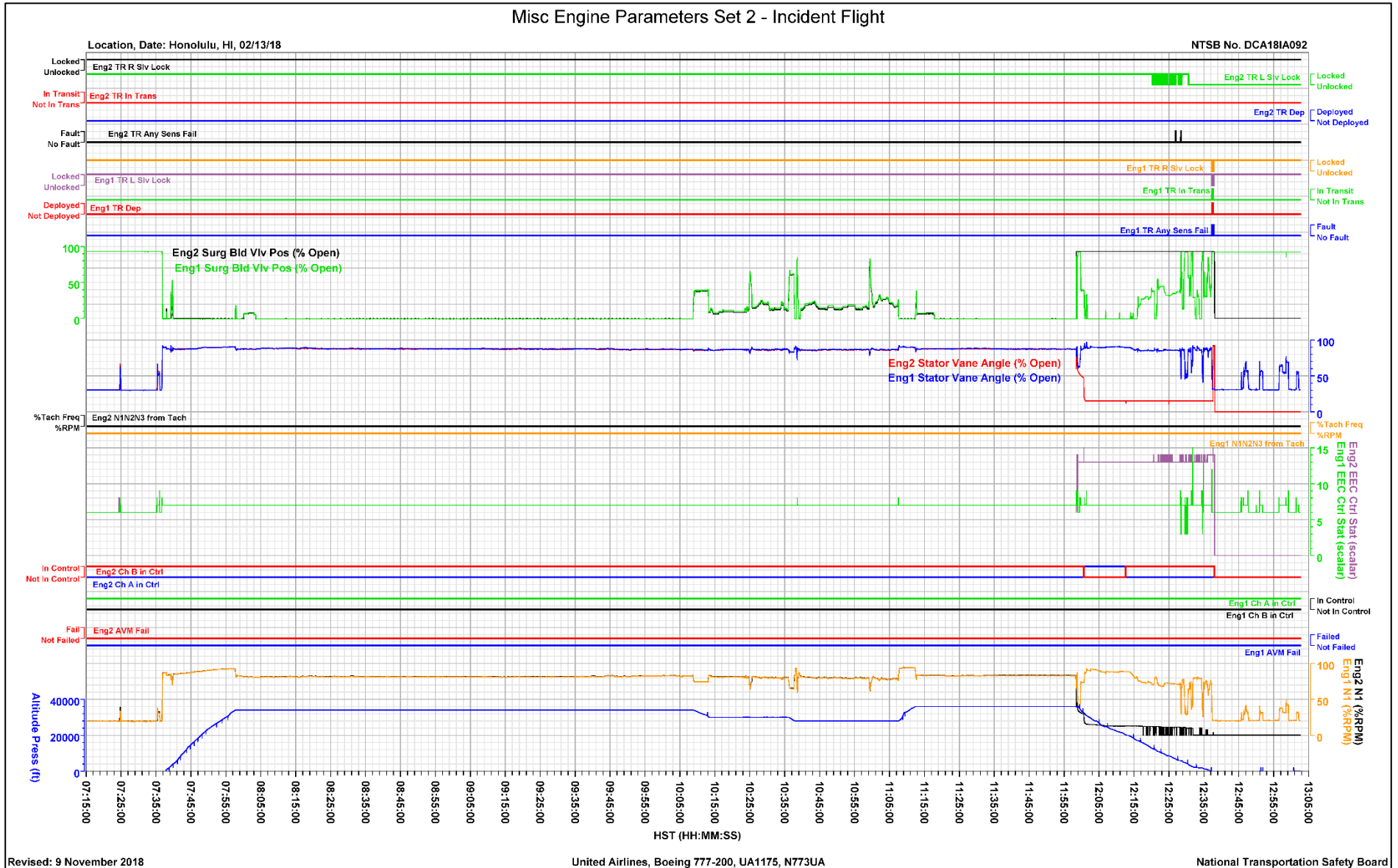


Figure 21. Miscellaneous engine parameter set 2 for the last 50 minutes of the flight.

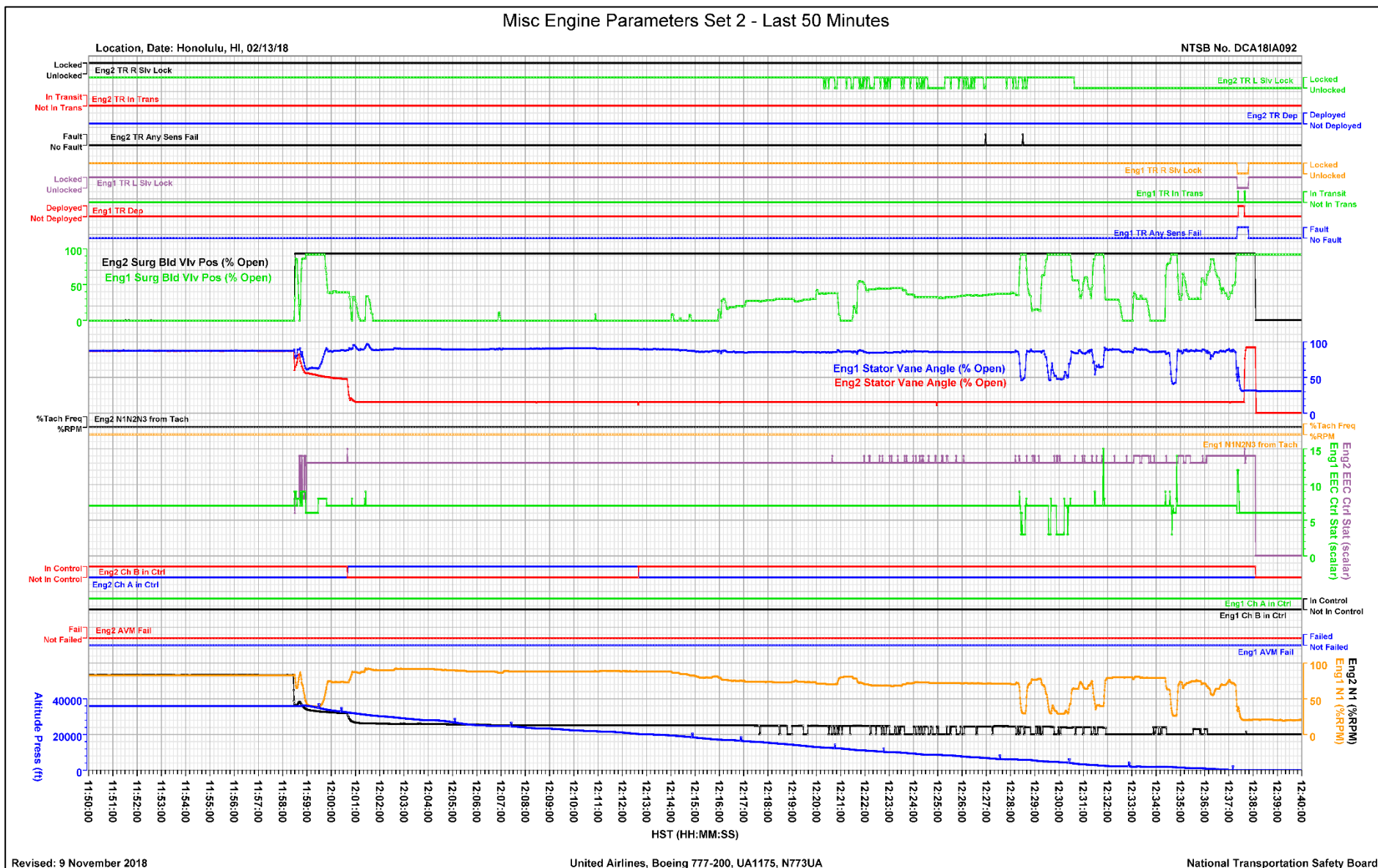


Figure 22. Miscellaneous engine parameter set 2 for the three minutes around the event.

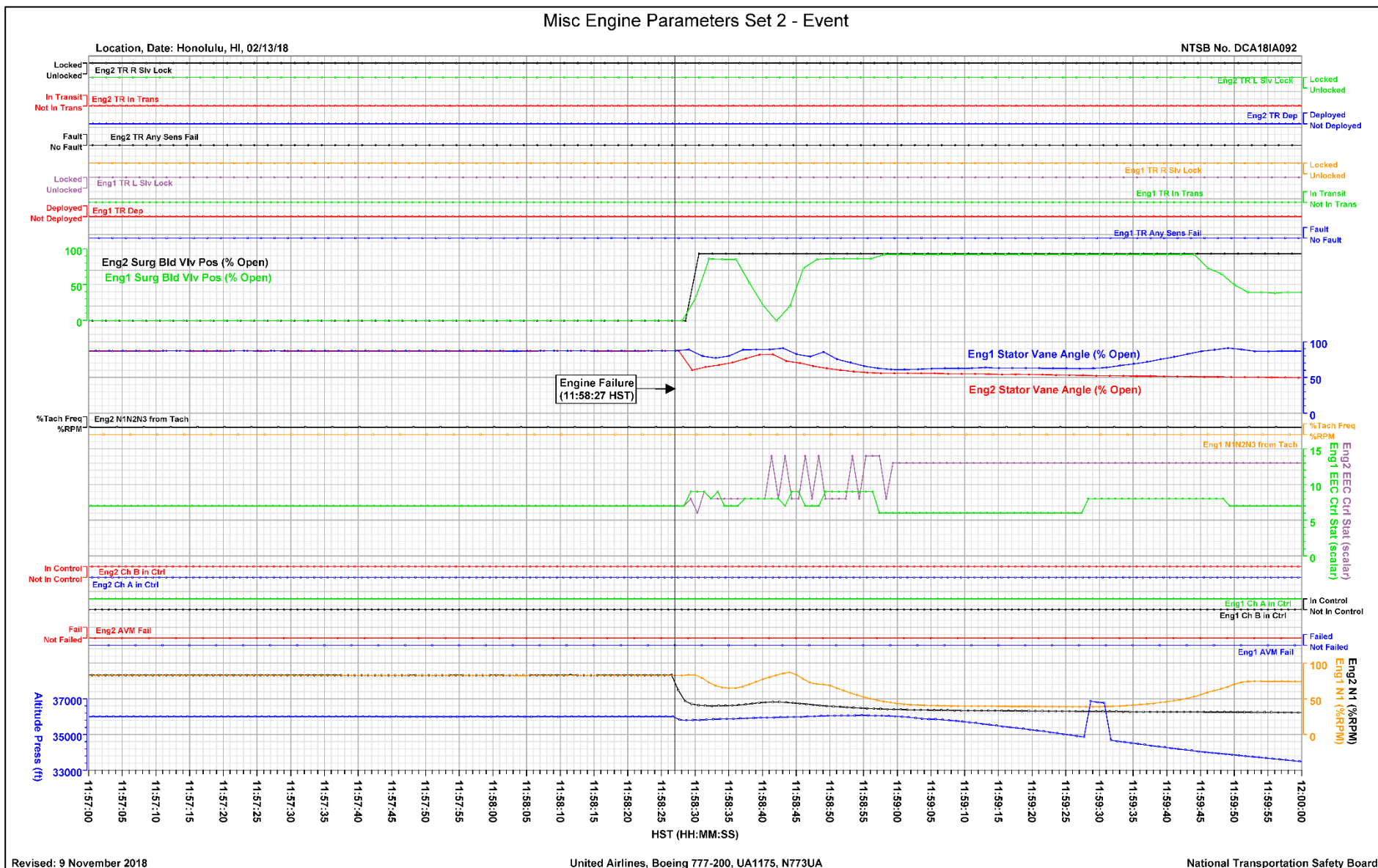
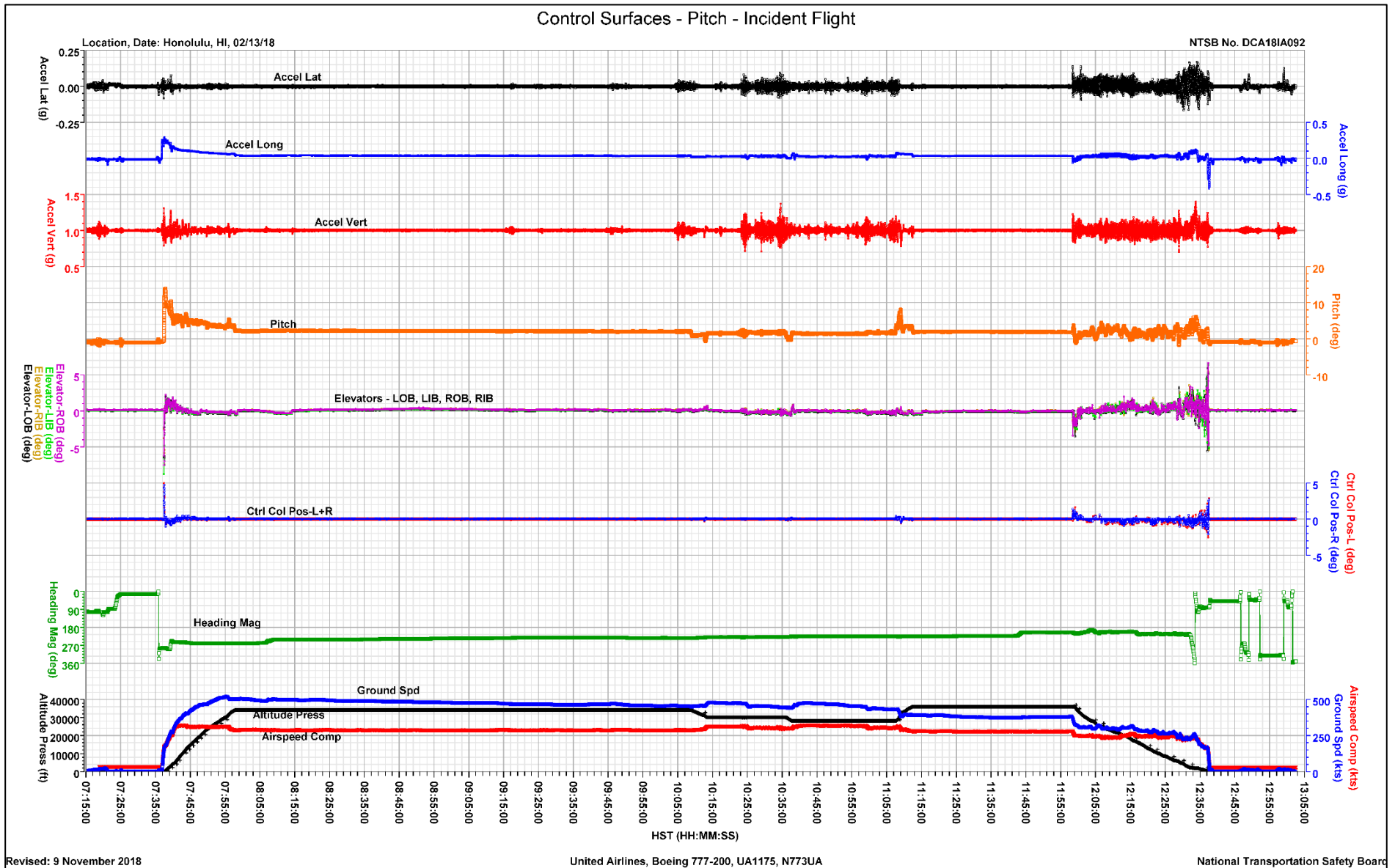


Figure 23. Pitch control parameter set for the incident flight timeframe.



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Figure 24. Pitch control parameter set for the last 50 minutes of the flight.

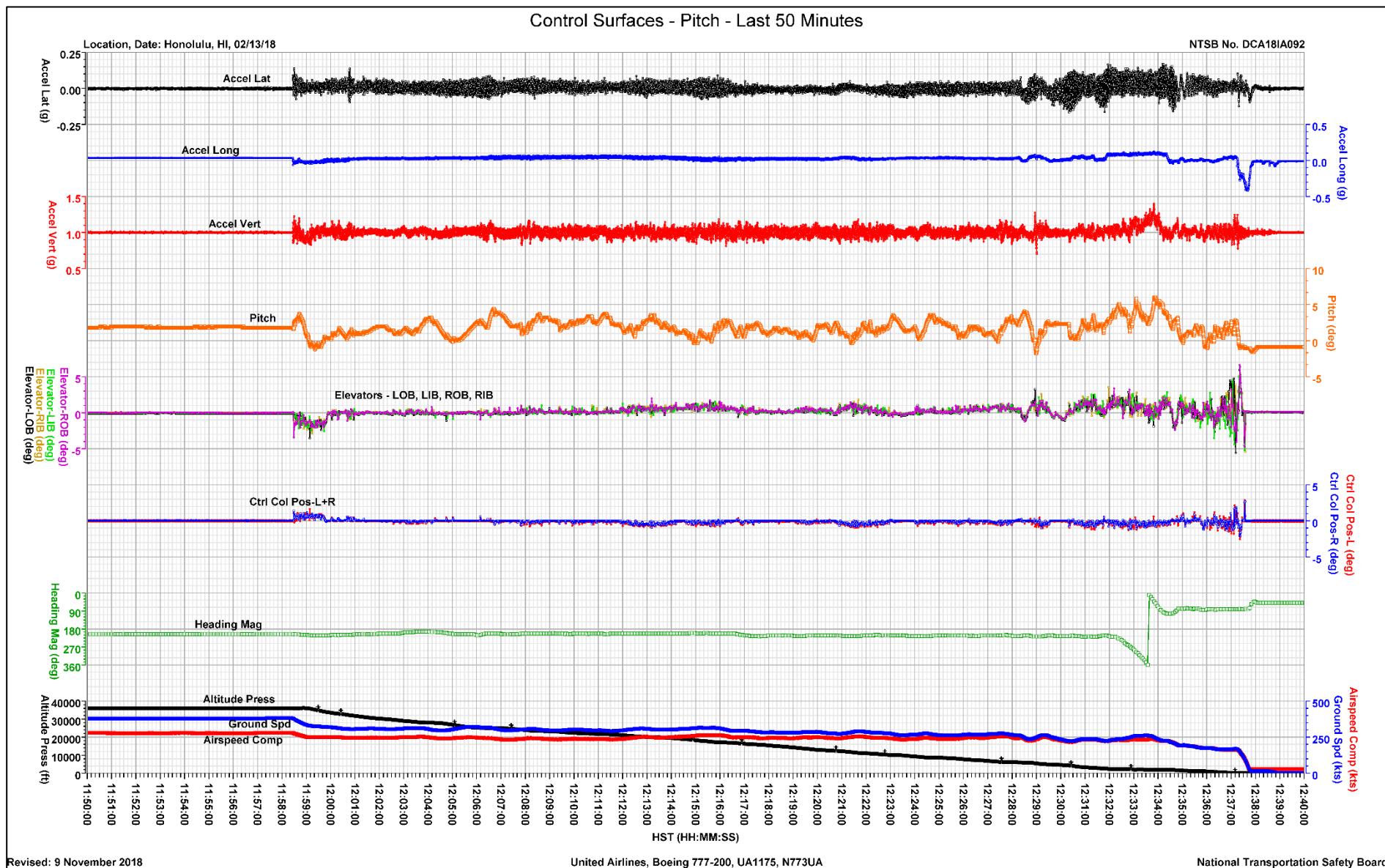


Figure 25. Pitch control parameter set for the three minutes around the event.

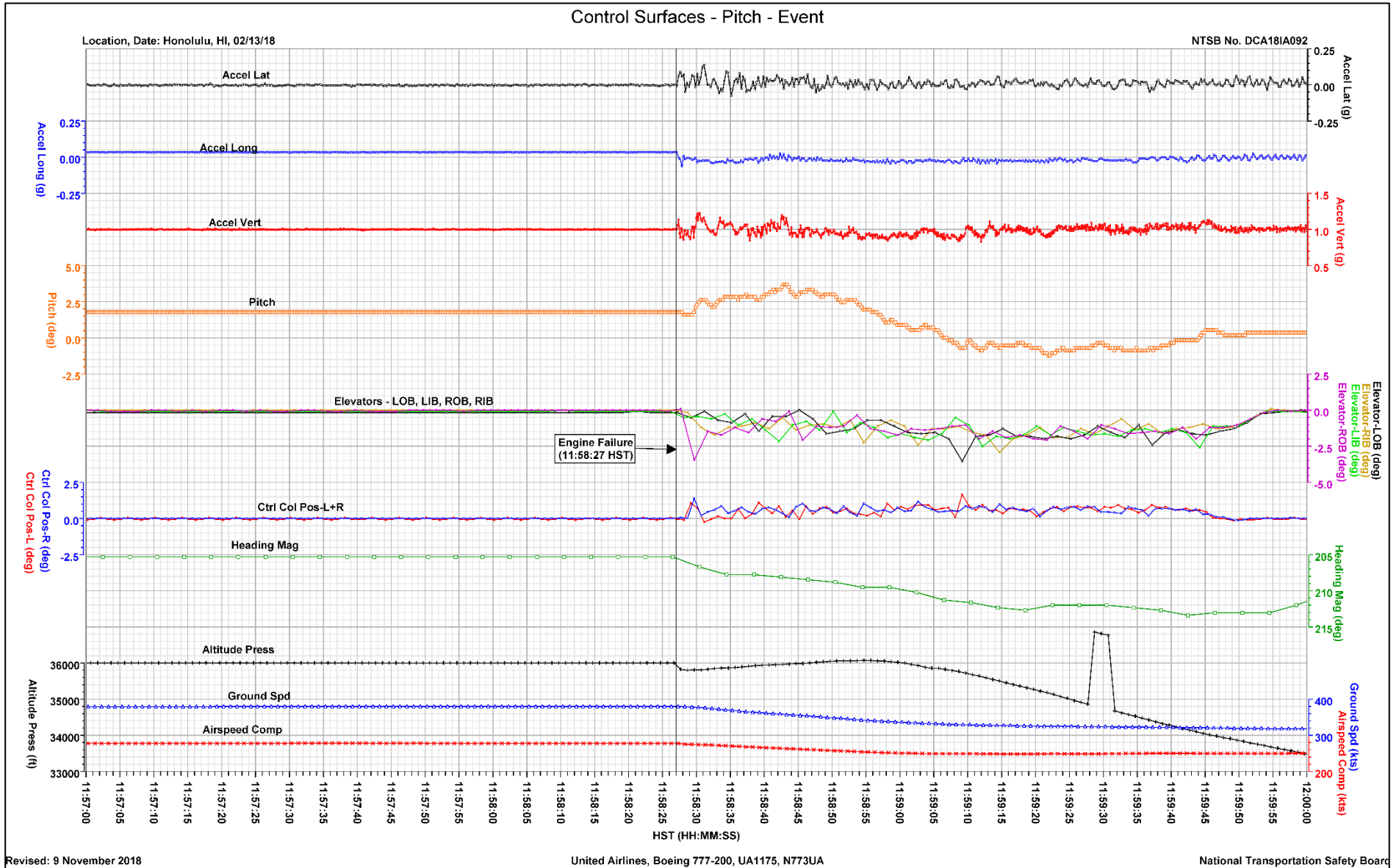


Figure 26. Roll control parameter set for the incident flight timeframe.

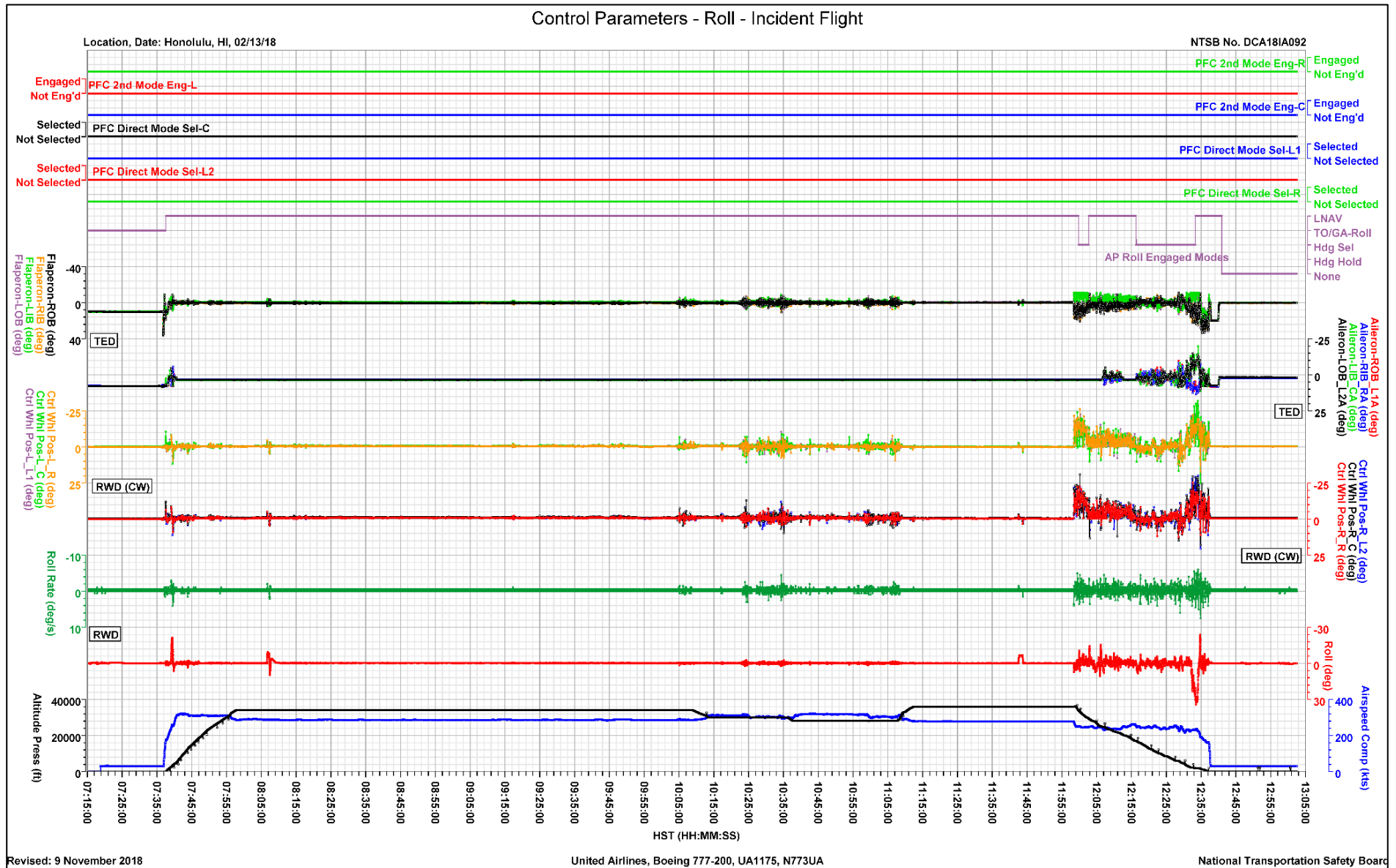


Figure 27. Roll control parameter set for the last 50 minutes of the flight.

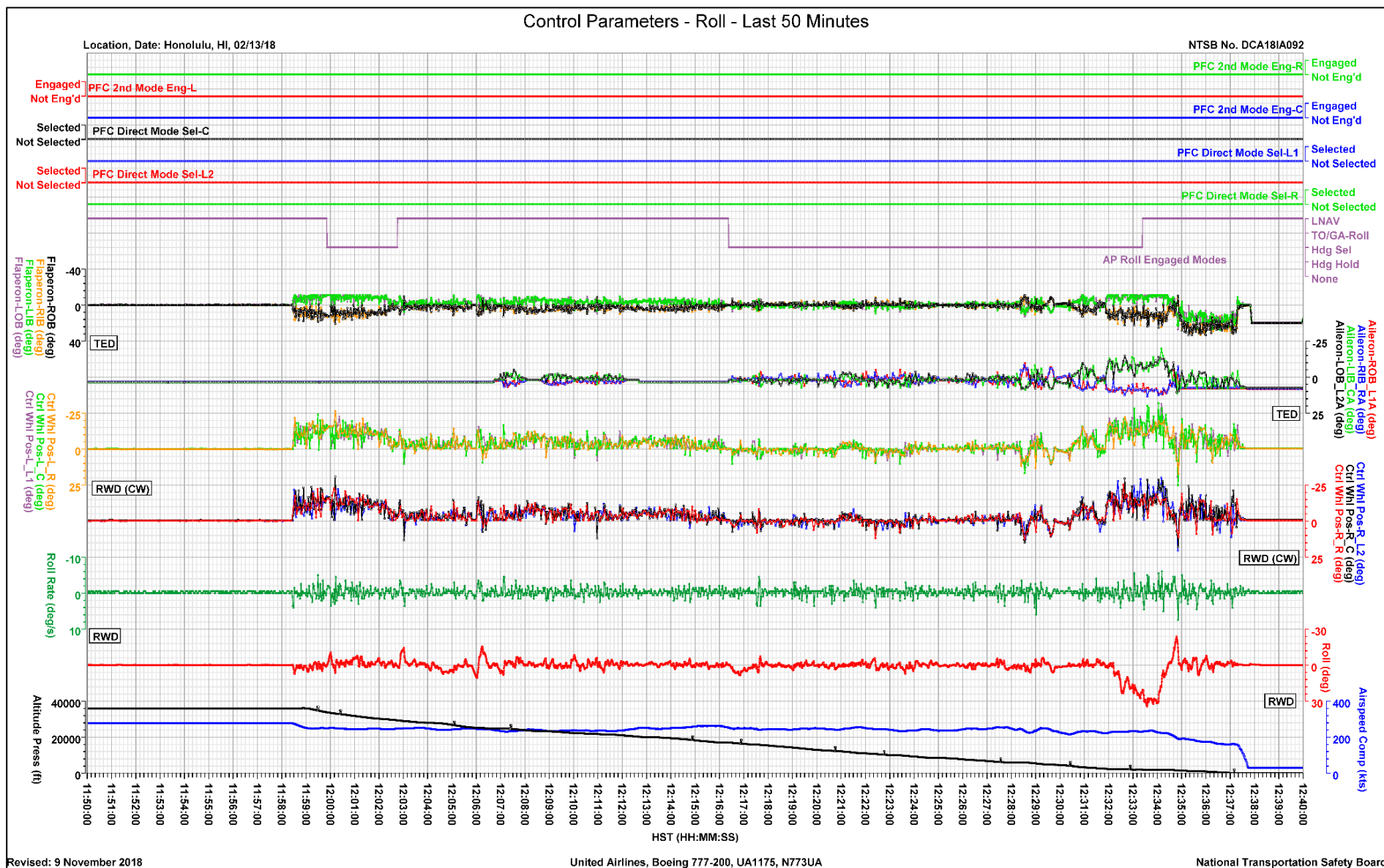


Figure 28. Roll control parameter set for the three minutes around the event.

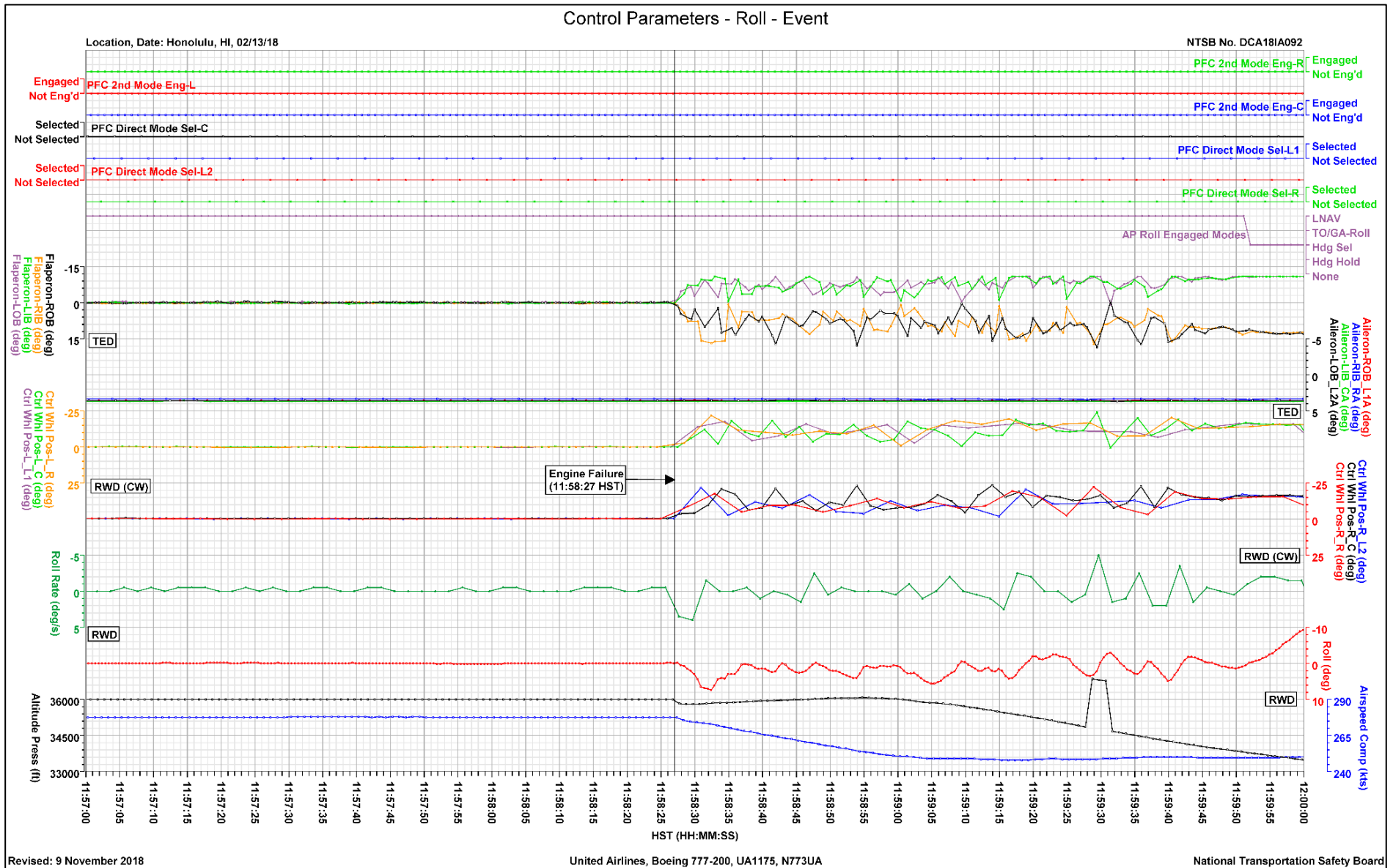


Figure 29. Autopilot parameter set for the incident flight timeframe.

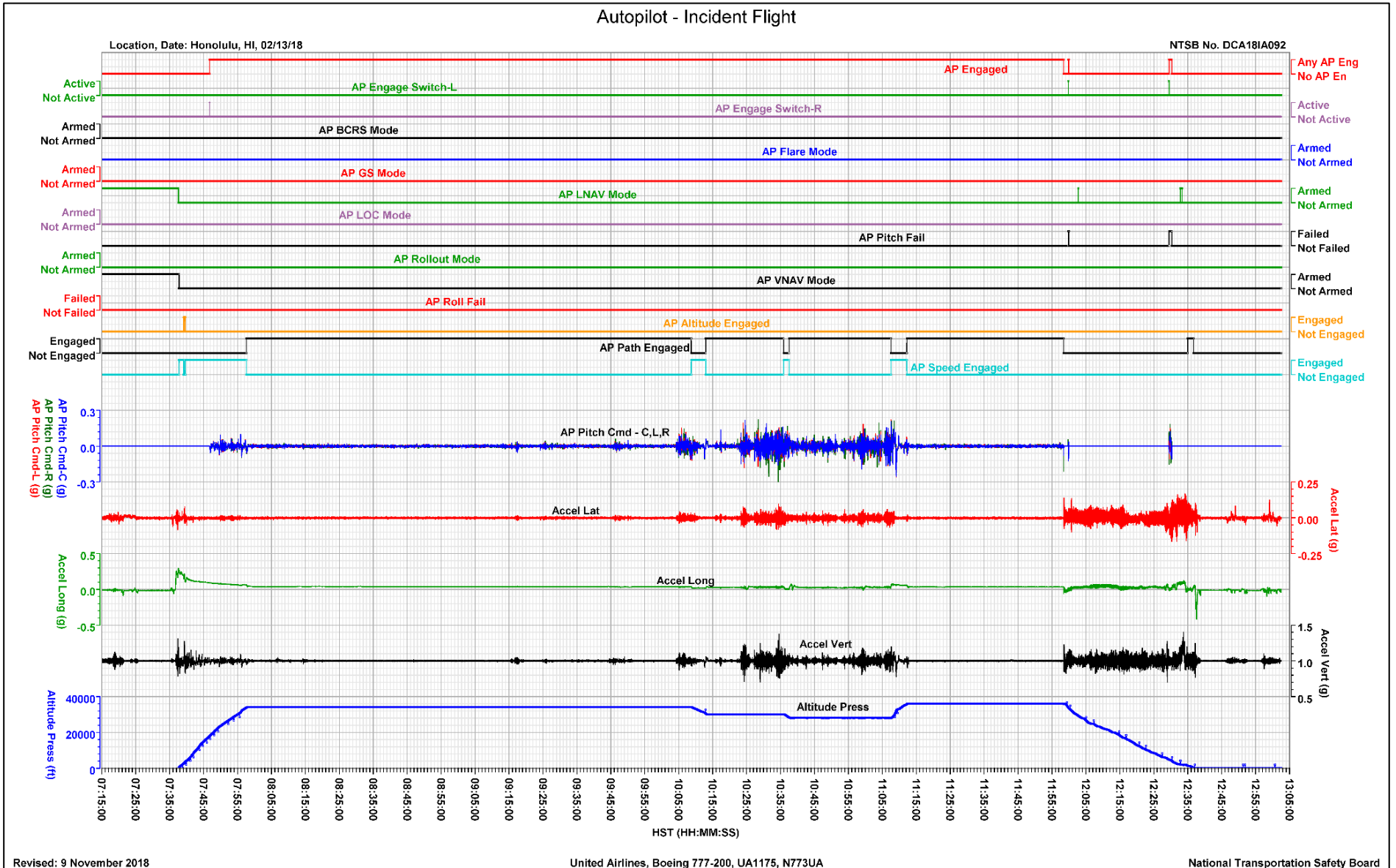


Figure 30. Autopilot parameter set for the last 50 minutes of the flight.

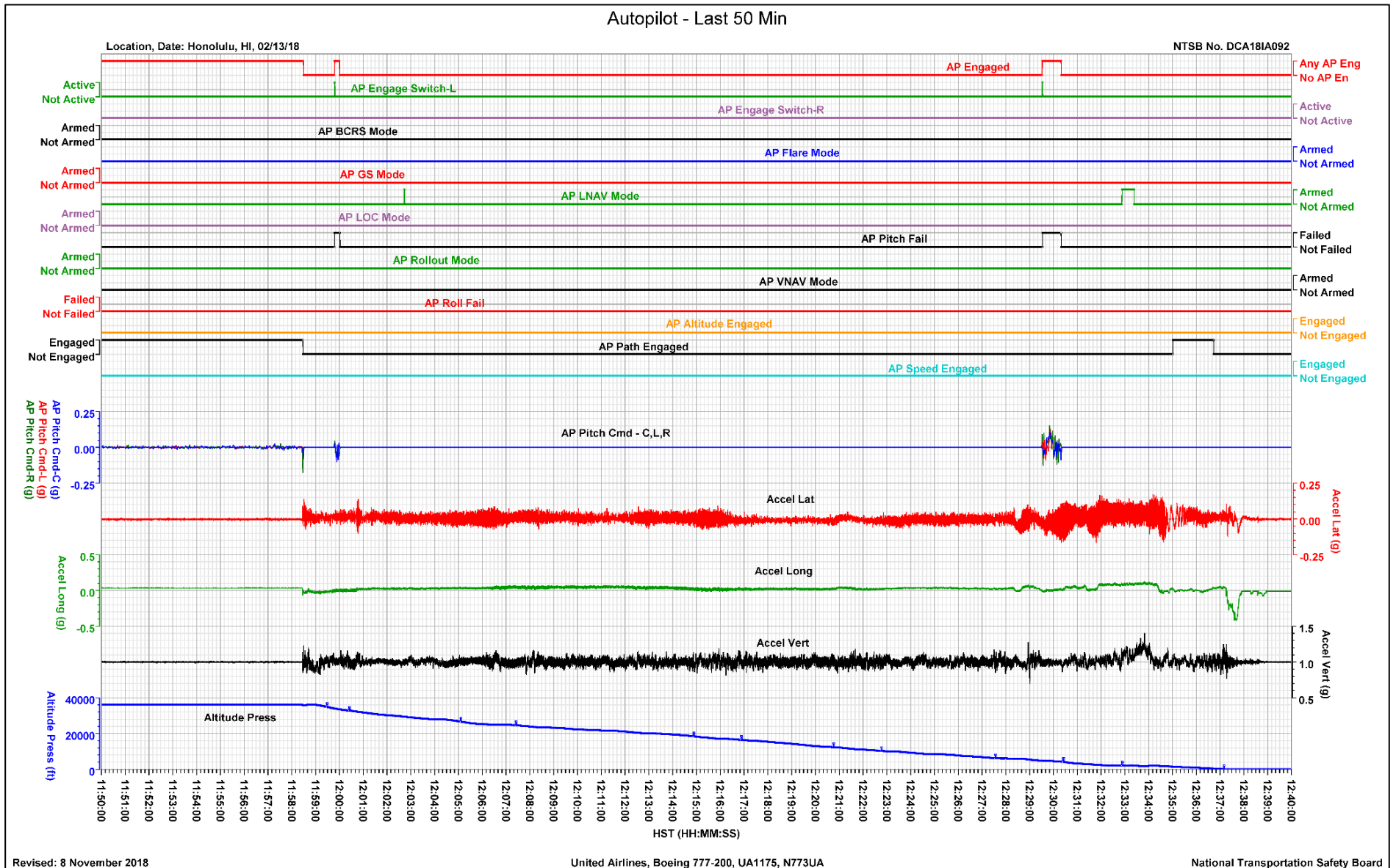
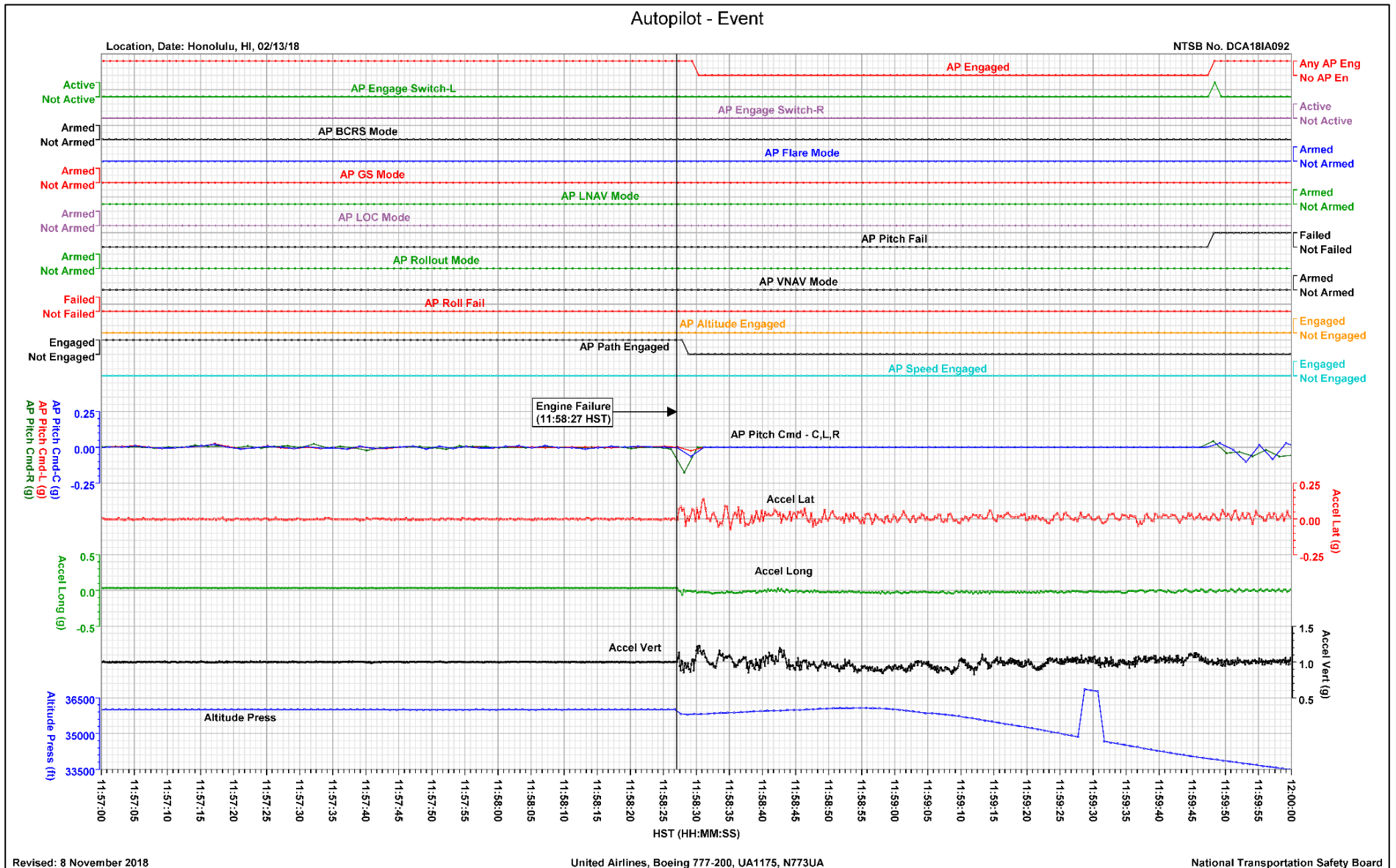


Figure 31. Autopilot parameter set for the three minutes around the event.



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-3. Verified and provided FDR parameters.

Plot/Table Labels	Parameter Names	Units
Accel Lat	Lateral Acceleration	g
Accel Long	Longitudinal Acceleration	g
Accel Vert	Vertical Acceleration	g
Aileron-LIB_CA	Aileron Position - Left Inboard Actuator	deg
Aileron-LOB_L2A	Aileron Position - Left Outboard Actuator	deg
Aileron-RIB_RA	Aileron Position - Right Inboard Actuator	deg
Aileron-ROB_L1A	Aileron Position - Right Outboard Actuator	deg
Airspeed Comp	Computed Airspeed	kts
Altitude Press	Uncorrected Barometric Pressure Altitude	ft
AOA-L Ind	Indicated Angle Of Attack - Left	deg
AOA-R Ind	Indicated Angle Of Attack - Right	deg
AP Altitude Engaged	Autopilot Engaged in Altitude Mode	
AP BCRS Mode	AFDS BCRS Mode Armed	
AP Engage Switch-L	Captain's Autopilot Engage Request Switch Pressed	
AP Engage Switch-R	First Officer's Autopilot Engage Request Switch Pressed	
AP Engaged	Any Autopilot Channel Engaged	
AP Flare Mode	AFDS Flare Mode Armed	
AP GS Mode	AFDS Glideslope Mode Armed	
AP LNAV Mode	AFDS LNAV Mode Armed	
AP LOC Mode	AFDS Localizer Mode Armed	
AP Path Engaged	Autopilot Engaged in Path Mode	
AP Pitch Cmd-C	A/P Pitch Command - Center	g
AP Pitch Cmd-L	A/P Pitch Command - Left	g
AP Pitch Cmd-R	A/P Pitch Command - Right	g
AP Pitch Fail	A/P F/D Pitch Mode Fail	
AP Pitch Mode Engaged	AFDS Pitch Engaged Modes	
AP Roll Engaged Modes	AFDS Roll Engaged Modes	
AP Roll Fail	A/P F/D Roll Mode Fail	
AP Rollout Mode	AFDS Rollout Mode Armed	
AP Speed Engaged	Autopilot Engaged in Speed Mode	
AP VNAV Mode	AFDS VNAV Mode Armed	
AT Engaged Mode	Autothrottle Engaged Modes	
CG-FMC	FMC Center of Gravity	%MAC
Ctrl Col Pos-L	Control Column Position - Captain (Combined)	deg
Ctrl Col Pos-R	Control Column Position - First Officer (Combined)	deg
Ctrl Whl Pos-L_C	Control Wheel Position - Captain - Center ACE	deg
Ctrl Whl Pos-L_L1	Control Wheel Position - Captain - Left 1 ACE	deg
Ctrl Whl Pos-L_R	Control Wheel Position - Captain - Right ACE	deg
Ctrl Whl Pos-R_C	Control Wheel Position - First Officer - Center ACE	deg
Ctrl Whl Pos-R_L2	Control Wheel Position - First Officer - Left 2 ACE	deg
Ctrl Whl Pos-R_R	Control Wheel Position - First Officer - Right ACE	deg
Data Source Eng1 Grp1	Selected Data Source For Left Engine Group 1 Parameters	
Data Source Eng1 Grp2	Selected Data Source For Left Engine Group 2 Parameters	

Plot/Table Labels	Parameter Names	Units
Data Source Eng1 Grp3	Selected Data Source For Left Engine Group 3 Parameters	
Data Source Eng1 Grp5	Selected Data Source For Left Engine Group 5 Parameters	
Data Source Eng1 Grp6	Selected Data Source For Left Engine Group 6 Parameters	
Data Source Eng1 Grp7	Selected Data Source For Left Engine Group 7 Parameters	
Data Source Eng2 Grp1	Selected Data Source For Right Engine Group 1 Parameters	
Data Source Eng2 Grp2	Selected Data Source For Right Engine Group 2 Parameters	
Data Source Eng2 Grp3	Selected Data Source For Right Engine Group 3 Parameters	
Data Source Eng2 Grp5	Selected Data Source For Right Engine Group 5 Parameters	
Data Source Eng2 Grp6	Selected Data Source For Right Engine Group 6 Parameters	
Data Source Eng2 Grp7	Selected Data Source For Right Engine Group 7 Parameters	
Data Source FMC Grp 5	Selected Data Source For FMC Group 5	
Data Source FMCF-TMCF Grp3	Selected Data Source For FMCF/TMCF Group 3 Parameters	
Drift Angle	Drift Angle	deg
Elev Feel Act-1_L2	Elevator Feel Actuator 1 Position	in
Elev Feel Act-2_C	Elevator Feel Actuator 2 Position	in
Elevator-LIB	Elevator Position - Left Inboard Actuator	deg
Elevator-LOB	Elevator Position - Left Outboard Actuator	deg
Elevator-RIB	Elevator Position - Right Inboard Actuator	deg
Elevator-ROB	Elevator Position - Right Outboard Actuator	deg
Eng Default Sel	Engine type undetermined - Default parameter set selected	
Eng Fire Bottle1 Disch PA	Engine Bottle 1 Pressure Low - Internal Path A	
Eng Fire Bottle1 Disch PB	Engine Bottle 1 Pressure Low - Internal Path B	
Eng Fire Bottle2 Disch PA	Engine Bottle 2 Pressure Low - Internal Path A	
Eng Fire Bottle2 Disch PB	Engine Bottle 2 Pressure Low - Internal Path B	
Eng Out Comp Inop-C	Engine Out Compensation Inoperative Status - Center PFC	
Eng Out Comp Inop-L	Engine Out Compensation Inoperative Status - Left PFC	
Eng Out Comp Inop-R	Engine Out Compensation Inoperative Status - Right PFC	
Eng Target Thrust (Ref EPR)	Engine Thrust Target (Reference Mode EPR Target)	ratio
Eng Target Thrust (Tgt EPR)	Engine Thrust Target (Target EPR)	ratio
Eng Target Thrust-FMC (EPR)	FMC Engine Thrust Target (Target EPR)	ratio
Eng Target Thrust-FMC (Spd)	FMC Engine Thrust Target (Target Speed)	fps
Eng1 AVM Fail	Left AVM Fail	
Eng1 Broadband Vib	Engine Vibration - Broadband - Left Engine	scalar
Eng1 Burner Press	Burner Pressure - Left Engine	psia
Eng1 Ch A in Ctrl	Channel A In Control - Left Engine	
Eng1 Ch B in Ctrl	Channel B In Control - Left Engine	
Eng1 Command Thrust (EPR)	Commanded Thrust (EPR) - Left Engine	ratio
Eng1 EEC Ctrl Stat	EEC Loop In Control Status - Left Engine	scalar
Eng1 EGT	Exhaust Gas Temperature - Left Engine	degC
Eng1 EPR	Actual EPR - Left Engine	ratio

Plot/Table Labels	Parameter Names	Units
Eng1 Fail Warn	Engine Fail Warn - Left	
Eng1 Fire Warn PA	Engine Fire Warn - Left - Internal Path A	
Eng1 Fire Warn PB	Engine Fire Warn - Left - Internal Path B	
Eng1 Fuel Flow	Fuel Flow Rate - Left Engine	lbs/hr
Eng1 N1	N1 RPM - Left Engine	%RPM
Eng1 N1 Vib	Engine Vibration - One Per N1 Revolution - Left Engine	scalar
Eng1 N1N2N3 from Tach	Left Engine N1/N2/N3 from Tachometer	
Eng1 N2	N2 RPM - Left Engine	%RPM
Eng1 N2 Vib	Engine Vibration - One Per N2 Revolution - Left Engine	scalar
Eng1 Oil Press	Engine Oil Pressure - Left Engine	psig
Eng1 Oil Quantity	Engine Oil Quantity - Left Engine	quarts
Eng1 Oil Temp	Engine Oil Temperature - Left Engine	degC
Eng1 Ovht Caut	Engine Overheat Caution - Left Engine (From EICAS)	
Eng1 Stator Vane Angle	Stator Vane Angle - Left Engine (PW/GE)	% Open
Eng1 Surg Bld Vlv Pos	Surge Bleed Valve Position - Left Engine	% Open
Eng1 Throt Rate Cmd	Throttle Rate Command - Left Engine	deg/sec
Eng1 TLA	Thrust Lever Angle - Left Engine	deg
Eng1 TR Any Sens Fail	Thrust Reverser Any Sensor Fail - Left Engine	
Eng1 TR Dep	Thrust Reverser Deployed - Left Engine	
Eng1 TR In Trans	Thrust Reverser In Transit - Left Engine	
Eng1 TR L Slv Lock	Thrust Reverser Left Sleeve Locked - Left Engine	
Eng1 TR R Slv Lock	Thrust Reverser Right Sleeve Locked - Left Engine	
Eng1 Vib Amb Exceed	Engine Vibration Amber Exceedance - Left Engine	
Eng1 Vib Red Exceed	Engine Vibration Red Exceedance - Left Engine	
Eng2 AVM Fail	Right AVM Fail	
Eng2 Broadband Vib	Engine Vibration - Broadband - Right Engine	scalar
Eng2 Burner Press	Burner Pressure - Right Engine	psia
Eng2 Ch A in Ctrl	Channel A In Control - Right Engine	
Eng2 Ch B in Ctrl	Channel B In Control - Right Engine	
Eng2 Command Thrust (EPR)	Commanded Thrust (EPR) - Right Engine	ratio
Eng2 Command Thrust (N1)	Commanded Thrust (N1) - Right Engine	%RPM
Eng2 EEC Ctrl Stat	EEC Loop In Control Status - Right Engine	scalar
Eng2 EGT	Exhaust Gas Temperature - Right Engine	degC
Eng2 EPR	Actual EPR - Right Engine	ratio
Eng2 Fail Warn	Engine Fail Warn - Right	
Eng2 Fire Warn PA	Engine Fire Warn - Right - Internal Path A	
Eng2 Fire Warn PB	Engine Fire Warn - Right - Internal Path B	
Eng2 Fuel Flow	Fuel Flow Rate - Right Engine	lbs/ hr
Eng2 N1	N1 RPM - Right Engine	%RPM
Eng2 N1 Vib	Engine Vibration - One Per N1 Revolution - Right Engine	scalar
Eng2 N1N2N3 from Tach	Right Engine N1/N2/N3 from Tachometer	
Eng2 N2	N2 RPM - Right Engine	%RPM
Eng2 N2 Vib	Engine Vibration - One Per N2 Revolution - Right Engine	scalar
Eng2 Oil Press	Engine Oil Pressure - Right Engine	psig
Eng2 Oil Quantity	Engine Oil Quantity - Right Engine	quarts
Eng2 Oil Temp	Engine Oil Temperature - Right Engine	degC
Eng2 Ovht Caut	Engine Overheat Caution - Right Engine (From EICAS)	
Eng2 Stator Vane Angle	Stator Vane Angle - Right Engine	% Open
Eng2 Surg Bld Vlv Pos	Surge Bleed Valve Position - Right Engine	% Open
Eng2 Throt Rate Cmd	Throttle Rate Command - Right Engine	deg/sec

Plot/Table Labels	Parameter Names	Units
Eng2 TLA	Thrust Lever Angle - Right Engine	deg
Eng2 TR Any Sens Fail	Thrust Reverser Any Sensor Fail - Right Engine	
Eng2 TR Dep	Thrust Reverser Deployed - Right Engine	
Eng2 TR In Trans	Thrust Reverser In Transit - Right Engine	
Eng2 TR L Slv Lock	Thrust Reverser Left Sleeve Locked - Right Engine	
Eng2 TR R Slv Lock	Thrust Reverser Right Sleeve Locked - Right Engine	
Eng2 Vib Amb Exceed	Engine Vibration Amber Exceedance - Right Engine	
Eng2 Vib Red Exceed	Engine Vibration Red Exceedance - Right Engine	
Flaperon-LIB	Flaperon Position - Left Inboard Actuator	deg
Flaperon-LOB	Flaperon Position - Left Outboard Actuator	deg
Flaperon-RIB	Flaperon Position - Right Inboard Actuator	deg
Flaperon-ROB	Flaperon Position - Right Outboard Actuator	deg
GMT Day	Date - Day	Day
GMT Month	Date - Month	mon
GMT Year	Date - Year	yr
Gross Weight	FMC Gross Weight	lb
Ground Spd	Groundspeed	kts
Heading Mag	Magnetic Heading	deg
Key VHF-1 PA	Radio Keying - VHF Radio 1 (Left) - Internal Path A	
Key VHF-1 PB	Radio Keying - VHF Radio 1 (Left) - Internal Path B	
Key VHF-2 PA	Radio Keying - VHF Radio 2 (Center) - Internal Path A	
Key VHF-2 PB	Radio Keying - VHF Radio 2 (Center) - Internal Path B	
Key VHF-3 PA	Radio Keying - VHF Radio 3 (Right) - Internal Path A	
Key VHF-3 PB	Radio Keying - VHF Radio 3 (Right) - Internal Path B	
Latitude ADIRS	Latitude from ADIRS	deg
Latitude FMC	Flight Management Computer Latitude	deg
Latitude GPS-L	Left Global Positioning System - Latitude	deg
Latitude GPS-R	Right Global Positioning System - Latitude	deg
LE Slat-L1	Left Leading Edge Slat Position - FSEU 1	deg
LE Slat-L2	Left Leading Edge Slat Position - FSEU 2	deg
LE Slat-R1	Right Leading Edge Slat Position - FSEU 1	deg
LE Slat-R2	Right Leading Edge Slat Position - FSEU 2	deg
Longitude ADIRS	Longitude from ADIRS	deg
Longitude FMC	Flight Management Computer Longitude	deg
Longitude GPS-L	Left Global Positioning System - Longitude	deg
Longitude GPS-R	Right Global Positioning System - Longitude	deg
Mach	Mach Number	mach
PFC 2nd Mode Eng-C	Center PFC Secondary Mode Engage Status	
PFC 2nd Mode Eng-L	Left PFC Secondary Mode Engage Status	
PFC 2nd Mode Eng-R	Right PFC Secondary Mode Engage Status	
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 Attitude	deg
Pitch Rate	Pitch Rate	deg/s
Roll	Roll Attitude	deg
Roll Rate	Roll Rate	deg/s
Rudder-L	Rudder Position - Lower Actuator	deg
Rudder-M	Rudder Position - Middle Actuator	deg
Rudder-U	Rudder Position - Upper Actuator	deg
Spoiler-1	Spoiler #1 Position	deg
Spoiler-2	Spoiler #2 Position	deg
Spoiler-3	Spoiler #3 Position	deg

Plot/Table Labels	Parameter Names	Units
Spoiler-4	Spoiler #4 Position	deg
Spoiler-5	Spoiler #5 Position	deg
Spoiler-6	Spoiler #6 Position	deg
Spoiler-7	Spoiler #7 Position	deg
Spoiler-8	Spoiler #8 Position	deg
Spoiler-9	Spoiler #9 Position	deg
Spoiler-10	Spoiler #10 Position	deg
Spoiler-11	Spoiler #11 Position	deg
Spoiler-12	Spoiler #12 Position	deg
Spoiler-13	Spoiler #13 Position	deg
Spoiler-14	Spoiler #14 Position	deg
Stabilizer	Pitch Trim Position - All ACES	deg
Static Press	Static Pressure	mb
Temp SAT	Static Air Temperature	degC
Temp TAT	Total Air Temperature	degC
Time GMT Hrs	Time (UTC) - Binary Hours	hrs
Time GMT Min	Time (UTC) - Binary Minutes	min
Time GMT Sec	Time (UTC) - Binary Seconds	sec
Total Press	Total Pressure	mb
Wind Direction	Wind Direction	deg
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-4. Unit and discrete abbreviations.

Unit and Discrete Abbreviations	Descriptions
deg	degrees
kts	knots
g	g
degC	degrees Celsius
%MAC	percent mean aerodynamic chord
in	inches
ft	feet
fps	feet per second
psia	pound per square inch - absolute
psig	pound per square inch - gauge
lb(s)	pounds
mon	month
yr	year
hrs	hours
min	minutes
sec	seconds
deg/s	degrees per second
%rpm	percent revolutions per minute
mb	millibars
A/P	autopilot

Unit and Discrete Abbreviations	Descriptions
AFDS	Autopilot Flight Director System
AVM	Airborne Vibration Monitor
BCRS	back course
EPR	Engine Pressure Ratio
F/D	Flight Director
FMC	Flight Management Computer