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

February 10, 2014

Digital Engine Controls Factual Report

Specialist's Factual Report
by Bill Tuccio, Ph.D.

1. EVENT

Location:	Ft Lauderdale, Florida
Date:	November 19, 2013
Aircraft:	Lear 35
Registration:	XA-USD
Operator:	Aero JL SA de CV
NTSB Number:	ERA14FA045

On November 19, 2013, at 1956 eastern standard time, a Learjet 35, Mexican registration XA-USD, operated by Aero JL SA de CV, was destroyed when it collided with the Atlantic Ocean after takeoff from Fort Lauderdale/Hollywood International Airport (FLL), Fort Lauderdale, Florida. The commercial pilot and a physician on board were lost and presumed fatally injured. The copilot and a flight nurse were fatally injured. Night visual meteorological conditions prevailed, and an instrument flight rules flight plan was filed for the positioning flight from FLL to Cozumel, Mexico.

2. DETAILS OF DEVICE INVESTIGATION

The Safety Board's Vehicle Recorder Division received the following devices:

Device 1:	Honeywell N1 Digital Electronic Engine Control (DEEC)
Device 1 Serial Number:	45-CF0149
Device 2:	Honeywell N1 Digital Electronic Engine Control (DEEC)
Device 2 Serial Number:	45-CF0152

2.1. Honeywell N1 DEEC Description

The N1 DEECs include an incident recorder which collects engine and aircraft operational data and records it into non-volatile memory (NVM)[1] for post-accident/incident download and analysis. The incident recorder provides a record of engine speeds, interstage turbine temperatures, aircraft parameters related to the engine, and control modes during operation. Some of the recorded data may come from

[1] Non-volatile memory is semiconductor memory that does not require external power for data retention.

direct measurement, while others may be calculated parameters; the method depends upon aircraft model. It should be noted that the DEEC casing is not designed to be crash worthy, and recorded data could be lost for a variety of reasons including, but not limited to, impact and fire damage.

The incident recorder collects data into ten memory buffers for the last 85 minutes, 20 seconds of engine ground and/or flight time. The recorder will automatically power off approximately five minutes after weight-on-wheels (WOW) is established. This feature prevents the DEEC from accidentally overwriting the data in memory if aircraft power remains on after the engines have been shut down.

The data set stored in the first memory buffer is recorded once per second for the last 512 seconds (8 minutes, 32 seconds) prior to power down or 5 minutes after weight on wheels. For data sets recorded beyond 512 seconds, individual scans are stored in nine additional buffers with decreasing frequency. As data points roll into the downstream buffers, certain data points are dropped. For example, the data points in the second buffer are two seconds apart and the data points in the third buffer are 4 seconds apart, and so on.

The data is recorded in data “buckets” to minimize the space required for data storage. With this recording methodology, the exact data parameter is not physically recorded to memory. A digital bit value that corresponds to a data parameter range is recorded to memory whenever a parameter is within a given range. For example a N1 speed of 37% may be recorded as one data point in the “30-40” bucket for that given moment in time. This results in transient data being displayed in a “stair-step” fashion, and not the smooth transient change that actually occurs during operation. In addition, the same parameters from each engine, even though close in actual value, may appear as having a larger difference when plotted. For example, N1 speeds of 39 and 40% will be plotted as “30-40” and “40-50”, respectively. Some of the parameters have finer bucket ranges than others, giving some parameters greater resolution than other parameters.

2.1.1. Honeywell N1 DEEC Data Recovery

Upon arrival at the Vehicle Recorder Laboratory, an exterior examination revealed the units had sustained impact damage and been exposed to salt water. According to the investigator-in-charge (IIC), the units were recovered from the Atlantic Ocean on December 4, 2013 after being submerged in salt water at a depth of 96 feet; the devices were exposed to salt water off the coast of Ft. Lauderdale for 15 days. The devices were transported in sea water to the Vehicle Recorder Lab on December 5, 2013, as shown in figure 1.

The devices were disassembled, removing the internal circuit boards. The internal circuit boards were rinsed with alcohol, rinsed with tap water, and then air dried, as shown in figure 2.

Before the boards completely air dried, they were repackaged in Aquafina® purified drinking water and transported to Honeywell in Tucson, AZ on December 6, 2013 for data recovery. On December 19, 2013, Honeywell began the data recovery process under the supervision of a representative from the Scottsdale FAA FSDO. Honeywell identified the appropriate NVM chips on the circuit boards and de-soldered the chips. The chips were then placed in a chip reader, the contents downloaded, and a cloned copy of each chip made. The cloned chips were placed into a slaved Honeywell N1 DEEC unit and data downloaded using standard production equipment. Attachment 1 contains Honeywell's report of the data recovery.

Figure 1. Devices upon arrival at Vehicle Recorder Laboratories.

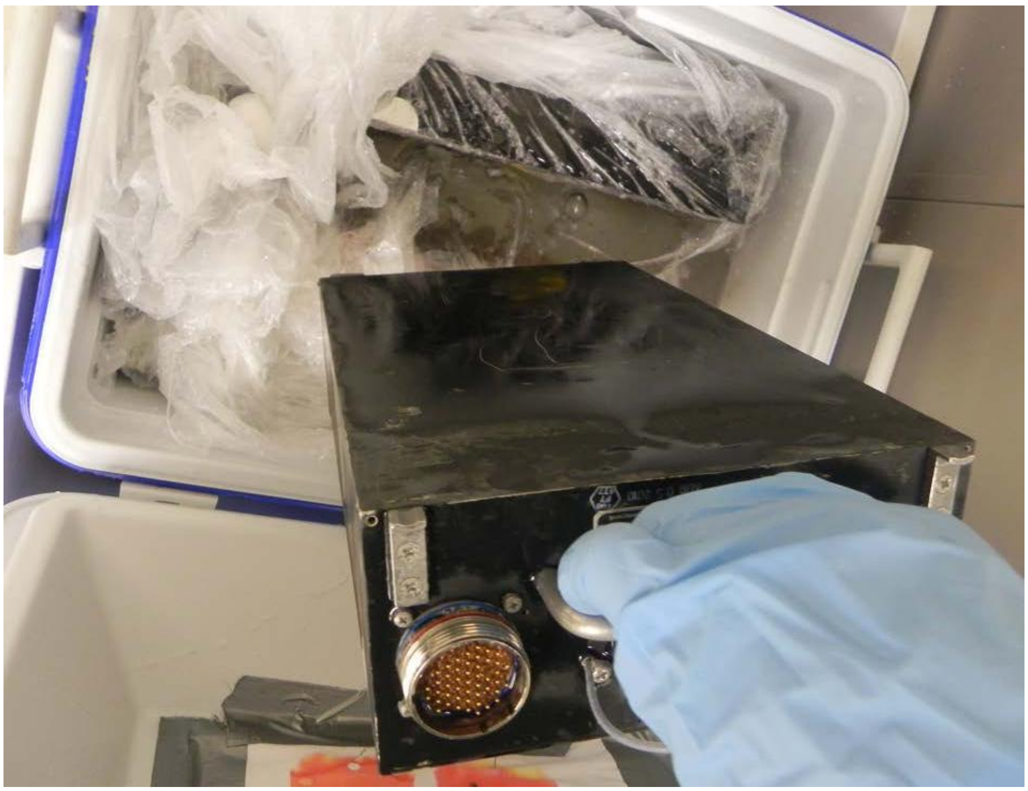


Figure 2. DEEC's boards after rinsing and drying.

2.1.2. Honeywell N1 DEEC Data Description

The data extracted from each N1 DEEC unit covered the last 5,120 seconds of engine operation. The data sample rate of the unit was designed to be more frequent towards the end of the recording. Table 1 shows the distribution of sample intervals and data points collected; for example, from 4,608 seconds until the end of the recording, a total of 512 points were sampled once per second.

Table 1. Data points and sample interval distribution.

Sample Interval (seconds)	Data Points	First Data Point (seconds)
1	512	4608
2	256	4096
4	128	3584
8	64	3072
16	32	2560
32	16	2048
64	8	1536
128	4	1024
256	2	512
512	1	0

The parameters provided in this report from each engine's DEEC unit are shown in table 2 and unit abbreviations described in table 3. All the parameters recorded a discrete value corresponding to a range of associated values. The WOW, Mach, and

Thrust Reverser parameter values were calculated by the internal logic of the DEEC recording system, rather than a direct measurement.

Table 2. Provided parameters.

Parameter Name	Parameter Description
Computer Mode (discrete)	Computer Mode
ITT (degC)	Interstage Turbine Temperature
Mach	Mach Number
N1 (%rpm)	Engine N1
N2 (%rpm)	Engine N2
PLA (deg)	Power Lever Angle
Pressure Altitude (ft)	Pressure Altitude
Thrust Reverser (discrete)	Thrust Reverser
Time (sec)	Elapsed time as recorded by each N1 DEEC
WOW (discrete)	Weight-on-Wheels

Table 3. Unit abbreviations.

Units Abbreviation	Description
%rpm	percent revolutions per minute
deg	degrees
degC	degrees Celsius
discrete	discrete
ft	feet
sec	seconds

2.1.3. Time Correlation

Time is reported as elapsed time since the start of the recording. Each N1 DEEC unit independently records the last 5,120 seconds of data. Furthermore, if a power interruption affected an N1 DEEC unit, the time discontinuity may not be shown in the data; that is, the data will appear to be a continuous sample even though more time elapsed between samples than is represented in the time scale.

Given the independence of the time scales and the limits of the recording system, it was not possible to time correlate the left and right engine N1 DEECs data for this report. As such, the left and right N1 DEECs data are presented on separate plots and provided in separate tabular data files[2].

[2] Latter fault data analysis by Honeywell indicated that adding 9 seconds to the last 512 data points of the left engine would time correlate the data with the right engine.

3. PLOTS AND TABULAR DATA

Figure 3 and 4 show all recorded data from the N1 DEEC units for engine 1 (left) and engine 2 (right), respectively. The variable sample rate of the recording is evidenced by fewer data points towards the left of the recording versus the right side of the recording. In figure 4, one invalid data point was recorded before the accident flight.

The accident flight is shown in figures 5 and 6 for the left and right engine DEECs, respectively. Figure 5 shows the left engine PLA and N1 began to increase at 4,761 seconds. By 4,795 seconds, the PLA was in a recorded range between 95 and 105 deg, and remained in this range until 4,913 seconds (118 seconds duration). By 4,795 seconds, N1 had increased to a recorded range between 90 and 95 %rpm; N2 had increased to a recorded range between 90 and 101.5 %rpm, and remained in this range until the end of the flight. The WOW derived parameter transitioned from ground to air at 4,816 seconds. At 4,849 seconds, N1 began to decrease. From 4,860 second to 4,929 seconds, the computer mode was in manual. Also at 4,860 seconds, the WOW derived parameter transitioned from air to ground. Two derived thrust reverser states at 4,861 and 4,862 seconds calculated the thrust reverser in a deployed state.

By 4,873 seconds, the left engine had reached a minimum N1 range between 60 and 65 %rpm. By 4,888 seconds, N1 began to increase. At 4,897 second, the WOW derived parameter transitioned from ground to air. At 4,913 seconds, the PLA angle decreased to a range between 60 deg and MX CRS. By 4,978 seconds, the PLA increased to a range between 105 and 117 deg.

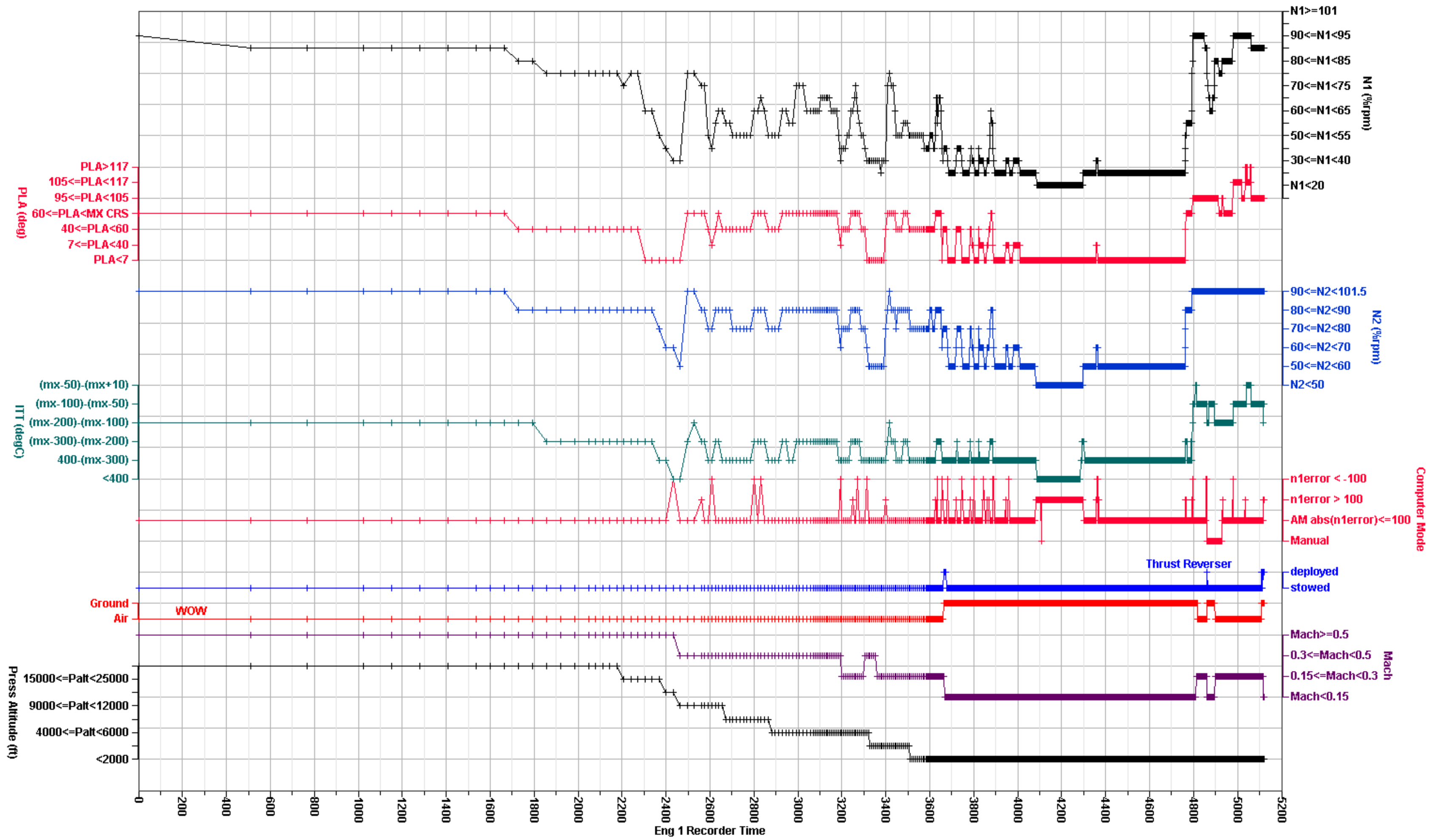
By 5,107 seconds, the left engine DEEC calculated the thrust reverser as deployed, then stowed for 2 seconds, then calculated the thrust reverser as deployed until the end of the recording at 5,119 seconds.

Figure 6 shows the right engine PLA and N1 began to increase at 4,752 seconds. During the accident flight, the right engine computer mode never recorded manual mode. By 4,786 seconds, the PLA was in a recorded range between 95 and 105 deg, and remained in this range until 4,905 seconds. By 4,788 seconds, N1 had increased to a recorded range between 90 and 95 %rpm.

By 4,809 seconds, the right engine's N1 decreased to a range between 85 and 90 %rpm; and by 4,850 seconds, N1 decreased to a range between 80 and 85 %rpm. At 4,905 seconds, the PLA decreased to a range between 60 and MX CRS, as N1 also decreased to range between 70 and 75 %rpm. At 4,923 seconds, N1 and the PLA increased. Between 4,980 and 5,061 seconds, the PLA range fluctuated between ranges of 95 and 117 deg. The last 3 seconds of recorded data calculated the right thrust reverser as deployed.

Tabular data for the left engine is included as Attachment 2. Tabular data for the right engine is included as Attachment 3. These attachments are provided in electronic comma-delimited (.CSV) format.

Figure 3. Engine 1 (Left) N1 DEEC – all recorded data.



Revised: 6 January 2014 | Engine 1 (Left) - All Recorded Data | National Transportation Safety Board

Figure 4. Engine 2 (Right) N1 DEEC – all recorded data.

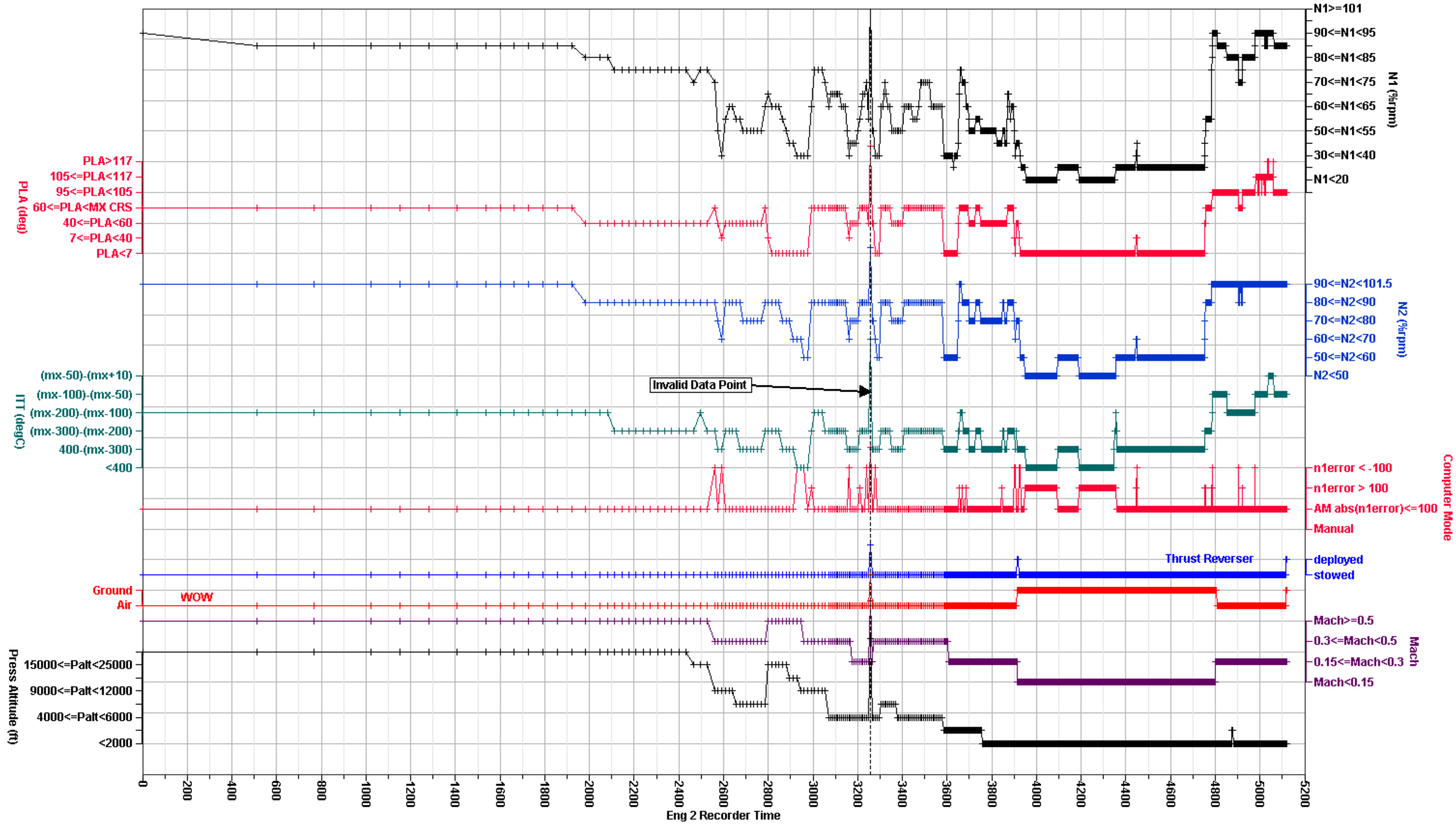
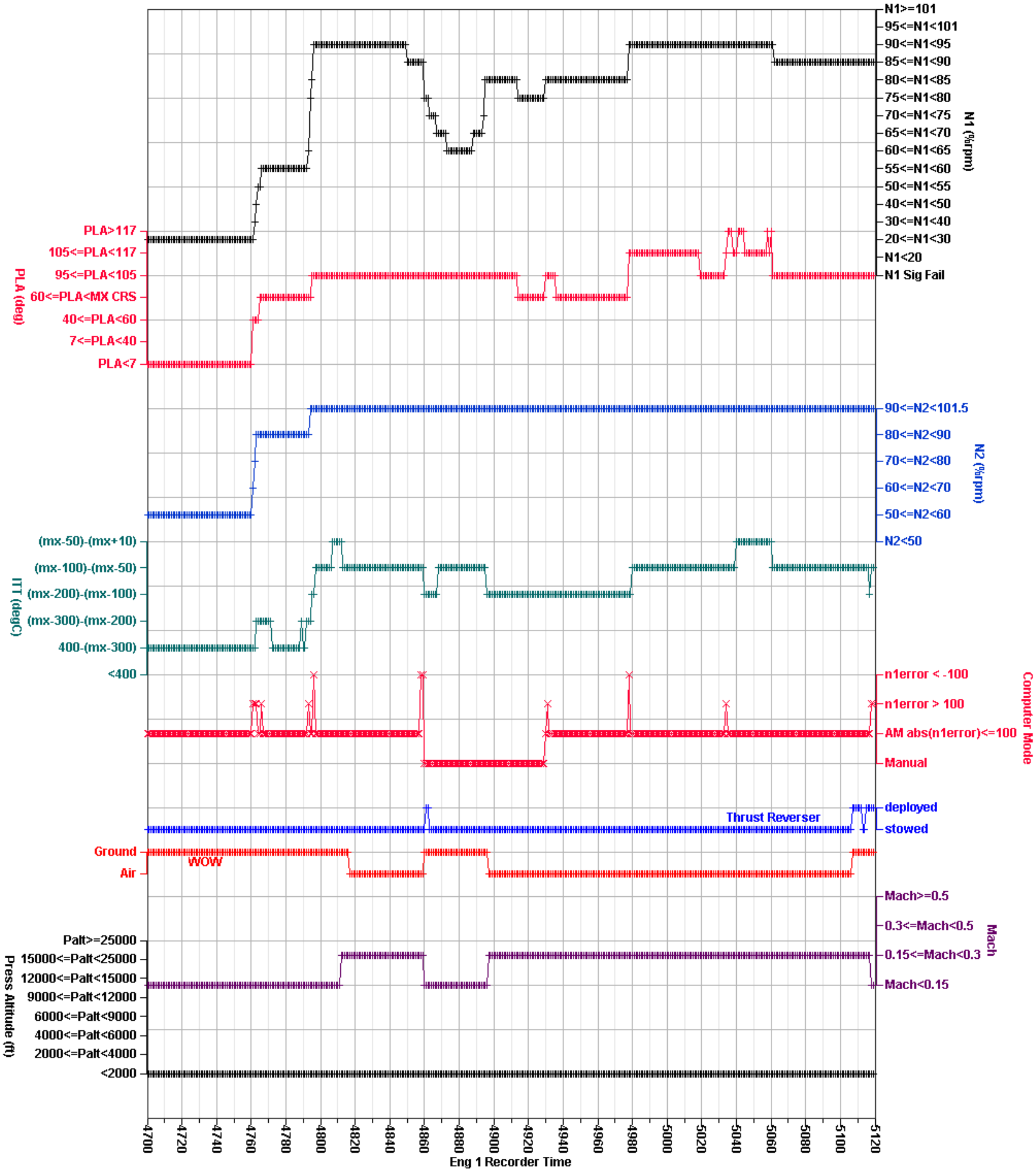
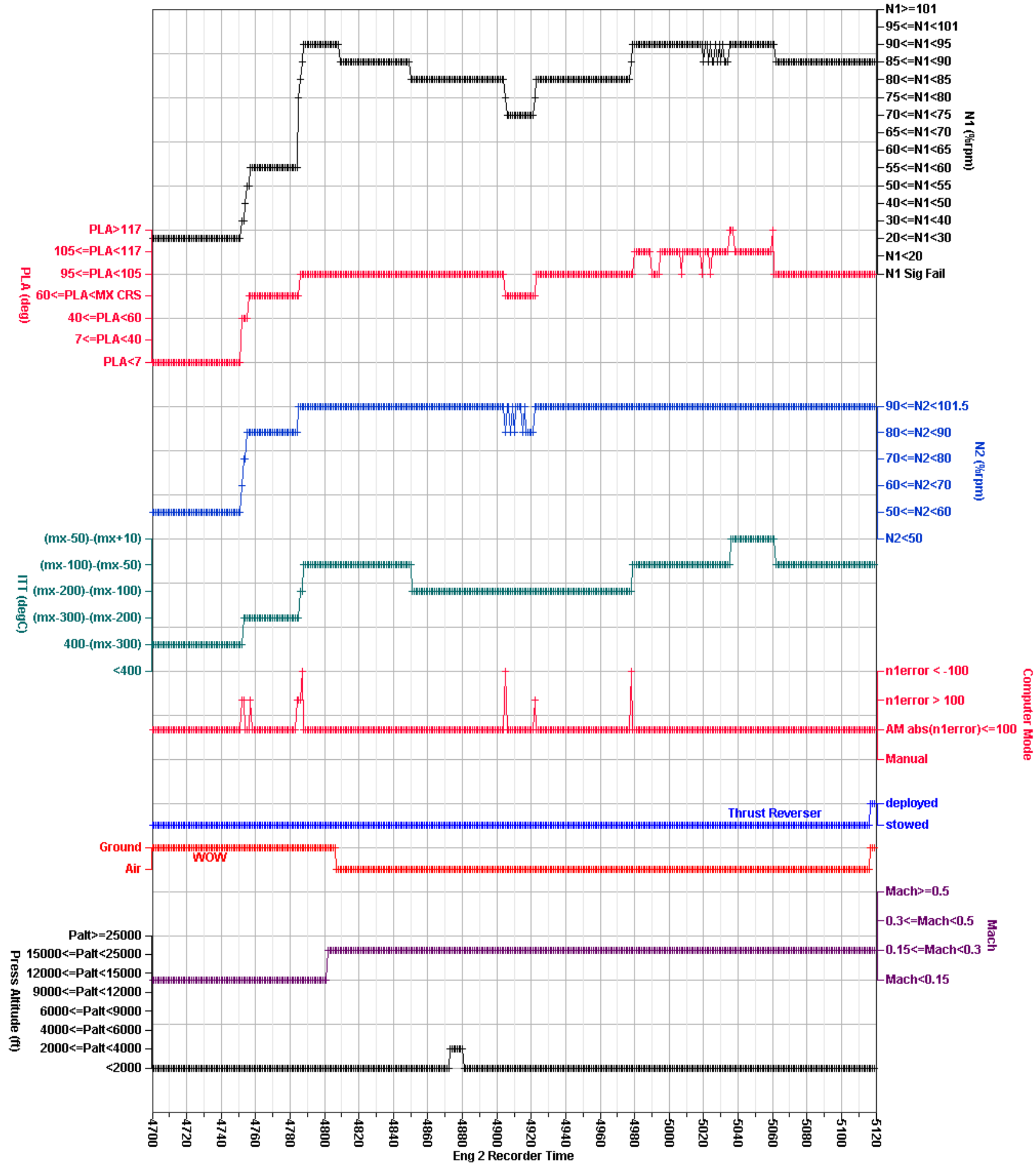


Figure 5. Engine 1 (Left) N1 DEEC – accident flight.



Revised: 17 January 2014 | Engine 1 (Left) - Accident Flight | National Transportation Safety Board

Figure 6. Engine 2 (Right) N1 DEEC – accident flight.



Revised: 6 January 2014 Engine 2 (Right) - Accident Flight National Transportation Safety Board