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

May 22, 2012

Non-Volatile Memory Devices

Specialist's Factual Report
By Michael Bauer

1. EVENT SUMMARY

Location: Key West, Florida
Date: October 31, 2011
Aircraft: Gulfstream G150
Registration: N480JJ
NTSB Number: ERA12FA056

On October 31, 2011, at about 1940 Eastern Daylight Time, an Israel Aircraft Industries G150, N480JJ, went off the end of the runway on landing roll out. The nose landing gear collapsed and the airframe sustained structural damage. Visual meteorological conditions prevailed and an instrument flight rules (IFR), flight plan was filed. The certificated airline transport rated pilot-in-command (PIC), airline transport rated co-pilot and one passenger reported minor injuries. One passenger sustained serious injuries. The flight departed from Witham Field Airport (SUA), Stuart, Florida at 1900 enroute to Key West International Florida (EYW), Key West, Florida. The flight was conducted under the provisions of 14 Code of Federal Regulations Part 91 as a personal flight.

2. DATA GROUP

A recorded data group was not convened.

3. DETAILS OF FLIGHT DATA INVESTIGATION

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

Device Manufacturer/Model: **Rockwell Collins MDC-3110**
Device Serial Number: **30C9B**

Device Manufacturer/Model: **Honeywell MK V EGPWS**
Device Serial Number: **EMK5-28457**

Device Manufacturer/Model: **Honeywell Digital Electronic Engine Control**
Device Serial Number: **67-BC0083**

Device Manufacturer/Model: **Honeywell Digital Electronic Engine Control**
Device Serial Number: **67-BC0086**

3.1. Rockwell Collins Maintenance Computer Card

The Rockwell Collins Maintenance Diagnostic Computer (MDC) aids an aircraft operator in detecting and troubleshooting aircraft component problems. The MDC monitors aircraft system line replaceable units (LRUs) to determine failures and to identify LRUs that may require replacement. It logs this information to help permit the diagnosis of LRU faults. Other MDC functions include real-time display of aircraft system parameter information.

The MDC sub-system is composed of two parts, the MDC application hardware/software and the MDT (Maintenance Data Tables.) The MDC provides the operating system, application software and hardware platform. The MDT provides aircraft specific configuration (i.e. Gulfstream G-150) and equipment information for the MDC application software. The MDC also utilizes a cockpit MFD as the display media for presenting its information to the operator and uses a variety of formats, including English-readable text and binary readouts, to depict diagnostic information.

The MDC includes the ability to download stored data through a download device. The MDC contains Non-Volatile Memory (NVM) used for storage of flight leg information and Fault and Service message events. Included with the Fault and Service message data is additional data pertaining to the stored messages.

3.1.1. Recorder Condition

The MDC was in good condition. The unit was downloaded at the manufacturer's facility in Cedar Rapids, IA. Safety Board staff from the Vehicle Recorder Division, a Gulfstream Aerospace representative and Rockwell Collins personnel were in attendance for the download.

3.1.2. Recording Description

Multiple reports were downloaded from the device. Data from the flight leg summary, fault message history and service message history was extracted from the device. The MDC flight leg summary contained 484 flight legs. Based on date and time information within the fault and service messages, flight leg 484 was identified as the event flight. The MDC typically will increment the flight leg when the aircraft weight on wheels indication transitions from "On Ground" to an "In Air" configuration[1]. Fault messages and service messages for flight legs 483 and 484 are summarized in Appendix A. The manufacturer of the MDC confirmed that the unit does not record and faults for aircraft braking system.[2]

3.2. Honeywell MK V EGPWS

The EGPWS NVM does not continuously record, but rather stores data only when certain criteria are met. The readout process at the manufacturer's facility produces several files of flight history data which encompass operational, documentary, fault and warning information.

[1] The MDC can also increment the flight leg based on other parameters such as airspeed, engine N2, or door position.

[2] The MDC does not receive data from and ATA 32 (Airline Transport Association – Landing Gear) devices in the G150 system architecture.

The documentary data file outputs position information with respect to take-off, landing and terrain inhibit selections. The device will record a take-off record when the EGPWS "In Air" transitions from "False" to "True". The device will record a landing record when the EGPWS terrain clearance is less than 50 feet and the aircraft is in a landing configuration (i.e gear or flaps in correct position). The position records include latitude and longitude position and altitude and system time.

The flight history data warning file outputs performance data as related to the operation of the aircraft. These data do not continuously record but, rather, if an alert or warning related to the EGPWS function activates, the unit retains data points for 20 seconds prior to the activation of the warning and 10 seconds afterwards. The EGPWS parameters are only sampled 1 time per second but the actual time of occurrence can be anywhere within the second.

3.2.1. Recorder Condition

The EGPWS was in good condition and the data were extracted normally from the device using the manufacturer's recommended procedure.

3.2.2. Recording Description

The data extracted from the device was provided to the EGPWS manufacturer for decoding. The decoded files were then provided to the NTSB. The EGPWS recorded 824 flight legs, with the last leg being the event flight from to SUA to EYW.

The unit recorded a landing record at EYW at a system time[3] of 2127:10:13. Table 1 contains the information from the position record.

Table 1 - Landing record from EGPWS

Parameter	Value
Latitude (deg)	24.55622
Longitude (deg)	-81.75233
Geometric Altitude (ft)	78.00
GPS Altitude (ft)	76.00
True Heading (deg)	272.81 (-87.19 recorded)
VFOM[4]	90.00
Position Uncertainty	0.0110
Position Source	GPS1

A terrain alert record was recorded at 2127:14:10; approximately four minutes after the landing record. All of the speed and position data in the record was invalid and unusable.

3.3. Honeywell Digital Electronic Engine Control (DEEC)

The TFE731 N1 DEEC's include an incident recorder which collects engine and aircraft operational data and records it into NVM for post accident/incident download and analysis. The incident recorder provides a record of engine speeds and inter-turbine temperatures, along with aircraft parameters relating to the engine, and control modes during operation. It

[3] System time is in hours, minutes, and seconds (HH:MM:SS), with hours being cumulative time.
[4] Vertical Figure of Merit (VFOM)

should be noted that the DEEC casing is not designed to be crash worthy, and memory 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. Appendix B contains a list of parameters the incident recorder stores in NVM.

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% will 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.

3.3.1. Recorder Condition

Both DEEC’s were in good condition. The units were downloaded at the manufacturer’s facility in Tucson, AZ. Safety Board staff from the Vehicle Recorder Division, a Gulfstream Aerospace representative and Honeywell personnel were in attendance for the download.

3.3.2. Recording Description

As described in section 3.3, 85 minutes and 25 seconds of data (5,120 seconds) was recovered from both the left and right engine DEEC’s. The event flight was captured by both DEEC’s.

3.3.3. Engineering Units Conversions

The data extracted from the DEECs were provided in engineering units.

As described in section 3.3, the digital value of the parameter is recorded in memory with respect to a data parameter range. For the parameter Eng1 PLA[5], the parameter range refers to both enumerations and position values. "Idle-40" refers to a PLA position range of idle to 40 degrees. Honeywell provided information stating that "Idle" refers to a PLA position of greater than or equal to 7 degrees and less than or equal to 26 degrees. Therefore the discrete position setting in the plotted data of "Idle-40" refers to a PLA position of 7 degrees to 40 degrees and the setting of "<Idle" refers to a PLA position less than 7 degrees.

Appendix B lists the parameters provided in this report.

3.4. Time Correlation

Each device stores the last 5,120 seconds. The data is plotted in reference to seconds and is not correlated to local time. Each DEEC's time is independent from the other.

3.5. Plots and Corresponding Tabular Data

The following three figures contain data recorded from the DEECs during the October 31, 2011 event.

Figure 1 contains a plot of data from both the left and right engine DEECs for the entire event flight. To illustrate the different data rates as recorded by each DEEC, lines are positioned on the plot at each data rate transition. The event flight was approximately 42 minutes long.

Figure 2 contains a plot of data from both the left and right engine DEECs for the final five minutes and twenty seconds recorded during the event flight.

Figure 3 contains a plot of two minutes of data during the landing portion of the event flight.

The Eng2 Gear WOW transitions from "Air" to "Ground" at 4,897 sec. Approximately 7 seconds after the WOW transition, Eng2 PLA advanced from the "Idle-40" position to ">TO" position. The Eng2 PLA returned to the "Idle-40" position approximately 14 seconds from the WOW transition. Approximately 23 seconds from the WOW transition, the Eng2 TR[6] transitioned from "Stowed" to "Deploy". The Eng 2 TR remained in the "Deploy" state for 71 seconds. The R DEEC continued to record data for an additional 127 seconds after the Eng2 TR transitioned to the "Stowed" state.

[5] Power Lever Angle (PLA)
[6] Thrust Reverser (TR)

The Eng1 Gear WOW transitioned from “Air” to “Ground” at 4,899 sec. Approximately 7 seconds after the WOW transition, Eng1 PLA advanced from the “Idle-40” position to “>TO” position. The Eng1 PLA returned to the “Idle-40” position approximately 13 seconds from the WOW transition. Approximately 22 seconds from the WOW transition, the Eng1 TR transitioned from “Stowed” to “Deploy”. The Eng 1 TR remained in the “Deploy” state for 72 seconds. The L DEEC continued to record data for an additional 125 seconds after the Eng1 TR transitioned to the “Stowed” state.

The corresponding tabular data used to create these three figures are provided in electronic (*.csv[7]) format as Attachment 1 to this report.

[7] Comma Separated Value format.

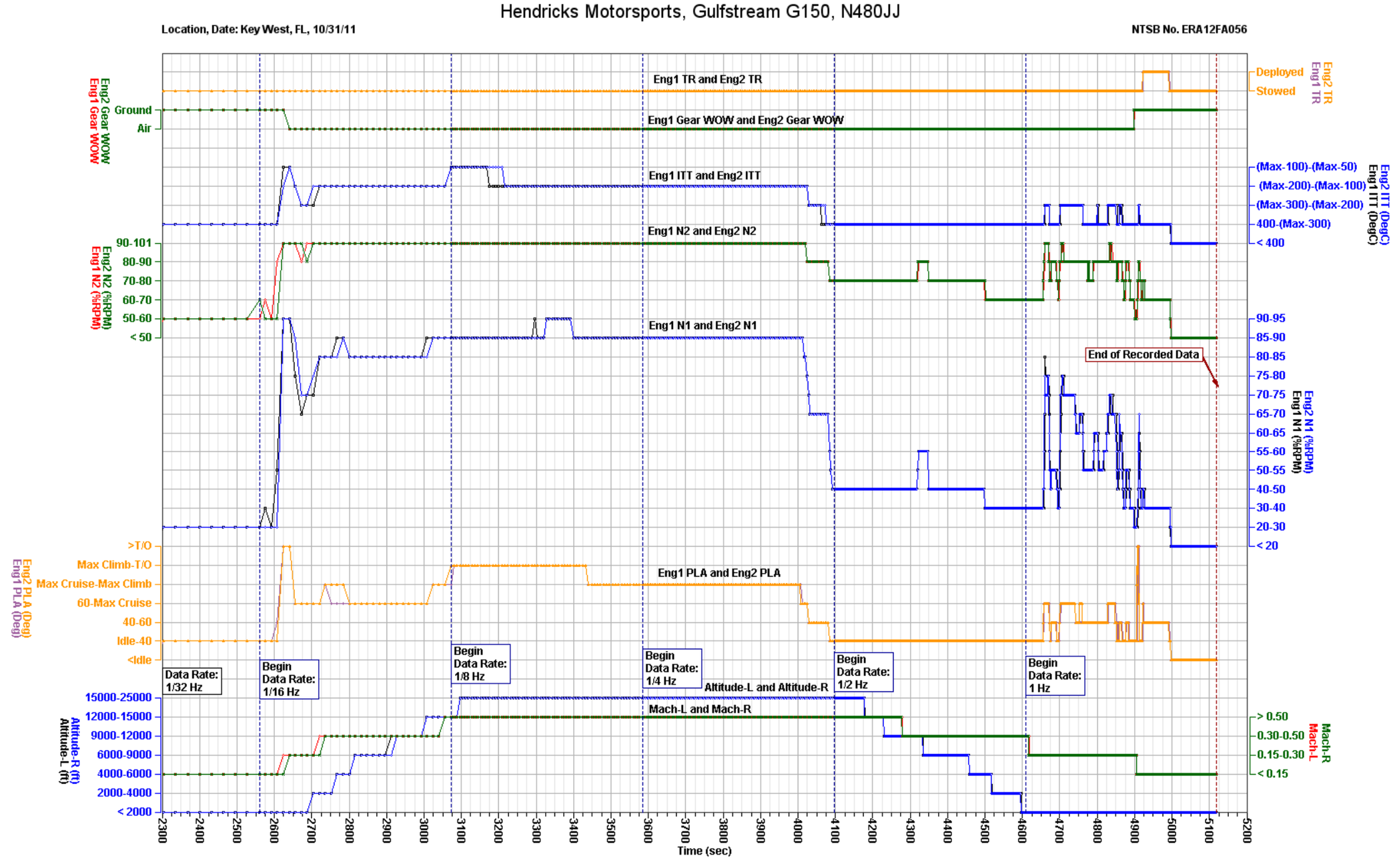

Figure 1 – Left and Right DEEC data for the entire event flight

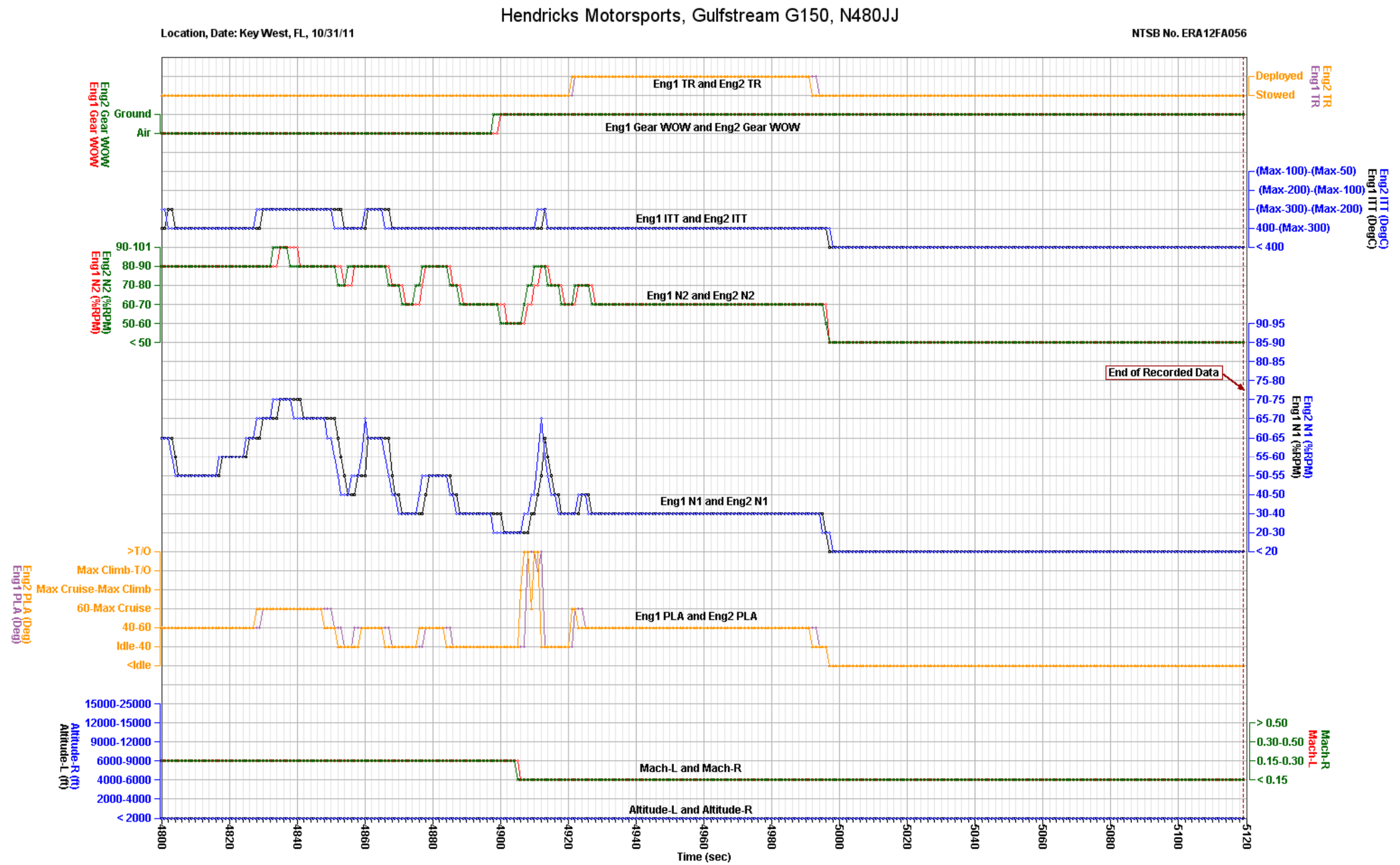

Figure 2 - Left and Right DEEC data for the final five minutes and 20 seconds of the event flight

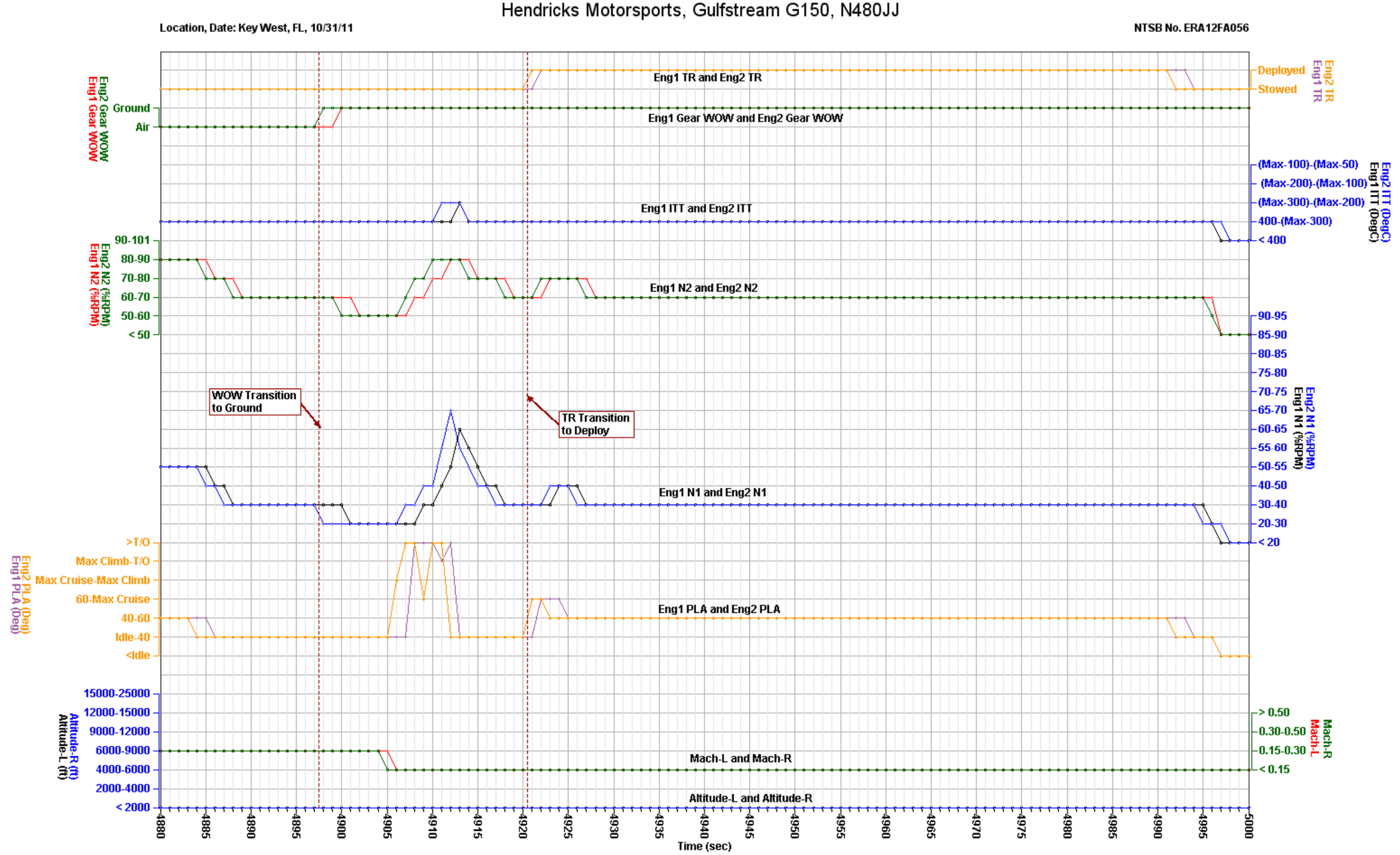

Figure 3 - Left and Right DEEC data for the landing sequence of the event flight

APPENDIX A

This appendix contains the MDC fault and service messages for the event flight. The recorded time is provided to the MDC from the GPS system. The estimated actual time is based on information from the aircraft maintenance data table (MDT) which includes two delays within the system architecture. The delays are variable within each message to avoid any erroneous maintenance fault indications.

Table A-1 - MDC fault and service messages from the event flight.

Fault/ Service Message	ATA		LRU	DATE	STATUS	FLIGHT LEG	FAULT MESSAGE	INTERMITTENT COUNT	GROUND/ AIR/TAXI	TIME (UTC)	EST ACTUAL TIME (UTC)
Fault	ATA34-15	STALL WARNING SYSTEM	SWT	31-Oct-11	FAILED	484	STALL WARN DISC OUT	INTERMITNT: 0	AIR	23:44:14	23:44:06
Fault	ATA34-25	EFIS	CCP 2	31-Oct-11	OFF/NO OUTPUT	484	NO OUTPUT	INTERMITNT: 0	AIR	23:43:46	23:43:33
Fault	ATA34-25	EFIS	MFD 2	31-Oct-11	FAILED/WIRING	484	NO R-MFD-3 BUS OUTPUT	INTERMITNT: 0	AIR	23:43:43	23:43:30
Fault	ATA46-20	FLIGHT DECK INFO SYSTEM	FSU 1	31-Oct-11	OFF/NO OUTPUT	484	NO OUTPUT TO IOC	INTERMITNT: 0	AIR	23:42:42	23:42:29
Fault	ATA34-43	TCAS	TCAS CH B	31-Oct-11	OFF/NO OUTPUT	484	NO OUTPUT	INTERMITNT: 0	AIR	23:42:34	23:42:28
Fault	ATA34-43	TCAS	TCAS CH A	31-Oct-11	OFF/NO OUTPUT	484	NO OUTPUT	INTERMITNT: 0	AIR	23:42:32	23:42:26
Fault	ATA46-20	FLIGHT DECK INFO SYSTEM	FSU 2	31-Oct-11	OFF/NO OUTPUT	484	NO OUTPUT TO IOC	INTERMITNT: 0	AIR	23:42:38	23:42:25
Fault	ATA34-58	GPS	GPS 1	31-Oct-11	FAILED/WIRING	484	NO R-GP-4 BUS INPUT	INTERMITNT: 0	AIR	23:42:38	23:42:25
Fault	ATA34-58	GPS	GPS 2	31-Oct-11	FAILED/WIRING	484	NO L-GP-4 BUS INPUT	INTERMITNT: 0	AIR	23:42:36	23:42:23
Fault	ATA22-12	IAPS	IAPS IOC 1	31-Oct-11	FAILED/WIRING	484	NO L-GP-4 BUS OUTPUT	INTERMITNT: 0	AIR	23:42:35	23:42:22
Fault	ATA22-12	IAPS	IAPS IOC 2	31-Oct-11	FAILED/WIRING	484	NO R-GP-4 BUS OUTPUT	INTERMITNT: 0	AIR	23:42:35	23:42:22
Fault	ATA34-21	AHRS	AHC 2	31-Oct-11	FAILED	484	INTERNAL FAULT	INTERMITNT: 0	AIR	23:42:39	23:42:21
Service	ATA46-20	FLIGHT DECK INFO SYSTEM	XM RECEIVER	31-Oct-11	LRU OK/INFO	484	SIGNAL BER >1%	INTERMITNT: >9	AIR	23:07	23:06:52
Fault	ATA46-20	FLIGHT DECK INFO SYSTEM	FSU 2 CHARTS	31-Oct-11	FAILED	484	APPLICATION FAULT	INTERMITNT: 0	AIR	23:04:20	23:04:12
Fault	ATA46-20	FLIGHT DECK INFO SYSTEM	FSU 2 CHARTS	31-Oct-11	FAILED	483	APPLICATION FAULT	INTERMITNT: 0	TAXI	23:00	22:59:52

APPENDIX B

This appendix describes the parameters recorded by the HI DEEC. Table B-1 lists the parameters and table B-2 describes the unit abbreviations used in this report.

Table B-1. Verified and provided parameters.

Parameter Name	Parameter Description
1. Altitude-L (ft)	Left DEEC Pressure Altitude
2. Altitude-R (ft)	Right DEEC Pressure Altitude
3. Eng1 Gear WOW (discrete)	Left DEEC Weight On Wheels Indication
4. Eng1 ITT (degC)	Left Engine Inter Turbine Temperature
5. Eng1 N1 (%RPM)	Left Engine N1, Low Pressure Spool Percent Speed
6. Eng1 N2 (%RPM)	Left Engine N2, High Pressure Spool Percent Speed
7. Eng1 PLA (Deg)	Left Engine Power Lever Angle
8. Eng1 TR (discrete)	Left Engine Thrust Reverser Position
9. Eng2 Gear WOW (discrete)	Right DEEC Weight On Wheels Indication
10. Eng2 ITT (deg C)	Right Engine Inter Turbine Temperature
11. Eng2 N1 (%RPM)	Right Engine N1, Low Pressure Spool Percent Speed
12. Eng2 N2 (%RPM)	Right Engine N2, High Pressure Spool Percent Speed
13. Eng2 PLA (Deg)	Right Engine Power Lever Angle
14. Eng2 TR (discrete)	Right Engine Thrust Reverser Position
15. Mach-L	Left DEEC Mach Number
16. Mach-R	Right DEEC Mach Number

Table B-2. Unit abbreviations.

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

NOTE: For parameters with a unit description of discrete, 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.