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

February 8, 2012

Data Recorders

Group Chairman's Factual Report
By Michael Bauer

1. EVENT SUMMARY

Location: Roswell, New Mexico
Date: April 02, 2011
Aircraft: Gulfstream G650
Registration: N652GD
Operator: Gulfstream Aerospace
NTSB Number: DCA11MA076

On April 2, 2011, about 0934 mountain daylight time, an experimental Gulfstream Aerospace Corporation (GAC) GVI (G650)[1], registration N652GD, serial number 6002, crashed during takeoff from runway 21 at Roswell International Air Center Airport (ROW), Roswell, New Mexico. The flight was being operated by the manufacturer as part of its G650 developmental field performance flight test program. The two pilots and the two flight test engineers were fatally injured, and the airplane was substantially damaged. The flight was being conducted under 14 *Code of Federal Regulations* Part 91, and visual meteorological conditions prevailed at the time of the accident.

2. DATA RECORDER GROUP

A data recorder group was convened on April 18, 2011 and completed on April 20, 2011.

Chairman: Michael Bauer
Aerospace Engineer
National Transportation Safety Board

Member: Cassandra Johnson
Mechanical Engineer
National Transportation Safety Board

Member: Nathan Rohrbaugh
Flight Data Analyst
Federal Aviation Administration

[1] Gulfstream uses the Roman numeral designation "GVI" for aircraft certification purposes and the designation "G650" for marketing purposes. These designations mean the same aircraft model for purposes of this report and are used interchangeably.

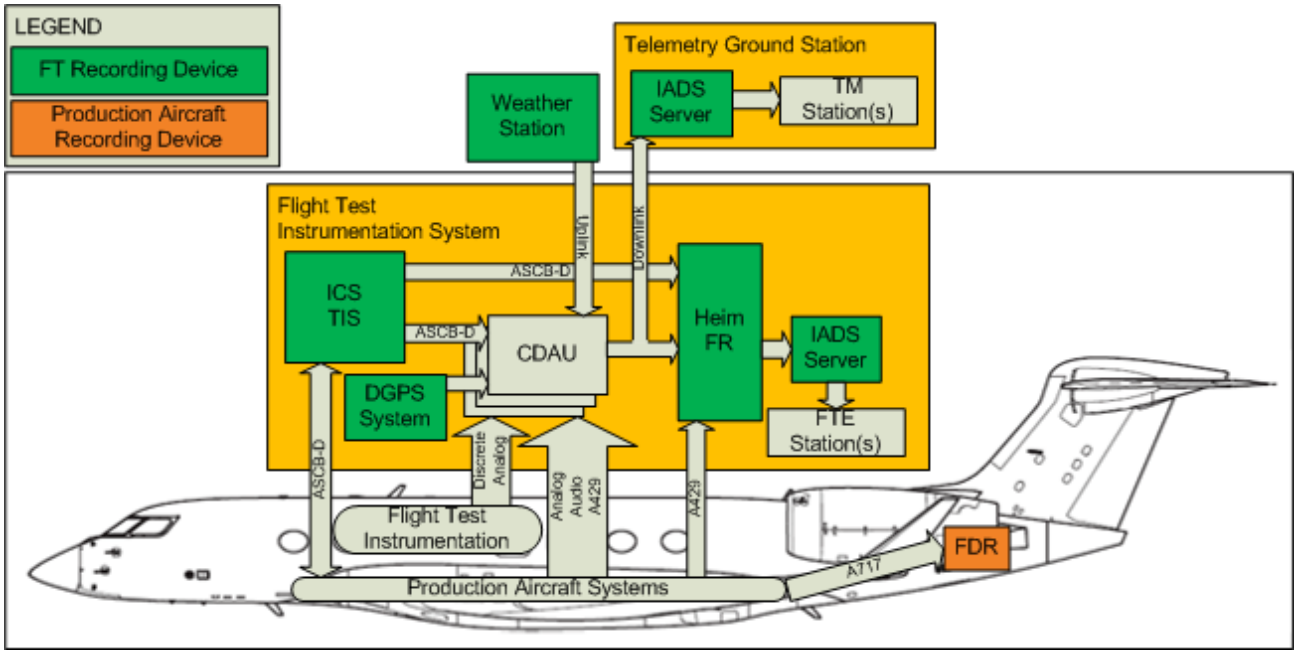
Member:	Grant Eaton Aerospace Engineer Federal Aviation Administration
Member:	Nathaniel Rutland Flight Test Engineer Gulfstream Aerospace Corporation
Member:	Robert Mills Aerodynamics Engineer Gulfstream Aerospace Corporation
Member:	Josef Schilcher BR725 Flight Test Team Leader Rolls-Royce
Member:	Dave Rumney Systems Engineer Parker Aerospace

3. DETAILS OF DATA RECORDER INVESTIGATION

The accident aircraft was an experimental Gulfstream G650 used by Gulfstream Aerospace to perform flight testing to support type certification of the aircraft type. In addition to a standard Flight Data Recorder (FDR), the aircraft was outfitted with various devices that were parts of the Flight Test Instrumentation System (FTIS). The FTIS includes different recording devices and system instrumentation (e.g. pressure gauges). Data from the avionics standard communications bus (ASCB) is recorded by the Innovative Control Systems, Inc (ICS) Test Interface System (TIS). Data from various ARINC 429, intercom audio, analog and discrete sensors and selected ASCB parameters from the TIS are routed to a CAIS[2] Bus Data Acquisition Unit (CDAU) which is then routed to the Heim Flight Recorder (FR). The Heim Flight Recorder (FR) can accept inputs from the TIS, multiple CDAU's and individual ARINC 429 data sources. Data from the CDAU was also routed to a telemetry system on the aircraft which allowed for select data to be broadcast to a dedicated ground station located in the vicinity of the testing. Data from the Heim FR was then routed to the Gulfstream Flight Test IADS data server. Data from a portable weather station was also transmitted from a ground based transmitter to the aircraft and acquired by the CDAU and recorded to the Heim FR. Figure 1 contains a block diagram showing the FTIS, dedicated audio (e.g. cockpit voice recorder) and video systems are not shown.

[2] CAIS – Common Airborne Instrumentation System

Figure 1 - Block Diagram of the G650 Flight Test Instrumentation System



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

Recorder Manufacturer/Model: **Universal Avionics FDR (Model 1607)**
Recorder Serial Number: **183**

Recorder Manufacturer/Model: **Rolls-Royce Deutschland Engine Monitoring System**
Recorder Serial Number: **N/A**

Recorder Manufacturer/Model: **Zodiac Aerospace Heim Data D120f/1 Flight Recorder (FR)**
Recorder Serial Number: **042717-032009**

Recorder Manufacturer/Model: **Audavi HardTape HTS-6555-250 (IADS)**
Recorder Serial Number: **AA000031048 (IADS-1)**

Recorder Manufacturer/Model: **Audavi HardTape HTS-6555-250 (IADS)**
Recorder Serial Number: **AA000031115 (IADS-2)**

Recorder Manufacturer/Model: **Audavi HardTape HTS-6555-250 (IADS)**
Recorder Serial Number: **AA000031164 (TM)**

Recorder Manufacturer/Model: **Audavi HardTape HTS-6555-250 (TIS)**
Recorder Serial Number: **AA000031163 (TIS)**

Recorder Manufacturer/Model: **Sandisk Extreme III 2GB CF Card (Novatel DGPS)**
Recorder Serial Number: **N/A**

3.1. Universal Avionics Flight Data Recorder Description

The Universal Avionics FDR records airplane flight information in a digital format using solid-state flash memory as the recording medium. The Universal Avionics FDR 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 512 12-bit words of digital information every second. Each grouping of 512 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 512-word intervals. Each data parameter (e.g. altitude, heading, airspeed) has a specifically assigned word number within the subframe. The Universal Avionics FDR is designed to meet the crash-survivability requirements of TSO C124b.

3.1.1. FDR Carriage Requirements

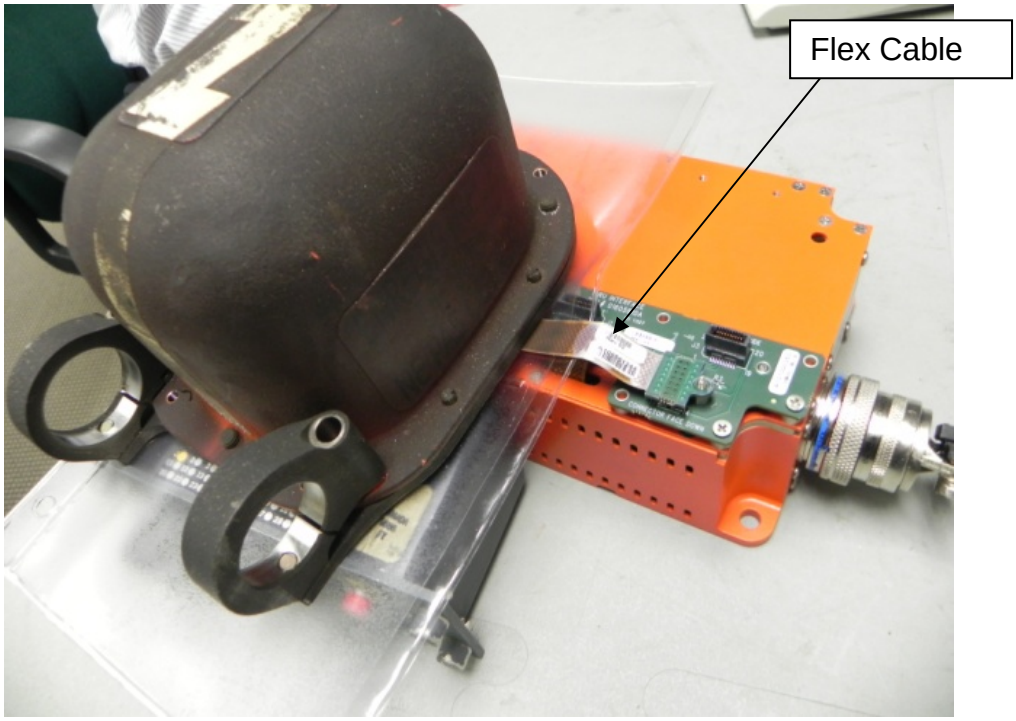
The event aircraft, N652GD, was manufactured in February 2010, and was operating under an experimental airworthiness certificate. At the time of the accident, the aircraft and the FDR system had not been validated yet nor certified. When the aircraft obtains its production type certificate, it will be required to be equipped with an FDR that records, at a minimum, 18 parameters, as cited in Title 14 CFR Part 91.609 or a minimum of 88 parameters as cited in Title 14 CFR Part 135.152.

3.1.2. Recorder Condition

The recorder had extensive heat damage as shown in Figure 2. An internal inspection was performed and no internal damage was evident. Therefore, a new flex cable was connected to the FDR memory module. The flex cable was then connected to a surrogate recorder as shown in Figure 3 and the data was successfully downloaded.

Figure 2 - Universal Avionics FDR as received.

Figure 3 - FDR's memory connected to surrogate recorder for downloading.



3.1.3. Recording Description

The FDR recording contained approximately 138.4 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 10 seconds.

3.1.4. FDR Power

The FDR is powered by the right essential DC bus. The FDR is powered unless the maintenance switch is "On", the impact switch activates or the aircraft is on the ground with the engines off.

Under a few conditions the FDR would not be powered. In particular, the maintenance switch inhibits the flight data recorder from giving nuisance faults from being logged during maintenance procedures. The flight data recorder is also inhibited while the aircraft is on the ground with the engines not running in order to prevent useful historic data from being lost.

Gulfstream reported that in late 2010 a wiring issue was identified that indicated power was not being applied to the FDR until the combined weight on wheels transitioned from ground to air. Therefore the FDR would only begin recording after the aircraft systems indicated "in air". At the time of the accident, this wiring issue had not been corrected in the N652GD aircraft, but had been identified as a deferred maintenance item.

3.1.5. 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=+).[3]

3.2. Rolls-Royce Deutschland Engine Monitoring System

The Rolls-Royce Deutschland Engine Monitoring System (EMS) is a recording station designed by Rolls-Royce and installed in the test aircraft to monitor and record information from the engine FADECs[4]. The EMS records information received by the FADEC or transmitted from the FADEC to a Hard Disk Drive (HDD). The unit was configured to record over 2,300 parameters at rates up to 25 ms (40 Hz). The unit was installed on a dedicated instrumentation rack in the main cabin.

3.2.1. Recorder Condition

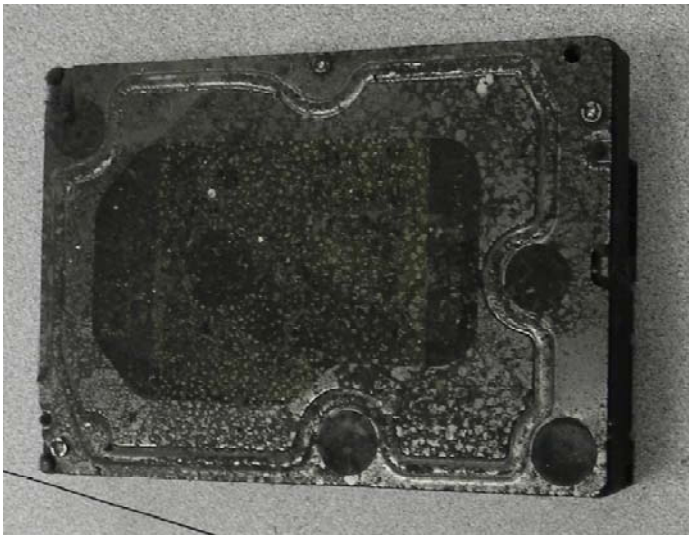
The EMS had extensive heat damage as shown in Figure 4. An external inspection was performed prior to removing the unit's top cover. The HDD was located and extracted from the unit. An external inspection of the HDD showed signs of smoke damage, but the case was not compromised, as shown in Figure 5. The unit and its connectors were cleaned and inspected. The unit was then installed in a surrogate PC and the contents of the HDD were successfully copied to a new HDD.

Figure 4 – Rolls-Royce Deutschland EMS after recovery from the aircraft.

[3] 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] FADEC – Full Authority Digital Electronic Control, is a system that controls an aircraft engine operation.

Figure 5 – HDD after extraction from the EMS.



3.2.2. Recording Description

The EMS HDD contained multiple files from previous test flights and from the day of the accident. With the assistance of Rolls-Royce Deutschland, two files per engine associated with the accident flight were identified and recovered. The files were approximately 2 hours and 55 minutes in length.

3.2.3. Engineering Units Conversions

The data files were provided to Rolls-Royce Deutschland for processing and conversion to engineering units.

3.3. Zodiac Aerospace Heim Data D120f/1 Flight Recorder

The Zodiac Aerospace Heim Data D120f/1 Flight Recorder (FR) is a digital data acquisition mainframe that is equipped with application specific signal conditioning modules[5]. The signal conditioning modules were equipped to interface with data from the aircraft ARINC 429 busses, the CDAU's and the ICS TIS system. The Heim FR records data to solid state interchangeable media cartridges. The solid state drives contain IEEE 1393b download port. The Heim FR was installed on the top of an instrumentation rack in the main cabin.

[5] Further specifications on the Heim flight recorder can be obtained at http://www.zodiac-data-systems.com

3.3.1. Recorder Condition

The Heim FR had extensive heat damage as shown in Figure 6. The interchangeable media cartridge (IMC) was removed from the flight recorder, as shown in Figure 7. The IMC was disassembled to allow for an internal inspection. The circuit cards and components on the IMC did not show any signs of thermal damage or stress. The unit was reassembled and the data was downloaded successfully using the IEEE-1394b port.

Figure 6 – Heim FR as recovered from the aircraft.

Figure 7 – Solid state data cartridge removed from Heim flight recorder.

3.3.2. Recording Description

The data cartridge contained multiple IRIG 106 Chapter 10[6] formatted data files. The data cartridge was installed in the aircraft prior to the April 2, 2011 test flight and recorded the accident flight. Using procedures provided by Symvionics and Gulfstream Aerospace the data files were converted to files to be used by the IADS system.

3.3.3. Engineering Units Conversions

The engineering units conversions used for the Heim FR data contained in this report are based on conversions programmed into the IADS software by the aircraft manufacturer/operator.

3.4. IADS Data System

IADS[7] is a data display and analysis system that allows for real-time and post-test inspection of flight test data. On the aircraft, select data is routed from the Heim FR to an IADS server which is then routed over a dedicated network to multiple IADS client consoles/displays. The IADS server on the aircraft was configured to record over 9,500 parameters. The IADS server was installed on a dedicated instrumentation rack in the main cabin. The aircraft also transmits a subset of data via an L-band datalink to a remote ground station, or telemetry (TM) station. The data transmitted to the TM station is a subset of the dataset that is onboard the aircraft. The data received by the TM station is routed to a separate IADS server which is then routed over a dedicated network to multiple IADS client displays in the TM station. The IADS server in the TM station was configured to record over 6,500 parameters. Each dedicated IADS server contains removable hard disk drives (HDD) that log the IADS configuration information and flight data.

At each user station, the operator can view customized displays that allow for monitoring of the flight data. The operator can also log events or test points to allow for post-test analysis and debriefing. During operations, the data can be replayed or paused to allow the operator to analyze the displayed data without affecting the real time data acquisition. User stations for IADS data were installed at various operator stations in the main cabin.

3.4.1. Recorder Condition

The IADS server in the aircraft was configured such that it contained two HDD in a RAID 1[8] scheme. A typical removable HDD is shown in Figure 8. Both HDDs showed signs of external smoke damage. The external cases were removed and the drives were inspected. Each HDD and its connectors were cleaned and inspected. The unit was then installed in a surrogate PC and the contents of the HDD were successfully copied to a new HDD.

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[6] IRIG 106 Chapter 10 is one chapter of a document produced by the Range Commanders Council (RCC) Telemetry Group (TG) related to telemetry standards. Chapter 10, Digital Recorder standards defines formats used to collect data onboard test vehicles. For further information refer to http://www.wsmr.army.mil/RCCsite/Pages/default.aspx

[7] Further information related to the IADS system can be found at http://iads.symvionics.com

[8] Redundant Array of Independent Disks (RAID) 1 scheme allows for identical sets of data to be written to multiple drives. In this installation the aircraft contained two identical removable hard disk drives.

The IADS server in the TM station was configured such that it contained one HDD. The unit was removed from the TM station. The contents of the HDD were successfully copied to a new HDD.

Figure 8 – An example of a removable hard disk drive from the IADS server.

3.4.2. Recording Description

The HDDs in the aircraft and inside the TM station were installed in their respective IADS servers prior to the April 2, 2011 test flights and both HDDs recorded the accident flight. Using procedures provided by Symvionics and Gulfstream Aerospace, the data files were converted to files to be used by the IADS system.

3.4.3. Engineering Units Conversions

The engineering units conversions used for the IADS data contained in this report are based on conversions programmed into the IADS software by the aircraft manufacturer.

3.5. ICS Telemetry-Acquisition Interface System (TIS) Data System

The ICS Telemetry-Acquisition Interface System (TIS) is a recording station designed by Honeywell and ICS Aero and was installed in the test aircraft to monitor and record information from the aircraft's ASCB-D[9] data bus. The TIS was configured to record over 12,000 parameters at rates up to 12.5 ms (80Hz). The TIS contained a removable HDD that logged ASCB-D data from the aircraft. The unit was installed on a dedicated instrumentation rack in the main cabin.

3.5.1. Recorder Condition

The TIS was configured such that it contained one removable HDD. A typical removable HDD is shown in Figure 8. The HDD showed signs of external smoke damage. The external case was removed and the drive was inspected. The HDD and its connectors were cleaned and inspected. The unit was then installed in a surrogate PC and the contents of the HDD were successfully copied to a new HDD.

[9] Avionics Standard Communication Bus – Revision D

3.5.2. Recording Description

The HDD in the TIS was installed in the aircraft prior to the April 2, 2011 test flight and recorded the accident flight. Using tools and procedures provided by Gulfstream Aerospace the data files were converted to allow for specific parameter data extraction.

3.5.3. Engineering Units Conversions

The engineering units conversions used for the extracted TIS data contained in this report are based on ASCB-D configuration controlled by Gulfstream and Honeywell.

3.6. Sandisk Extreme III CF Card

The aircraft was equipped with a NovAtel DL-V3 Global Navigation Satellite System (GNSS). High accuracy position data can be provided by the DL-V3 when coupled with real-time differential GPS (DGPS) service from OmniStar. GPS data from the DL-V3 system is routed to the CDAU for inclusion in the flight test data set sent to the Heim FR or TM station. The GPS data is also logged to a dedicated CompactFlash (CF) card installed in the DL-V3. The DL-V3 was installed on the top of an instrumentation rack in the main cabin.

3.6.1. Recorder Condition

The CF card was extracted from the DL-V3 unit on the aircraft. The CF card had some signs of smoke and heat damage as shown in Figure 9. The unit was inspected and cleaned, the CF card was imaged and data was successfully extracted from the CF Card.

Figure 9 – Sandisk Extreme III CF Card as received.

3.6.2. Recording Description

Multiple log files including the accident flight were identified and extracted.

3.7. Data Source Overlap

The aircraft involved in the accident was specifically outfitted to record data from various aircraft systems to support FAA certification, as shown in Figure 1. The amount of data was in excess of the number of parameters that would be normally required for the FDR. The availability of multiple recording devices (FDR, IADS, Heim FR, TIS, etc.) allows for individual parameters (e.g. Pitch, Roll, Heading, etc.) to be recorded by each device. The data recorded by the TIS recorder is limited to parameters from the ASCB-D data bus and

subsets of these parameters are provided to both the CDAU and the Heim FR. The data recorded by the Heim FR consists of select ASCB-D bus data from the TIS, data transmitted by the CDAU's, and select ARINC 429 data busses. The data recorded by the IADS server on the aircraft is a subset of parameters that are recorded by the Heim FR. The data recorded by the IADS server in the TM Station includes all of the data acquired by the aircraft CDAU and received via the RF link from the aircraft. Data from the DGPS and the weather station are logged by their respective devices and also recorded in the FTIS.

After reviewing all of the available flight test data sources available to the group and the limited data from the FDR, the determination was made to primarily use the data recovered from the Heim FR and the TIS for the investigation. Select FDR data is included for comparison.

Unless noted, 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=+).[3]

Appendix A lists the FTIS parameters verified and provided in this report.

Appendix B lists the Universal Avionics FDR parameters verified and provided in this report.

3.8. Time Correlation

The FTIS time source is synchronized to Coordinated Universal Time (UTC) via a built-in GPS receiver. The time source signal is provided to the Heim FR, IADS Servers, and the TIS recorder.

Correlation of the Universal Avionics FDR data from SRN to UTC was established by the comparing FTIS data with extracted Universal Avionics FDR Data.

The accident occurred in Roswell, NM which is in the Mountain Time zone. To reference the data in the report to Mountain Daylight Time (MDT), six hours needs to be subtracted from UTC.

Data presented in this report related to accident flight 153 is presented in MDT. All previous flights are presented in UTC.

4. Plots and Corresponding Tabular Data

The following 24 figures contain data recorded during the flight 153 testing on April 2, 2011 and two previous uncommanded roll events. Data from flight 153 on April 2, 2011 was recovered from the devices described earlier in this report. Data from the two previous events, flight 088 and flight 132, were provided by Gulfstream Aerospace.

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.

4.1. Accident Flight 153 Test Run 7A2

Figures 10 through 17 contain data from the test run 7A2, flight 153, during which the accident occurred. The time covers 09:33:15 to 09:34:25 MDT. Due to the impact and subsequent loss of data sources (e.g. IRS, ADC, etc.) various parameters become unreliable after 09:34:00 MDT. Loss of data is shown on the plots when a data parameter trace ends prior to the noted end of recorded data at approximately 09:34:23 MDT. Figure 10 contains basic aircraft parameters recorded during the accident. Figure 11 contains engine parameters recorded during the accident. Figure 12 contains pitch axis parameters recorded during the accident. Figure 13 contains roll axis parameters recorded during the accident. Figure 14 contains yaw axis parameters recorded during the accident. Figure 15 contains hydraulic, brake system and select environmental parameters recorded during the accident. Flap and horizontal stabilizer position are also included in this figure. Figure 16 is a comparison of the data recorded by the flight test system and the Universal Avionics FDR from time 09:33:20 to 09:34:10 MDT. Figure 17 contains flight path information overlaid on a Google Earth image of KROW runway 21.

The corresponding tabular data used to create these 8 figures are provided in electronic (*.csv[10]) format as Attachment 1 to this report.

The corresponding tabular data from the FDR used to create figure 16 is provided in electronic (*.csv[10]) format as Attachment 2 to this report.

4.2. Accident Flight 153 Test Run 7A1

Figures 18 through 23 contain data from the test run 7A1, flight 153. Test Run 7A1 was performed just prior to the accident. The time covers 09:25:30 to 09:26:50 MDT. Figure 18 contains basic aircraft parameters. Figure 19 contains engine parameters recorded. At approximately 09:26:30 MDT, a spike in the thrust data can be seen. The thrust parameters were recovered from telemetry data and during certain conditions, telemetry data can “drop-out”. A drop-out is indicated by a momentary, large change in the recorded value, typically to an out of range value. Figure 20 contains pitch axis parameters recorded. Figure 21 contains roll axis parameters recorded. Figure 22 contains yaw axis parameters recorded. Figure 23 contains hydraulic, brake system and select environmental parameters recorded. Flap and horizontal stabilizer position are also included in this figure.

The corresponding tabular data used to create these 6 figures are provided in electronic (*.csv[10]) format as Attachment 1 to this report.

[10] Comma Separated Value format.

4.3. Previous Event Flight 132 Test Run 3B2

Figures 24 through 28 contain data from the test run 3B2, flight 132. Flight 132 was performed on March 14, 2011. The time covers 13:32:50 to 13:33:25 UTC. The data indicate that an uncommanded roll event occurs at 13:33:14 UTC. Figure 24 contains basic aircraft parameters recorded. Figure 25 contains engine parameters. Prior to 13:32:56 UTC thrust data is unreliable. Figure 26 contains pitch axis parameters. Figure 27 contains roll axis parameters. Figure 28 contains yaw axis parameters.

The corresponding tabular data used to create these 5 figures are provided in electronic (*.csv[10]) format as Attachment 3 to this report.

4.4. Previous Event Flight 088 Test Run 2A

Figures 29 through 33 contain data from the test run 2A, flight 088. Flight 088 was performed on November 16, 2010. The time covers 13:29:35 to 13:30:10 UTC. The data indicate that an uncommanded roll event occurs at 13:29:58 UTC. Figure 29 contains basic aircraft parameters recorded. Figure 30 contains engine parameters. Figure 31 contains pitch axis parameters. Figure 32 contains roll axis parameters. Figure 33 contains yaw axis parameters.

The corresponding tabular data used to create these 5 figures are provided in electronic (*.csv[10]) format as Attachment 4 to this report.

4.5. IADS Log Data

As described in section 3.4, users can log event data into the IADS system.

Table 1 and Table 2 contain recovered log information from the aircraft during flight 153 and the telemetry stations.

The “User” column indicates the user (typically a flight test engineer on the aircraft) logged in at an IADS client. FTE1 refers to Lead Onboard Flight Test Engineer, FTE2 refers to Second Onboard Flight Test Engineer. TMStation4 refers to the engineer located at TM IADS client station number 4.

The “Time” column refers to the time in the data corresponding to the event, not necessarily the time the event was logged.

The “Time Recorded…” column refers to the local IADS client time (user’s PC) of the logged event. Individual IADS client clocks are not synced to the local time zone or a reference clock.

Table 1 - IADS Event logged on the aircraft

User	Time Recorded by IADS client	Time (Day:HH:MM:SS)	Comment
FTE2	7:49:05	092:12:52:28.000	R Eng Start
FTE1	7:48:00	092:12:52:48.380	RH Eng Start
FTE2	7:49:51	092:12:53:48.000	L Eng Start
FTE2	8:01:47	092:13:05:46.716	taxi
FTE2	8:31:10	092:13:20:38.745	Touchdown #1
FTE2	8:29:05	092:13:33:04.603	Touchdown #2
FTE2	8:46:05	092:13:50:04.917	Touchdown #3
FTE2	8:48:17	092:13:52:16.234	Brk/Rel #4
FTE2	8:51:31	092:13:55:30.525	Touchdown #4
FTE2	9:08:47	092:14:12:46.641	Touchdown #5
FTE2	9:12:15	092:14:16:14.106	B/Rel #6
FTE1	9:18:02	092:14:16:44.940	VR
FTE1	9:17:30	092:14:16:57.950	35
FTE2	9:20:22	092:14:24:22.170	Touchdown #6
FTE2	9:23:30	092:14:27:28.720	B/Rel #7
FTE2	9:27:19	092:14:31:18.439	Touchdown #7
FTE2	9:39:30	092:14:42:21.618	B/Rel #8
FTE2	9:41:57	092:14:45:57.088	Touchdown #8
FTE2	10:08:24	092:15:12:23.367	B/Rel #9
FTE1[11]	10:09:06	092:15:12:58.030	E2
FTE2	10:11:42	092:15:15:41.706	Touchdown #9
FTE2	10:15:30	092:15:19:27.000	B/Rel #10
FTE1[11]	10:16:03	092:15:19:59.870	35
FTE2	10:18:30	092:15:22:30.204	Touchdown #10
FTE2	10:21:52	092:15:25:50.000	R/Rel #11
FTE1[11]	10:23:32	092:15:26:34.390	E6

[11] From this point in the flight, FTE1 reset the IADS client he was using. FTE1 logged into the client using a login that was different to the login used at the beginning of the flight.

Table 2 - IADS Event logged in the Telemetry Trailer during runs 7A1 and 7A2

User	Time Recorded by IADS client	Time (Day:HH:MM:SS)	Comment
TMStation4	10:31:18	092:15:25:48.125	TARE
TMStation4	10:31:20	092:15:25:50.235	BR
TMStation4	10:31:42	092:15:26:09.978	EF
TMStation4	10:31:45	092:15:26:15.457	WM
TMStation4	10:31:49	092:15:26:19.834	VR
TMStation4	10:31:55	092:15:26:21.302	LO
TMStation4	10:32:03	092:15:26:32.476	15
TMStation4	10:32:04	092:15:26:34.185	35
TMStation4	10:38:46	092:15:33:15.507	E87
TMStation4	10:38:48	092:15:33:17.333	E88
TMStation4	10:39:08	092:15:33:36.572	E89
TMStation4	10:39:11	092:15:33:42.398	E90
TMStation4	10:39:15	092:15:33:46.271	E91
TMStation4	10:39:20	092:15:33:47.621	E92
TMStation4	10:39:27	092:15:33:56.284	E93

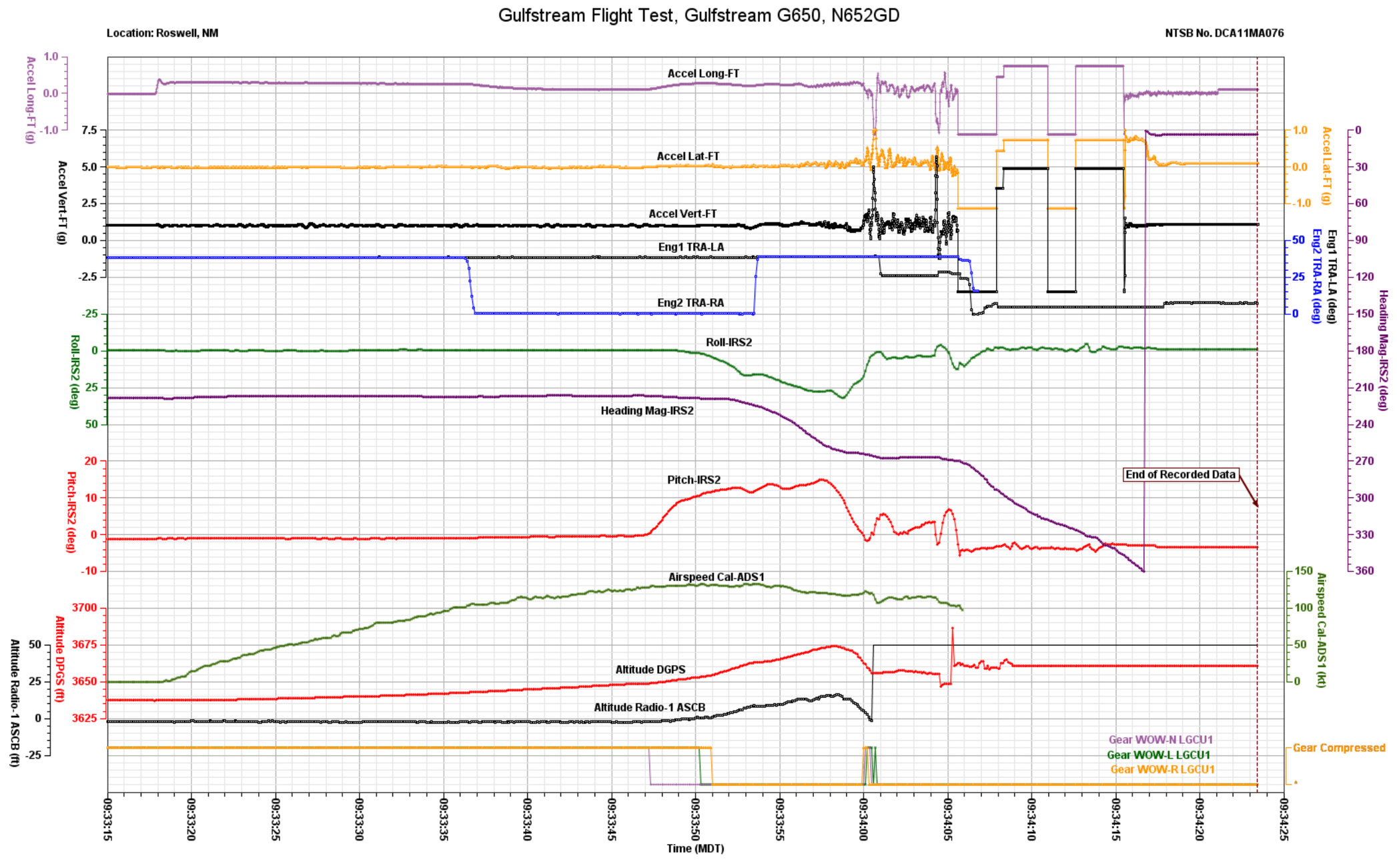


Figure 10 - Basic aircraft parameters from the accident flight 153 test run 7A2

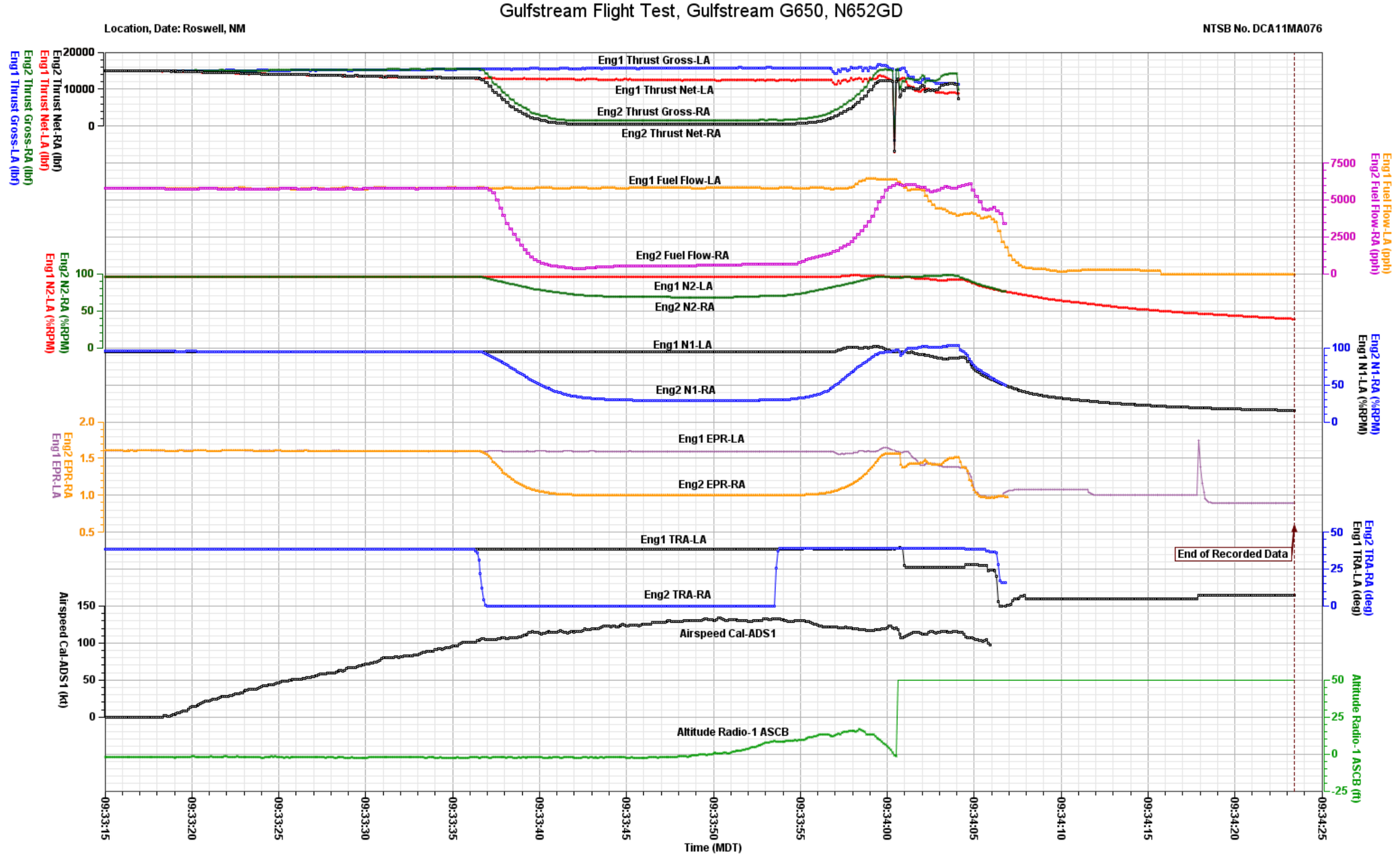
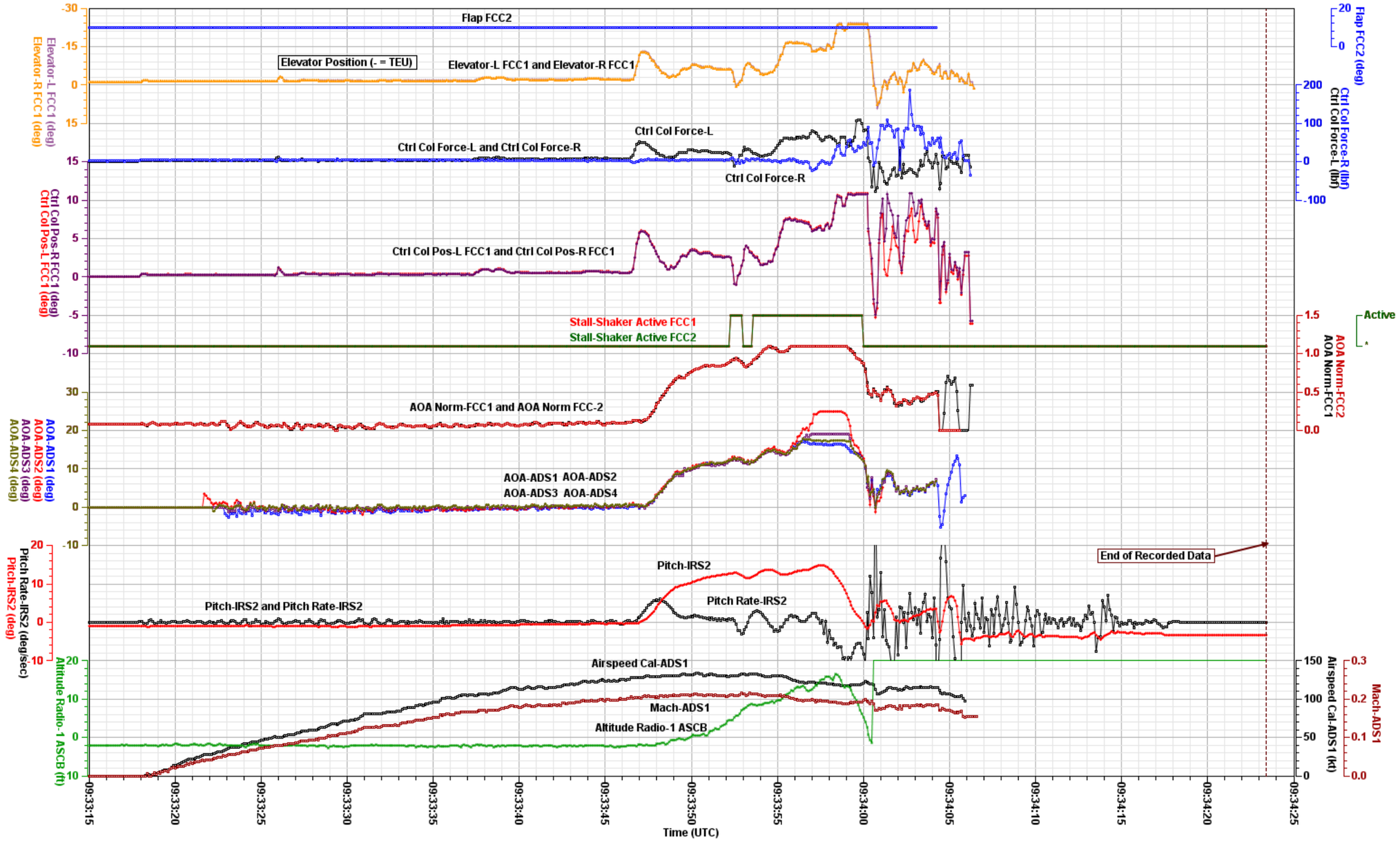


Figure 11 - Engine parameters from the accident flight 153 test run 7A2

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 19 January 2012

Flight 153 Run 7A2 - Pitch Axis Parameters

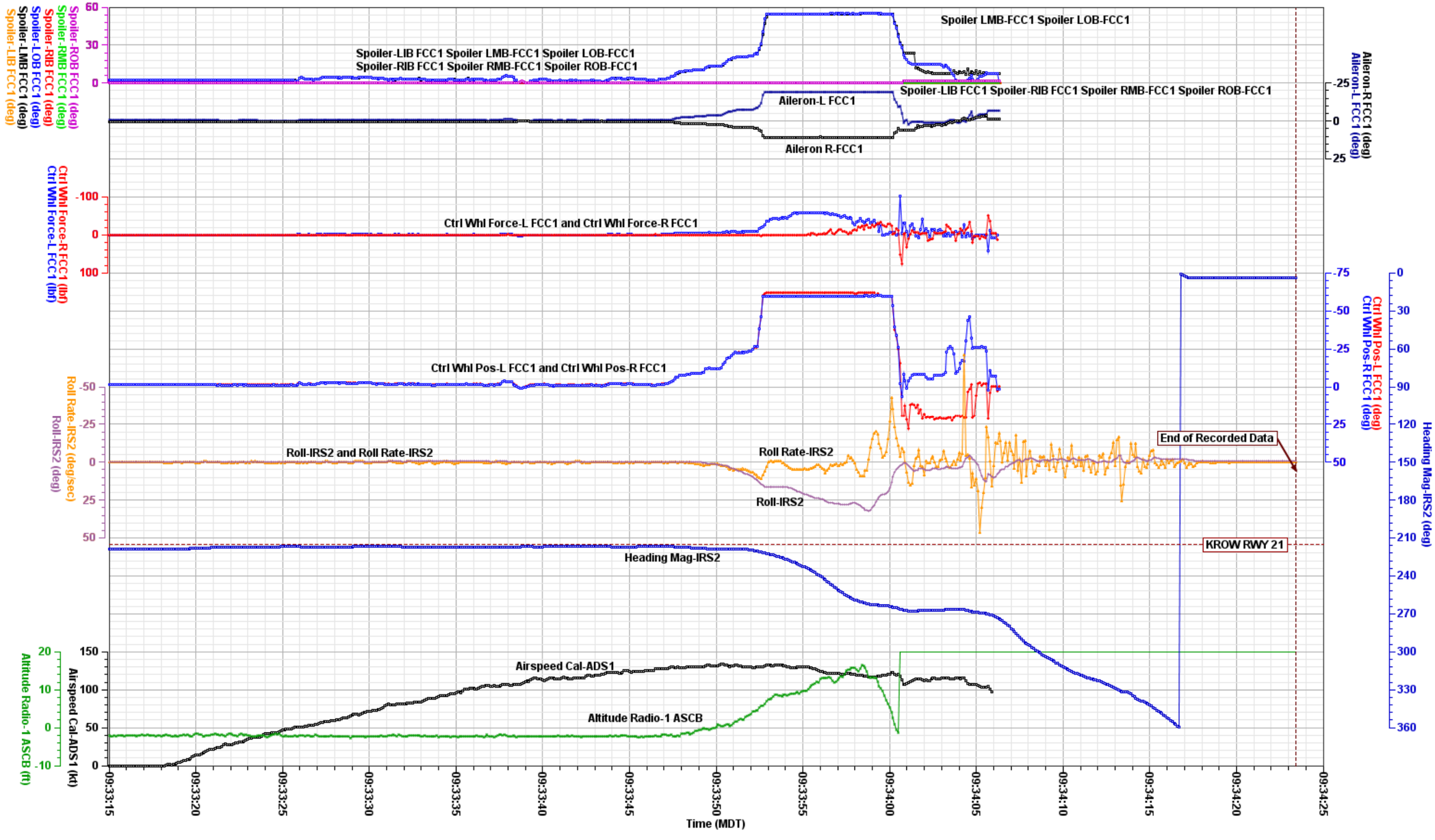
National Transportation Safety Board

Figure 12 - Pitch axis parameters from the accident flight 153 test run 7A2

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 153 Run 7A2 - Roll Axis Parameters

National Transportation Safety Board

Figure 13 - Roll axis parameters from the accident flight 153 test run 7A2

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076

Rudder Ped Force-L FCC1

Rudder Ped Force-R FCC1

Rudder Ped Pos FCC1 and Rudder Ped Pos FCC2

Rudder-FCC1

AOS-ADS1 AOS-ADS2 AOS-ADS3 AOS-ADS4

Heading Mag-IRS2

Yaw Rate Body-IRS2

Roll Rate-IRS2 and Roll-IRS2

Roll Rate-IRS2

Roll-IRS2

Heading Mag-IRS2

End of Recorded Data

Airspeed Cal-ADS1

Altitude Radio-1 ASCB

Time (MDT)

Revised: 17 January 2012

Flight 153 Run 7A2 - Yaw Axis Parameters

National Transportation Safety Board

Figure 14 - Yaw axis parameters from the accident flight 153 test run 7A2

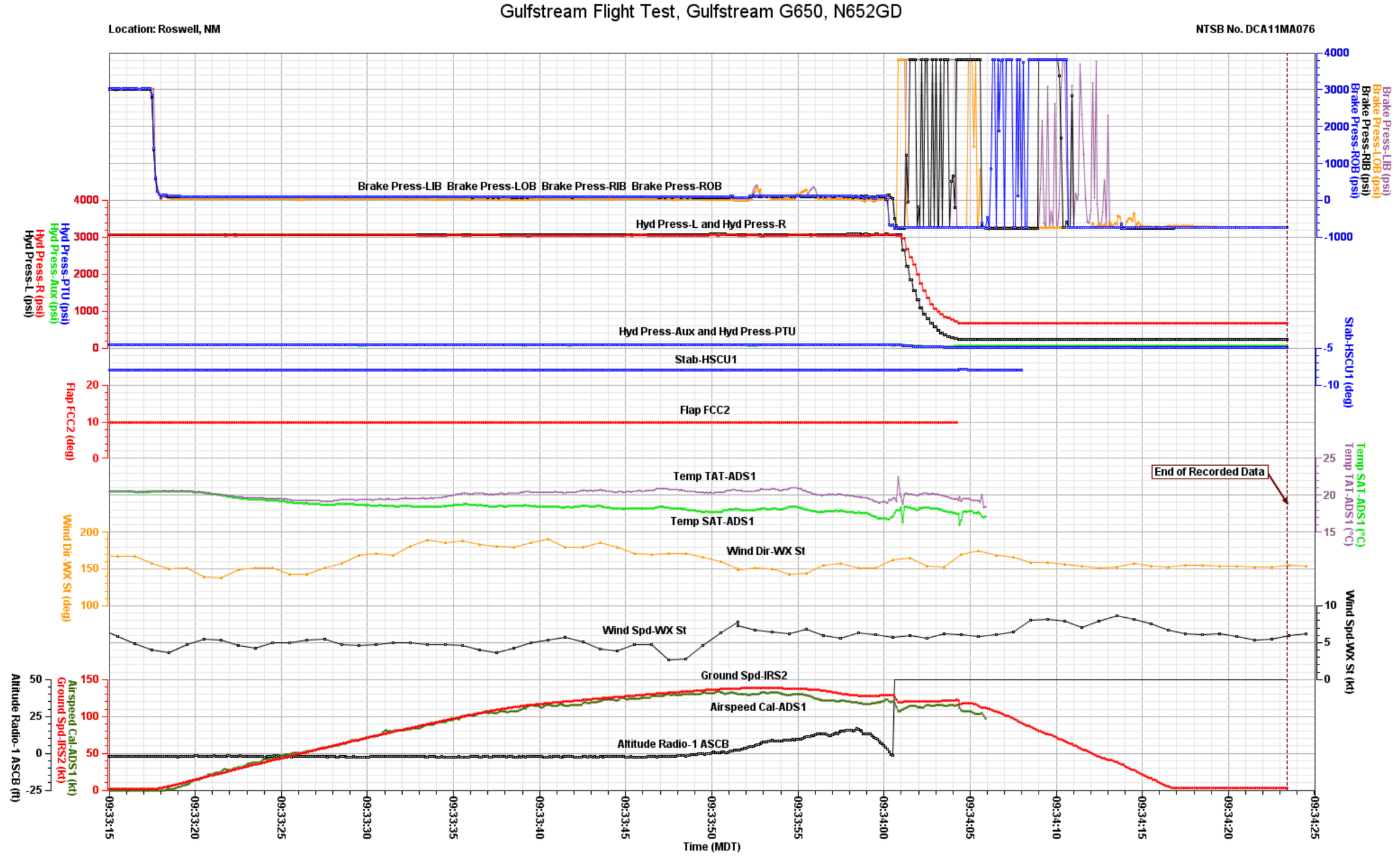


Figure 15 - Hydraulic, brake system and environmental parameters from the accident flight 153 test run 7A2

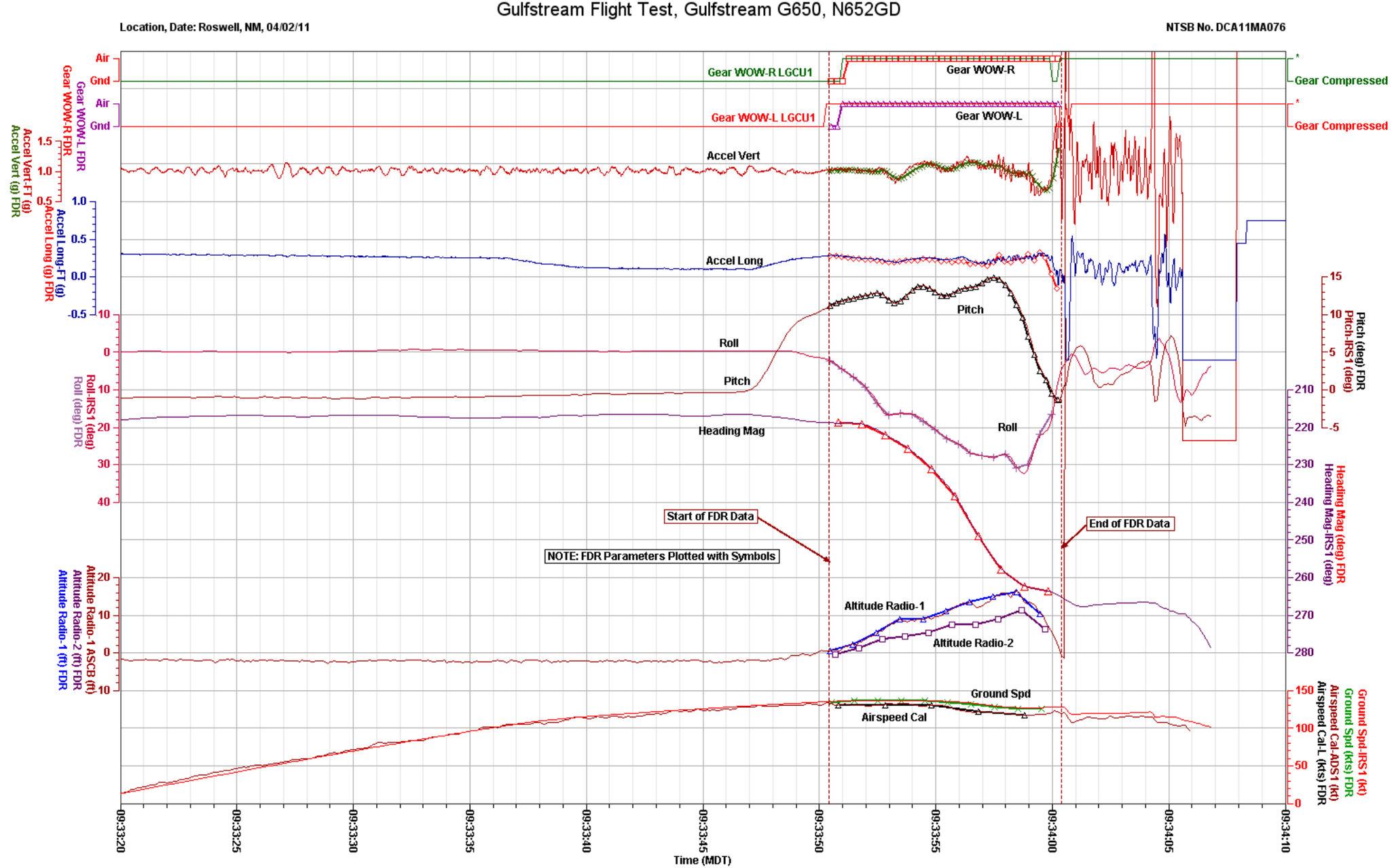


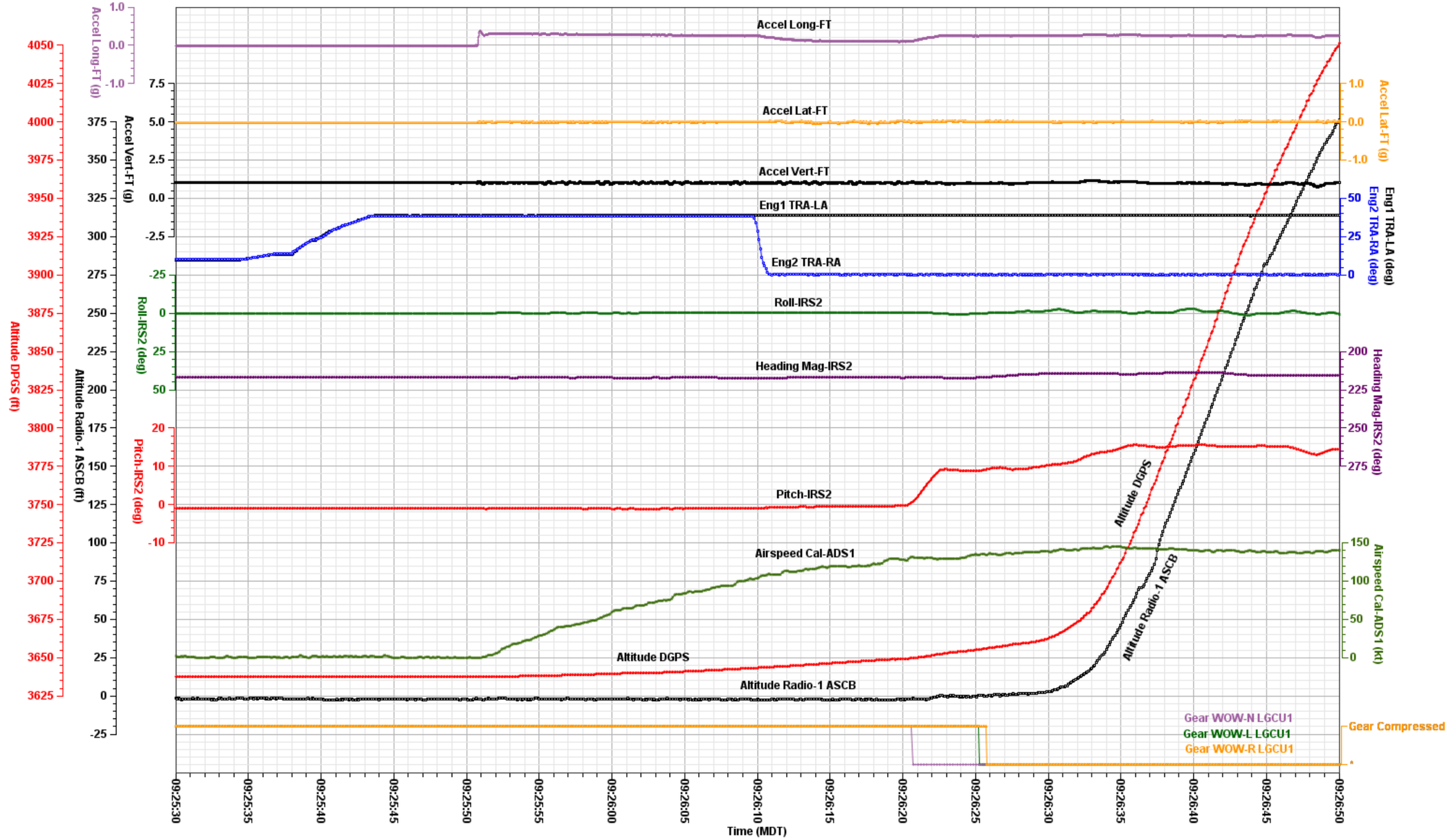
Figure 16 - Comparison of production FDR data and select flight test parameters from the accident flight 153 test run 7A2

Figure 17 - Flight path of the accident flight 153 test run 7A2 (times shown are UTC)

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 153 Run 7A1 - Basic Parameters

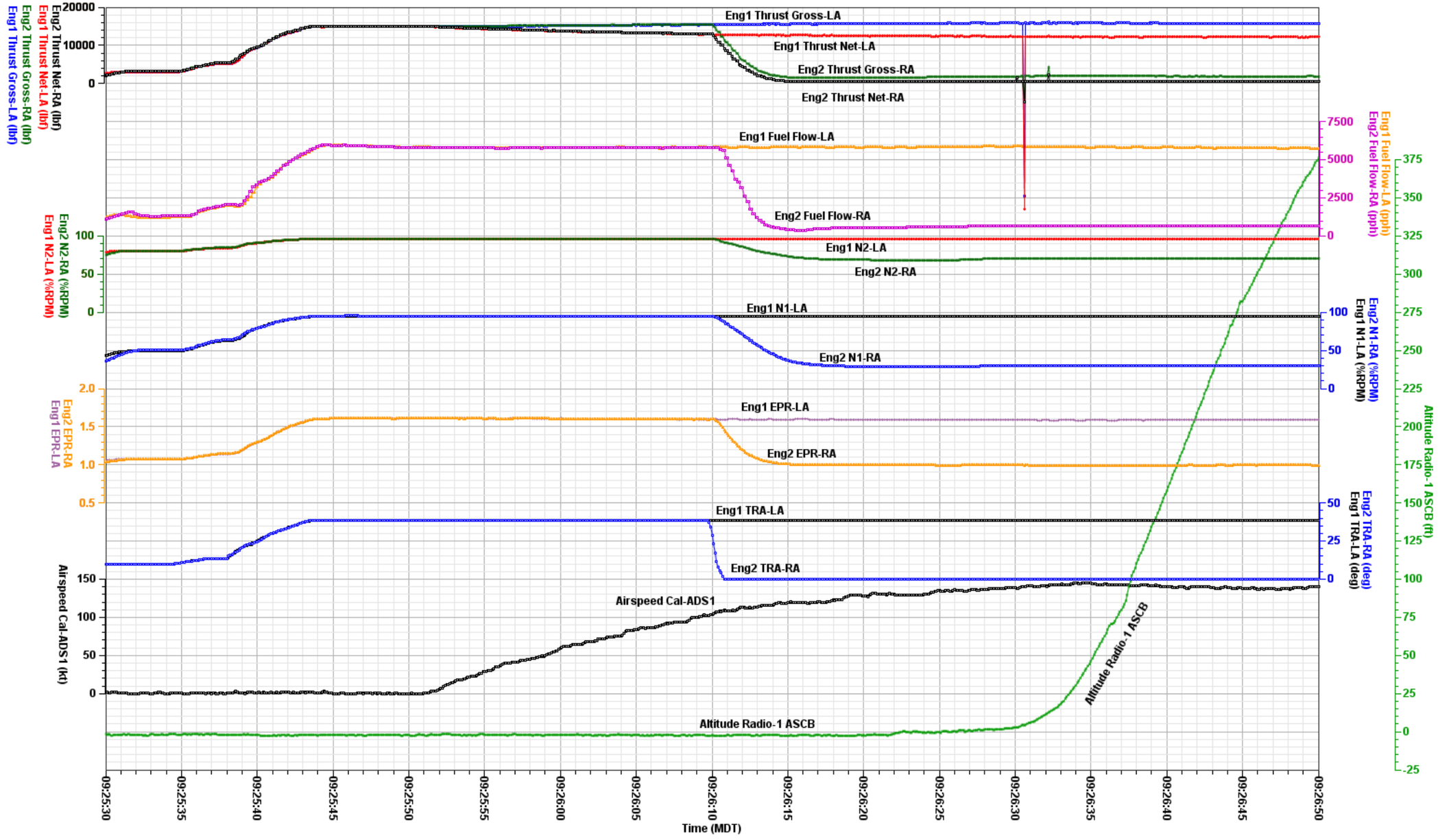
National Transportation Safety Board

Figure 18 - Basic aircraft parameters from the flight 153 test run 7A1

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 153 Run 7A1 - Engine Parameters

National Transportation Safety Board

Figure 19 - Engine parameters from the flight 153 test run 7A1

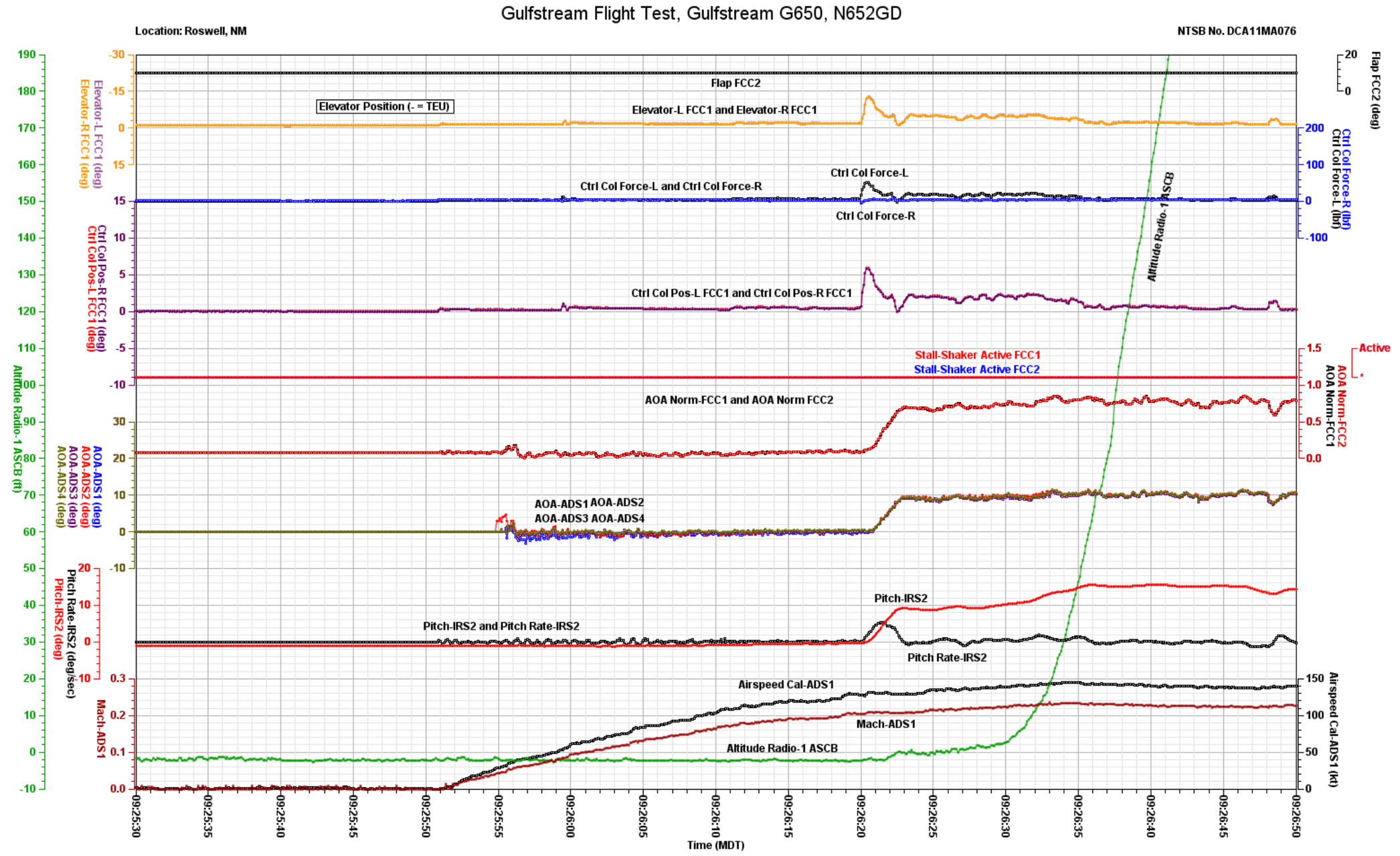
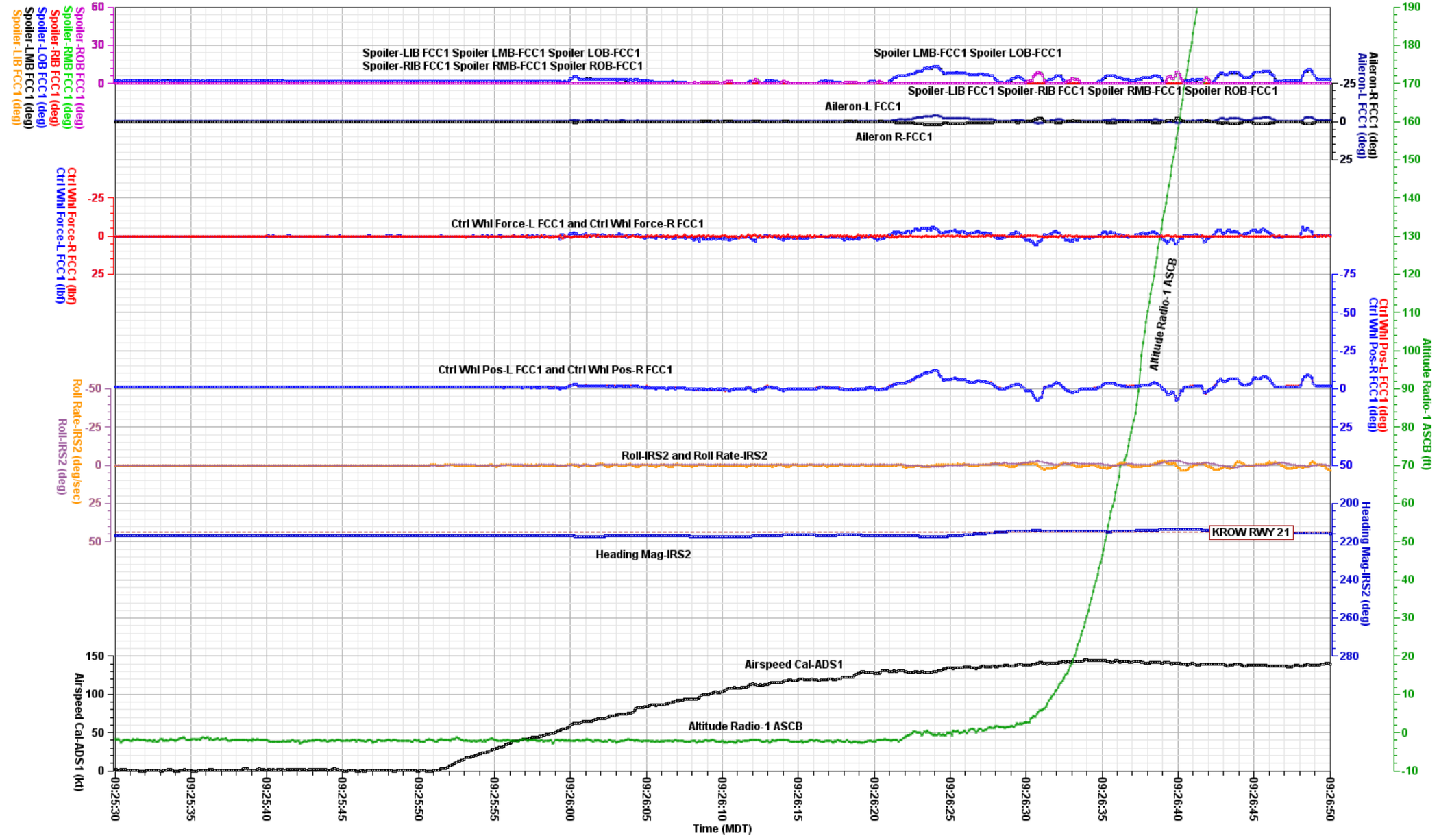


Figure 20 - Pitch axis parameters from the flight 153 test run 7A1

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 153 Run 7A1 - Roll Axis Parameters

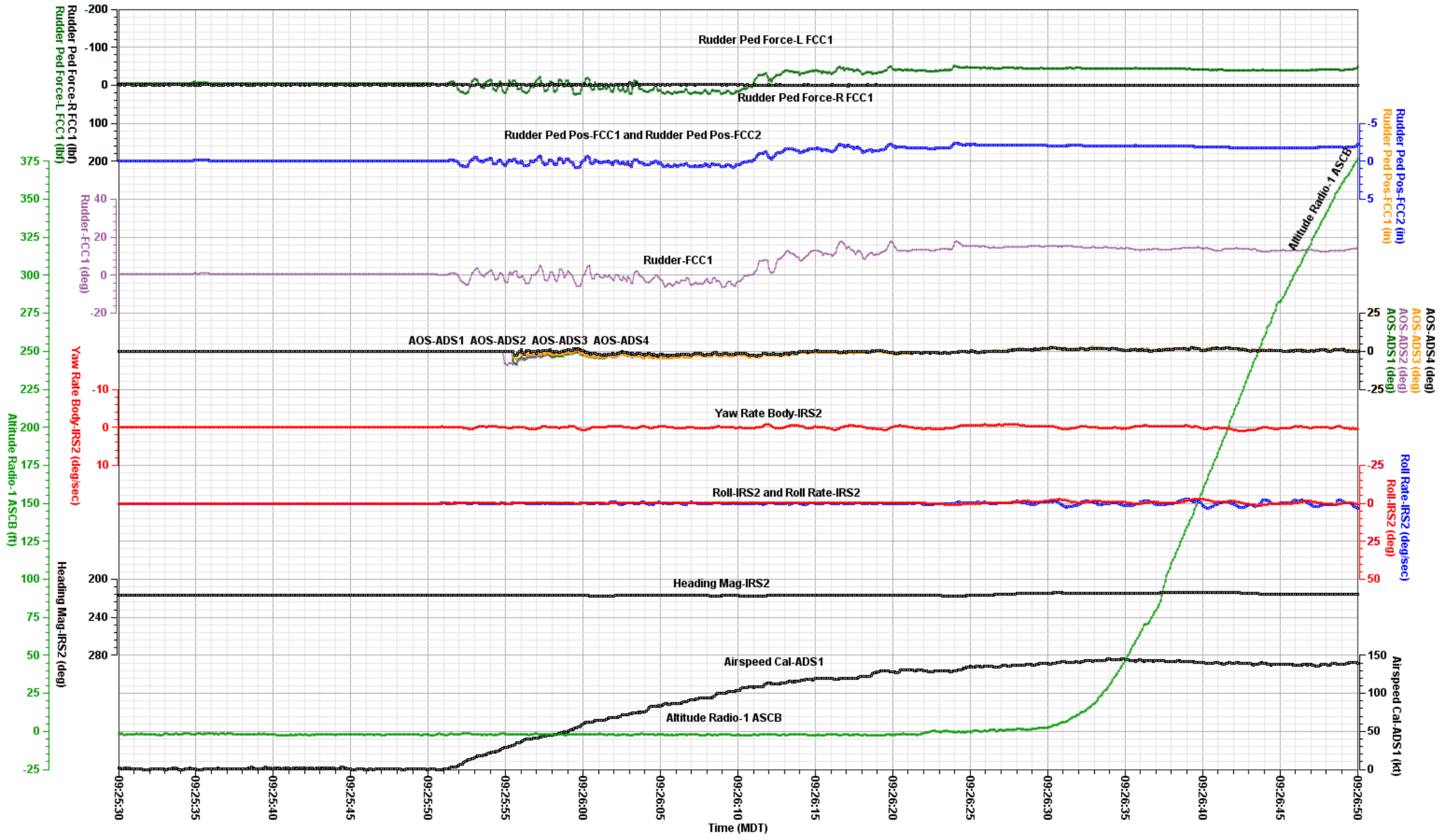
National Transportation Safety Board

Figure 21 - Roll axis parameters from the flight 153 test run 7A1

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 153 Run 7A1 - Yaw Axis Parameters

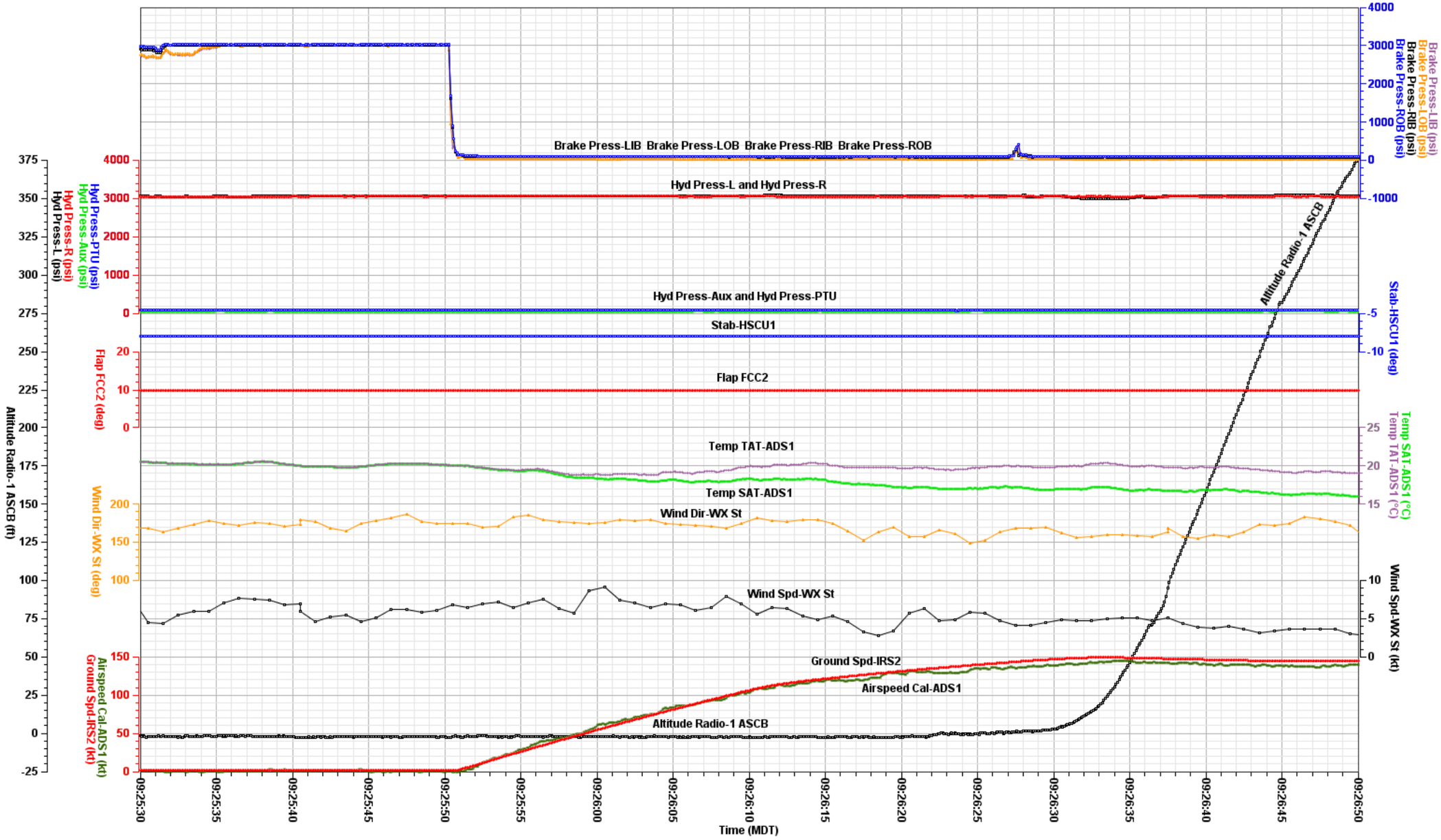
National Transportation Safety Board

Figure 22 - Yaw axis parameters from the flight 153 test run 7A1

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 153 Run 7A1 - Hydraulic,Brake and Environmental Parameters

National Transportation Safety Board

Figure 23 - Hydraulic, brake system and environmental parameters from the flight 153 test run 7A1

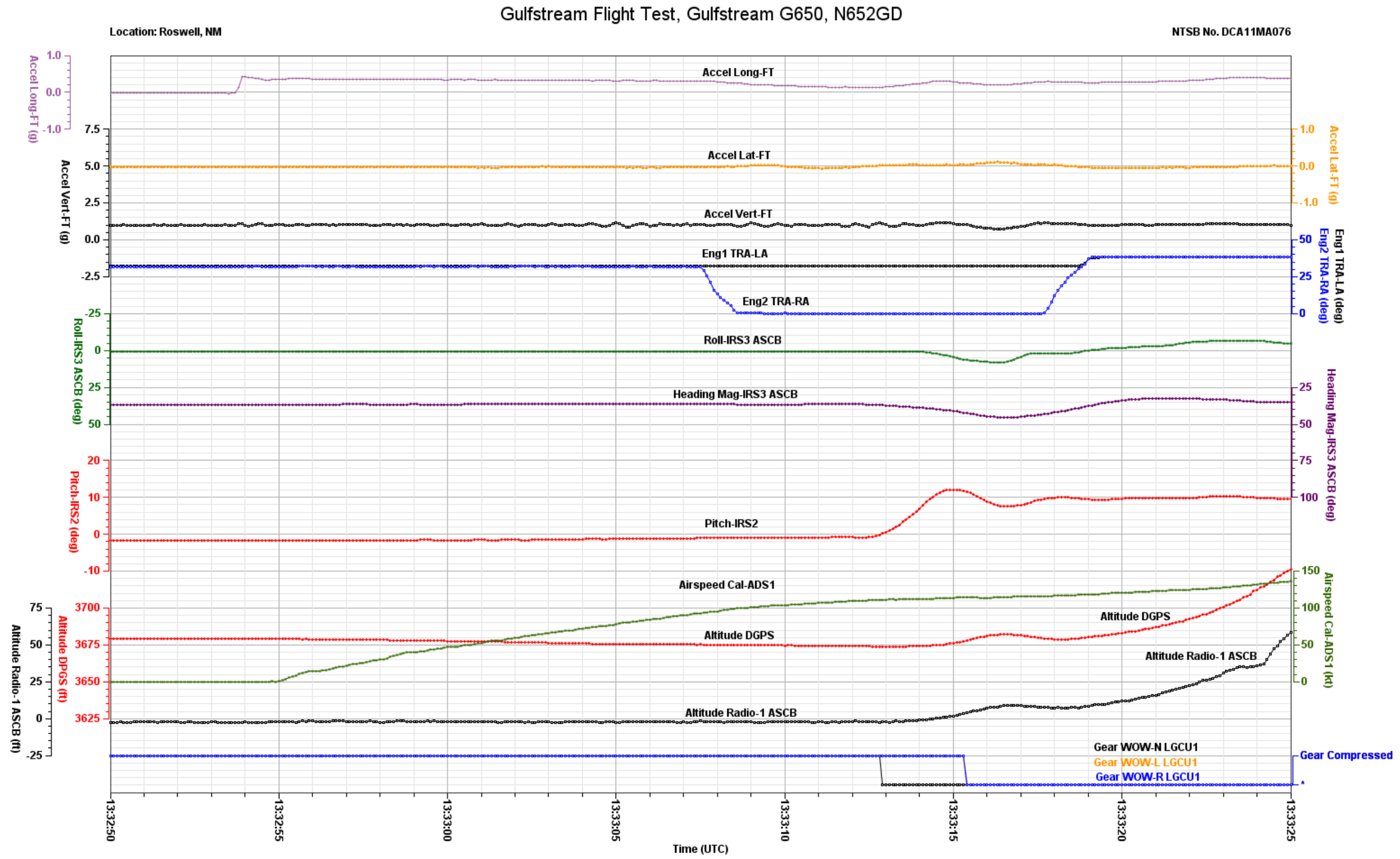


Figure 24 - Basic aircraft parameters from the flight 132 test run 3B2

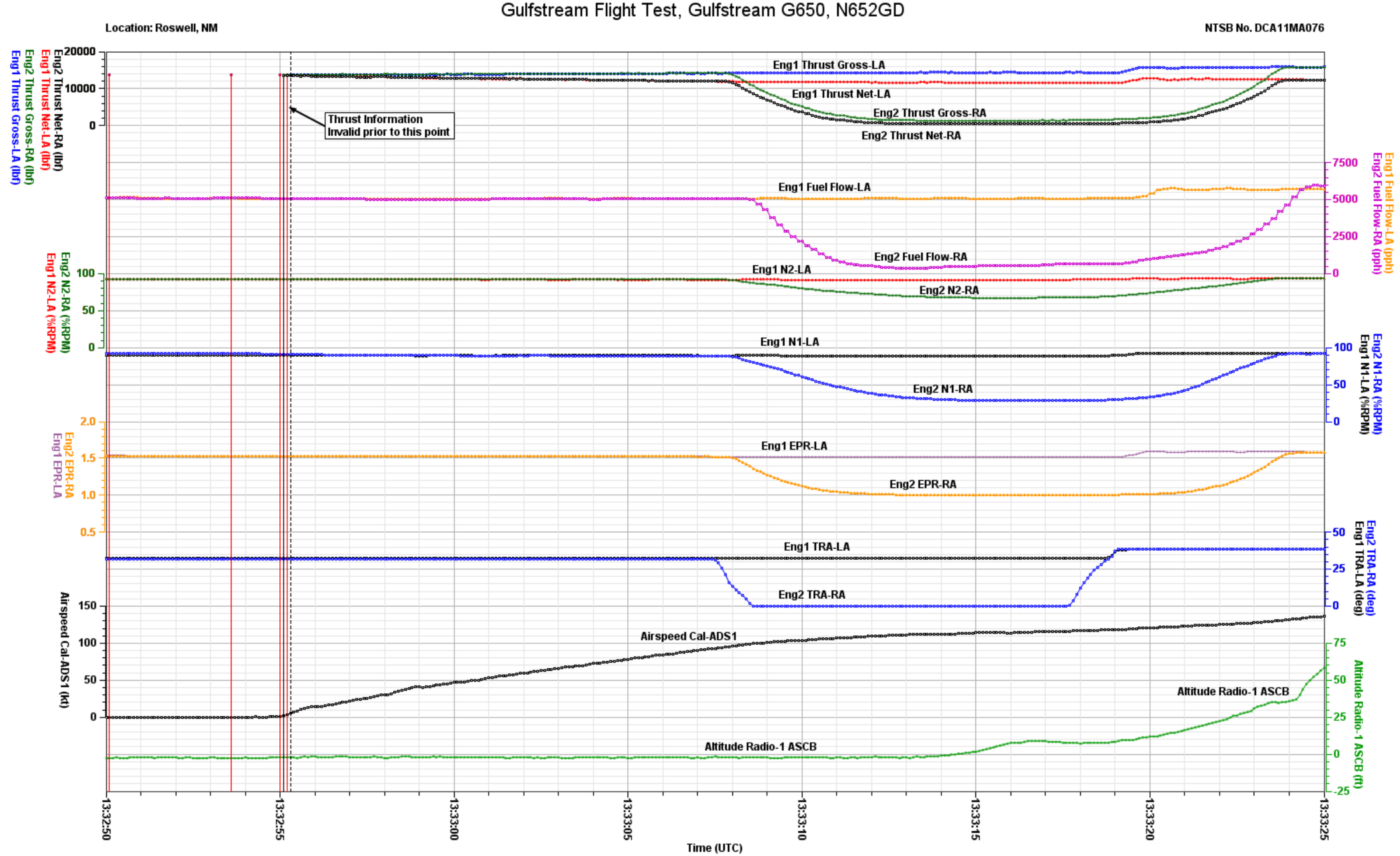


Figure 25 - Engine parameters from the flight 132 test run 3B2

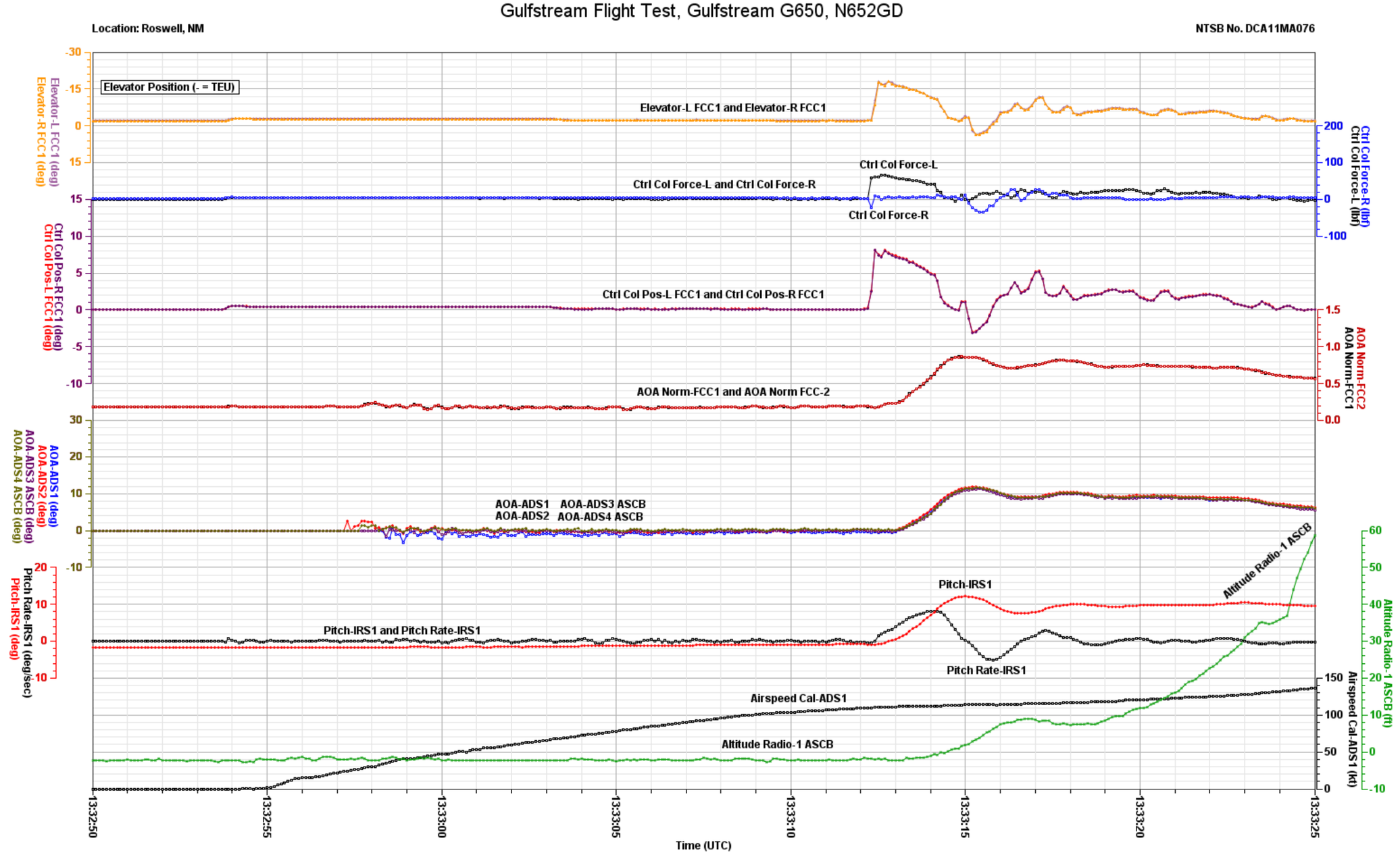


Figure 26 - Pitch axis parameters from the flight 132 test run 3B2

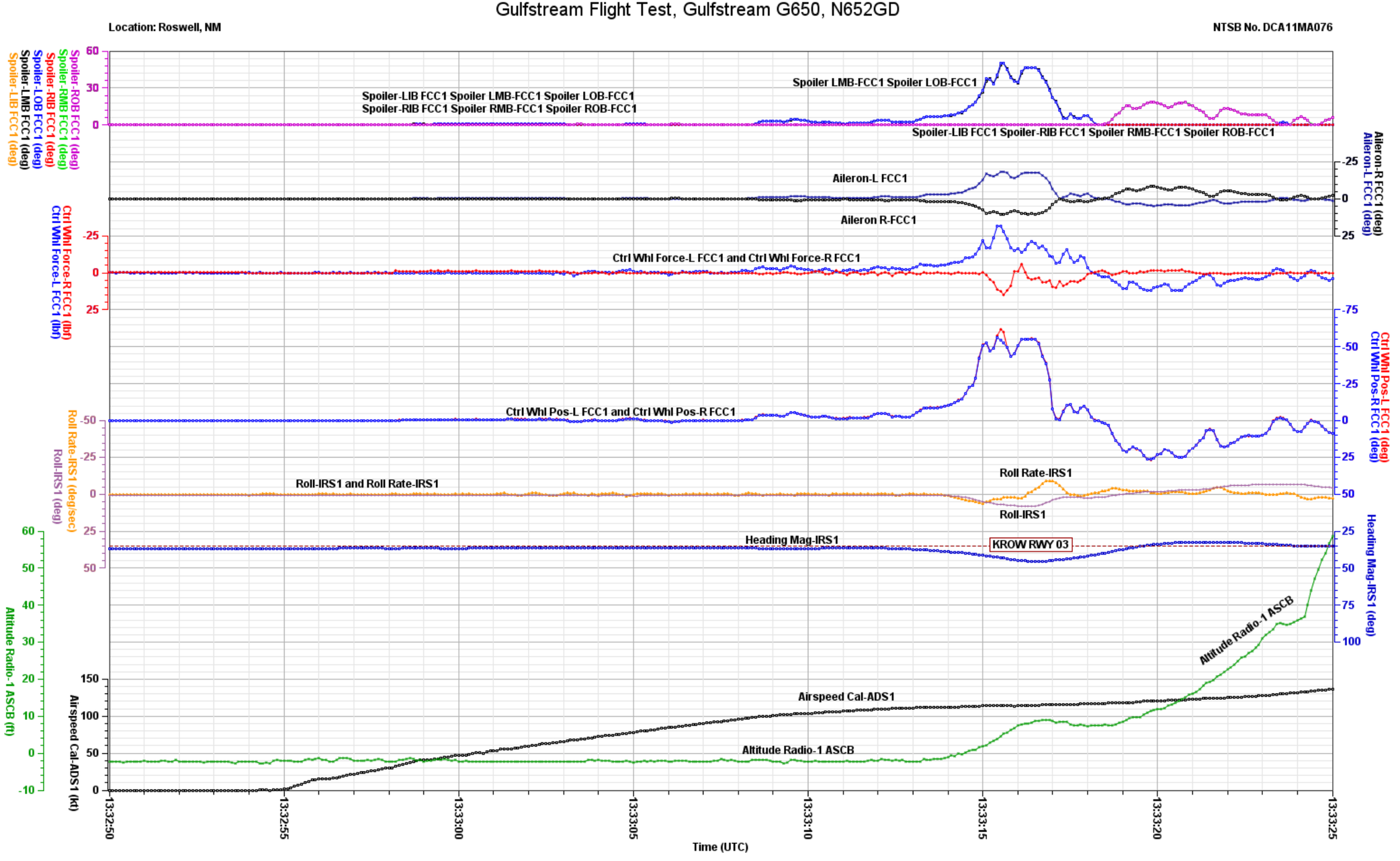


Figure 27 - Roll axis parameters from the flight 132 test run 3B2

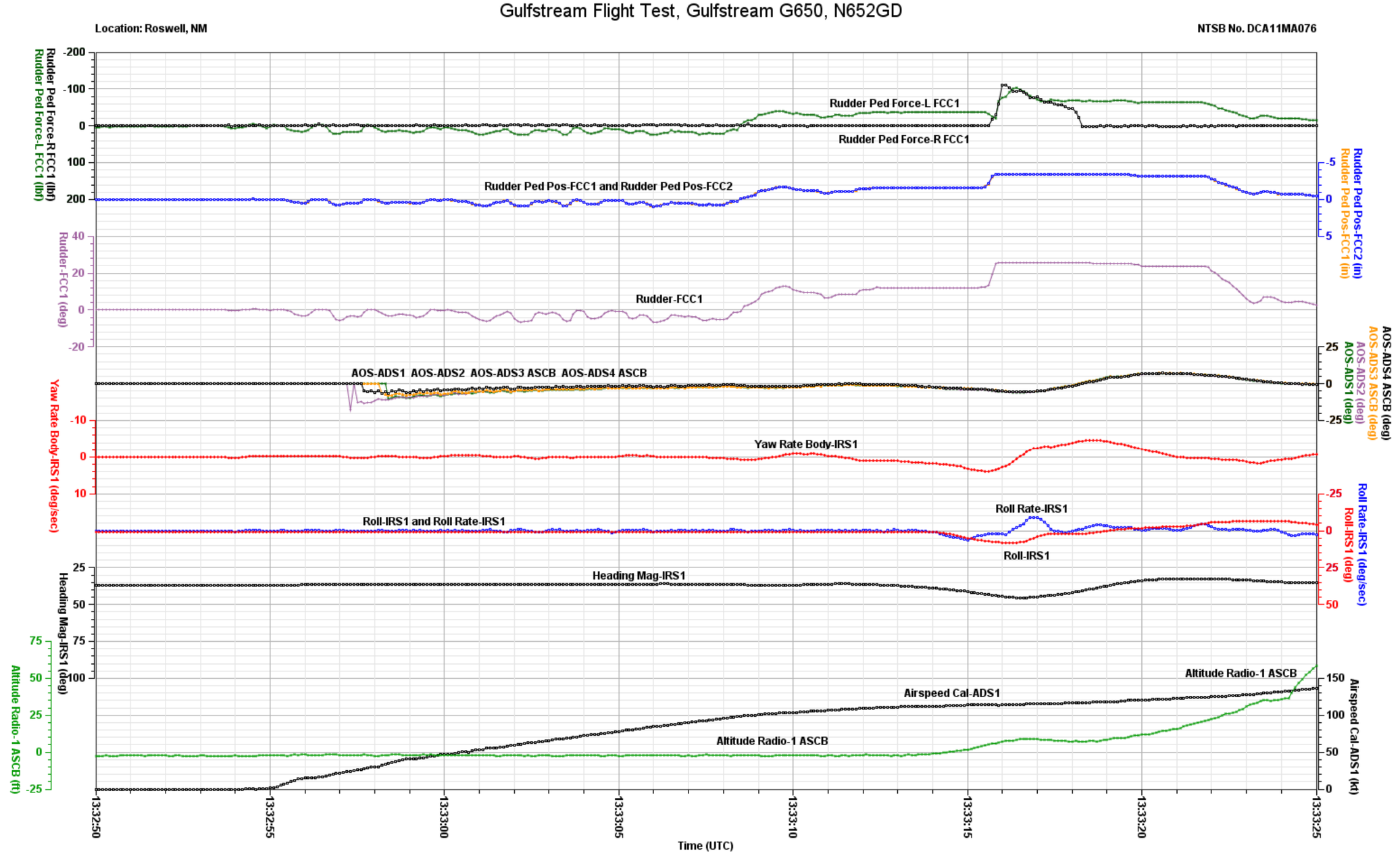


Figure 28 - Yaw axis parameters from the flight 132 test run 3B2

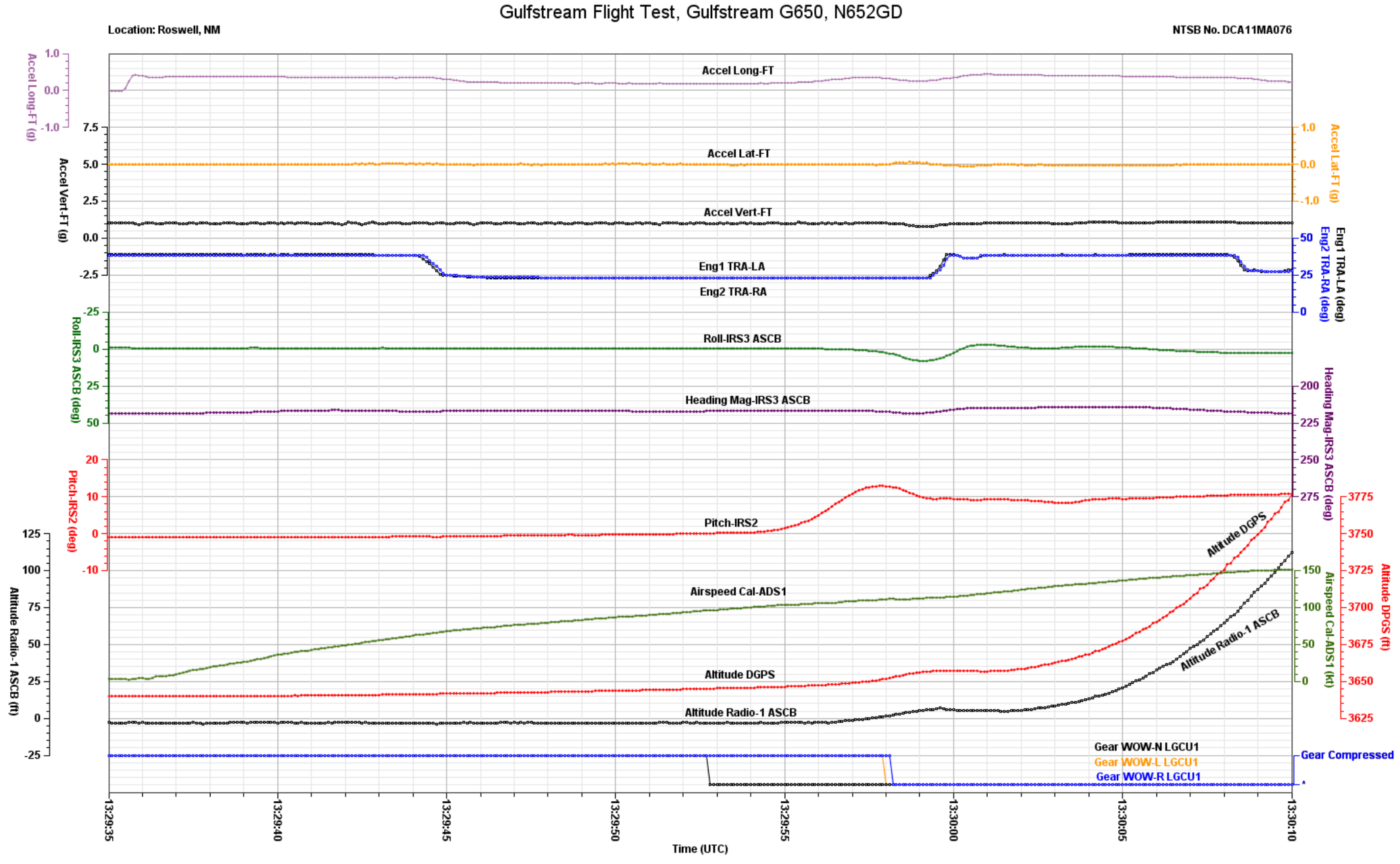


Figure 29 - Basic aircraft parameters from the flight 088 test run 2A

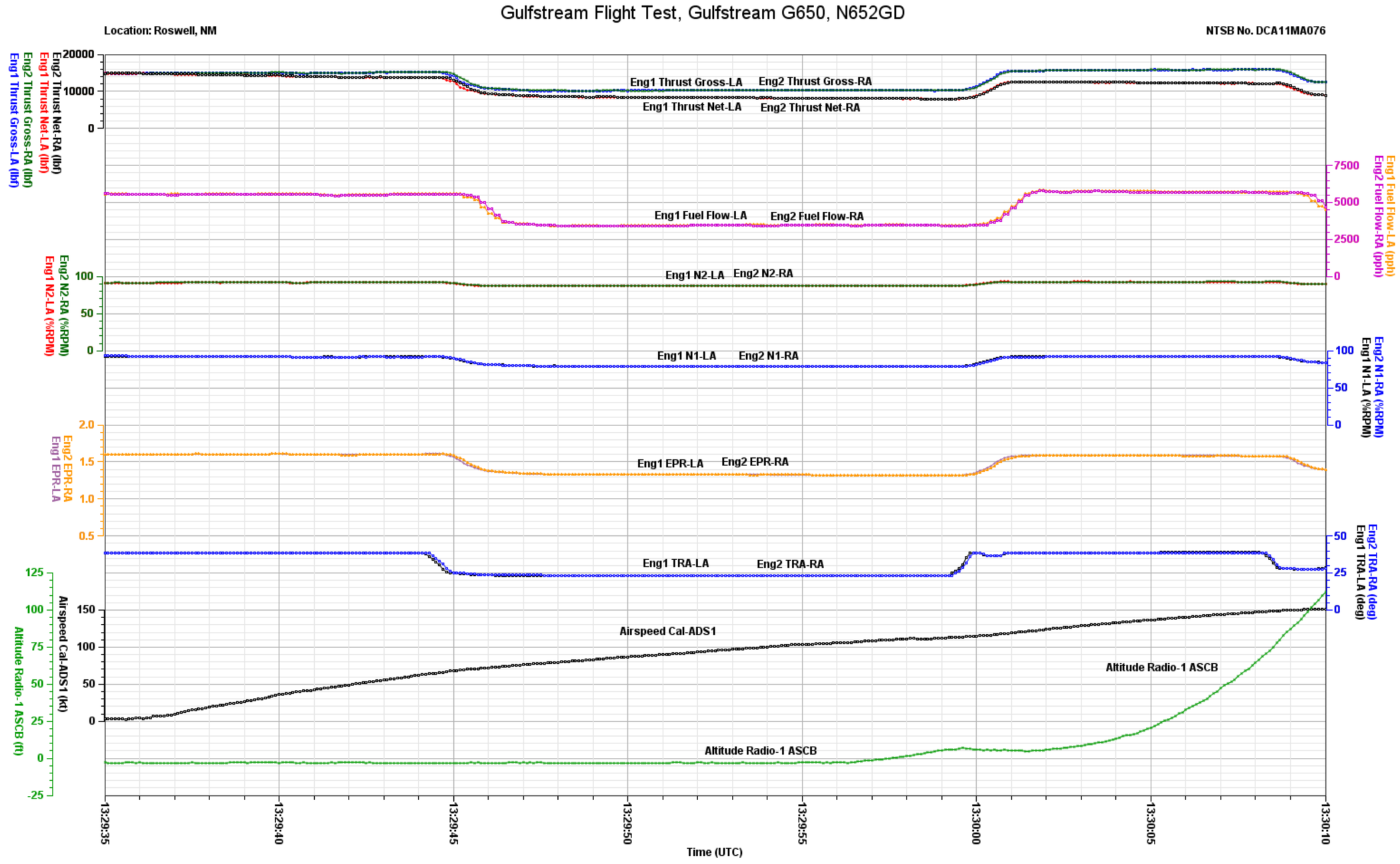
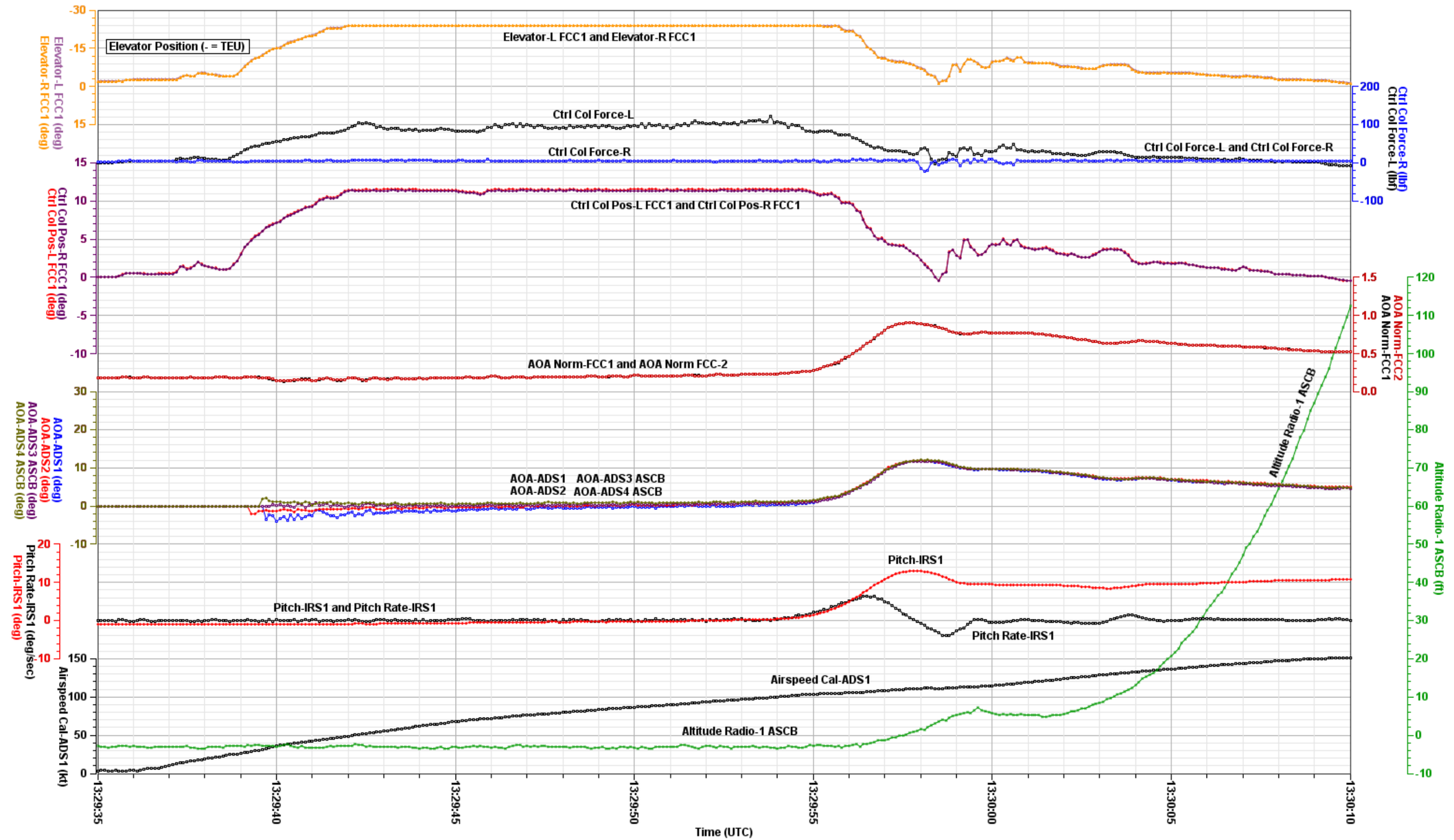


Figure 30 - Engine parameters from the flight 088 test run 2A

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 088 Run 2A - Pitch Axis Parameters

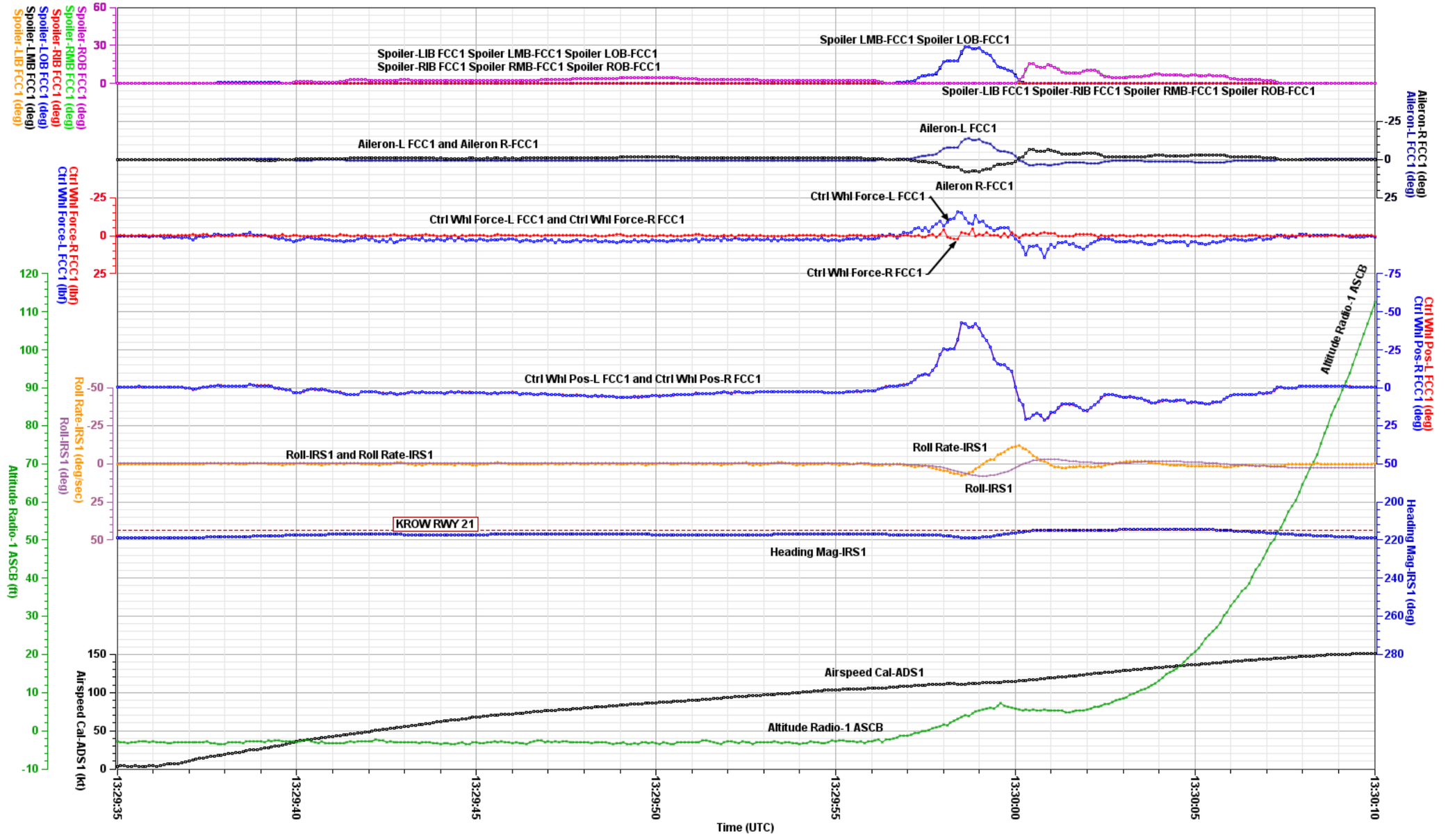
National Transportation Safety Board

Figure 31 - Pitch axis parameters from the flight 088 test run 2A

Gulfstream Flight Test, Gulfstream G650, N652GD

Location: Roswell, NM

NTSB No. DCA11MA076



Revised: 17 January 2012

Flight 088 Run 2A - Roll Axis Parameters

National Transportation Safety Board

Figure 32 - Roll axis parameters from the flight 088 test run 2A

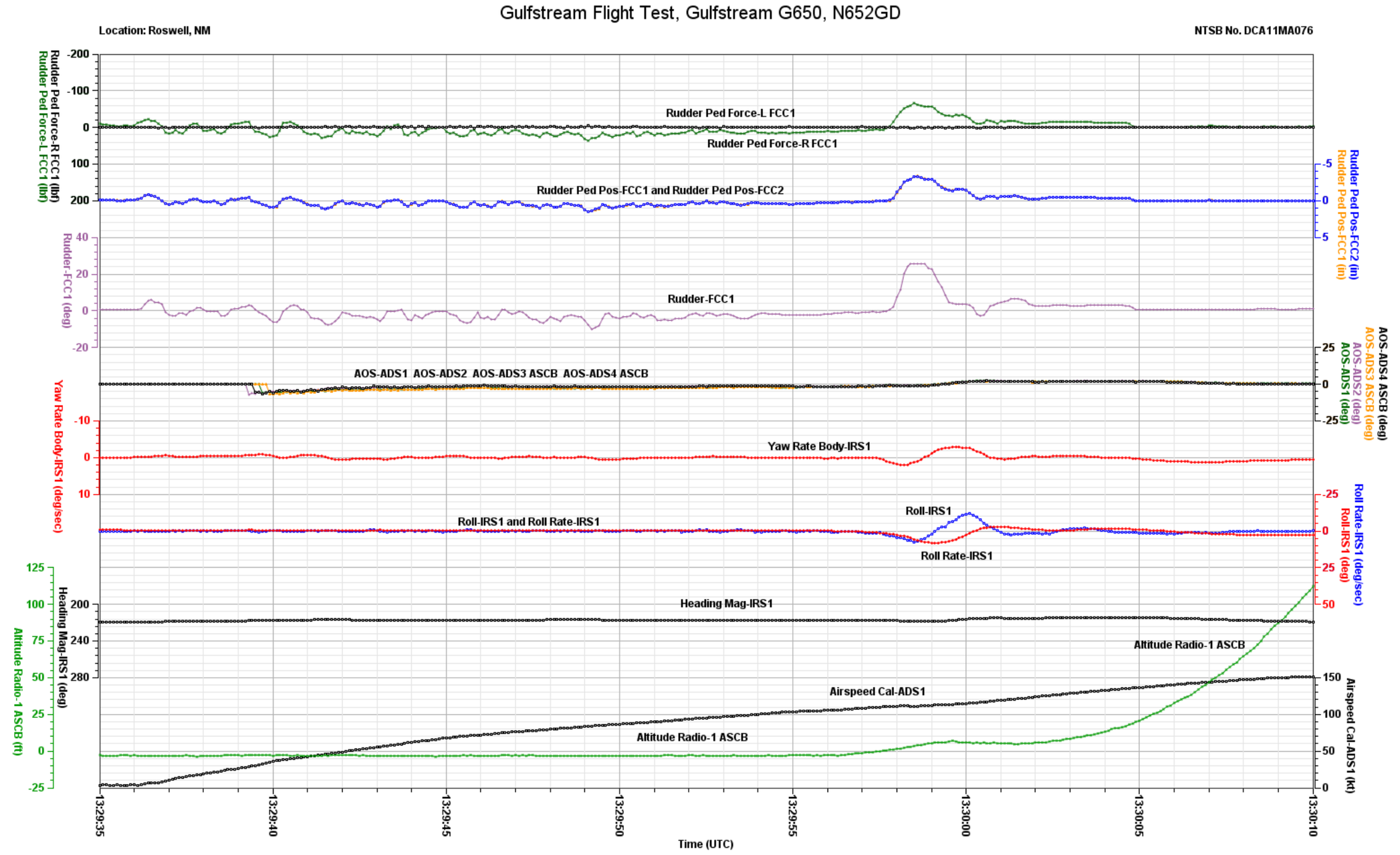


Figure 33 - Yaw axis parameters from the flight 088 test run 2A

APPENDIX A

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

Table A-1. Verified and provided FDR parameters.

Parameter Name	Parameter Description	Source
1. Accel Lat-FT (g)	Lateral Acceleration	Flight Test Accelerometer
2. Accel Long -FT (g)	Longitudinal Acceleration	Flight Test Accelerometer
3. Accel Vert-FT (g)	Vertical Acceleration	Flight Test Accelerometer
4. Aileron-L FCC1 (deg)	Left Aileron Position	Flight Control Computer 1
5. Aileron-R FCC1 (deg)	Right Aileron Position	Flight Control Computer 1
6. Airspeed Cal-ADS1 (kt)	Calibrated Airspeed	Air Data System 1
7. Altitude DGPS(ft)	GPS Altitude	Differential GPS
8. Altitude Radio-1 ASCB (ft)	Left Radio Altitude	ASCB Bus
9. AOA Norm-FCC1	Normalized Angle of Attack	Flight Control Computer 1
10. AOA Norm-FCC2	Normalized Angle of Attack	Flight Control Computer 2
11. AOA-ADS1 (deg)	Angle of Attack	Air Data System 1
12. AOA-ADS2 (deg)	Angle of Attack	Air Data System 2
13. AOA-ADS3 (deg)	Angle of Attack	Air Data System 3
14. AOA-ADS4 (deg)	Angle of Attack	Air Data System 4
15. AOA-ADS3 ASCB (deg)	Angle of Attack	Air Data System 3 via ASCB-D
16. AOA-ADS4 ASCB (deg)	Angle of Attack	Air Data System 4 via ASCB-D
17. AOS-ADS1 (deg)	Angle of Sideslip	Air Data System 1
18. AOS-ADS2 (deg)	Angle of Sideslip	Air Data System 2
19. AOS-ADS3 (deg)	Angle of Sideslip	Air Data System 3
20. AOS-ADS4 (deg)	Angle of Sideslip	Air Data System 4
21. AOS-ADS3 ASCB (deg)	Angle of Sideslip	Air Data System 3 via ASCB-D
22. AOS-ADS4 ASCB (deg)	Angle of Sideslip	Air Data System 4 via ASCB-D
23. Brake Press-LIB (psi)	Left Inboard Brake Pressure	Flight Test Installation
24. Brake Press-LOB (psi)	Left Outboard Brake Pressure	Flight Test Installation
25. Brake Press-RIB (psi)	Right Inboard Brake Pressure	Flight Test Installation
26. Brake Press-ROB (psi)	Right Outboard Brake Pressure	Flight Test Installation
27. Ctrl Col Force-L (lbf)	Left Control Column Force	Flight Control Computer 1
28. Ctrl Col Force-R (lbf)	Right Control Column Force	Flight Control Computer 1
29. Ctrl Col Pos-L FCC1 (deg)	Left Control Column Position	Flight Control Computer 1

Parameter Name	Parameter Description	Source
30. Ctrl Col Pos-R FCC1 (deg)	Right Control Column Position	Flight Control Computer 1
31. Ctrl Whl Force-L FCC1 (lbf)	Left Control Wheel Force	Flight Control Computer 1
32. Ctrl Whl Force-R FCC1 (lbf)	Right Control Wheel Force	Flight Control Computer 1
33. Ctrl Whl Pos-L FCC1 (deg)	Left Control Wheel Position	Flight Control Computer 1
34. Ctrl Whl Pos-R FCC1 (deg)	Right Control Wheel Position	Flight Control Computer 1
35. Elevator-L FCC1(deg)	Left Elevator Position	Flight Control Computer 1
36. Elevator-R FCC1(deg)	Right Elevator Position	Flight Control Computer 1
37. Eng1 EPR-LA	Left Engine Pressure Ratio	Left FADEC Channel A
38. Eng1 Fuel Low-LA (pph)	Left Engine Fuel Flow	Left FADEC Channel A
39. Eng1 N1-LA (%RPM)	Left Engine N1 Speed	Left FADEC Channel A
40. Eng1 N2-LA (%RPM)	Left Engine N2 Speed	Left FADEC Channel A
41. Eng1 Thrust Gross-LA (lbf)	Left Engine Gross Thrust	IADS System
42. Eng1 Thrust Net-LA (lbf)	Left Engine Net Thrust	IADS System
43. Eng1 TRA-LA (deg)	Left Engine Throttle Resolver Angle	Left FADEC Channel A
44. Eng2 EPR-RA	Right Engine Pressure Ratio	Right FADEC Channel A
45. Eng2 Fuel Low-RA (pph)	Right Engine Fuel Flow	Right FADEC Channel A
46. Eng2 N1-RA (%RPM)	Right Engine N1 Speed	Right FADEC Channel A
47. Eng2 N2-RA (%RPM)	Right Engine N2 Speed	Right FADEC Channel A
48. Eng2 Thrust Gross-RA (lbf)	Right Engine Gross Thrust	IADS System
49. Eng2 Thrust Net-RA (lbf)	Right Engine Net Thrust	IADS System
50. Eng2 TRA-RA (deg)	Right Engine Throttle Resolver Angle	Right FADEC Channel A
51. Flap FCC2 (deg)	Flap Position	Flight Control Computer 2
52. Gear WOW-L LGCU1 (discrete)	Left Main Gear Weight On Wheels	Landing Gear Control Unit 1
53. Gear WOW-N LGCU1 (discrete)	Nose Gear Weight On Wheels	Landing Gear Control Unit 1
54. Gear WOW-R LGCU1 (discrete)	Right Main Gear Weight On Wheels	Landing Gear Control Unit 1
55. Ground Spd-IRS2 (kts)	Ground Speed	Inertial Reference System 2
56. Heading Mag – IRS 1(deg)	Magnetic Heading	Inertial Reference System 1
57. Heading Mag – IRS 2(deg)	Magnetic Heading	Inertial Reference System 2
58. Heading Mag – IRS 3 ASCB(deg)	Magnetic Heading	Inertial Reference System 3 via ASCB-D
59. Hyd Press-Aux (psi)	Auxiliary Hydraulic System Pressure	ASCB-D
60. Hyd Press-L (psi)	Left Hydraulic System Pressure	ASCB-D
61. Hyd Press-PTU (psi)	Power Transfer Unit Hydraulic System Pressure	ASCB-D
62. Hyd Press-R (psi)	Right Hydraulic System Pressure	ASCB-D

Parameter Name	Parameter Description	Source
63. Latitude DGPS (deg)	Latitude	Differential GPS
64. Longitude DGPS (deg)	Longitude	Differential GPS
65. Mach-ADS1	Mach	Air Data System 1
66. Pitch IRS-1 (deg)	Pitch Angle	Inertial Reference System 1
67. Pitch IRS-2 (deg)	Pitch Angle	Inertial Reference System 2
68. Pitch Rate IRS-1 (deg/sec)	Rate of Pitch Angle change	Inertial Reference System 1
69. Pitch Rate IRS-2 (deg/sec)	Rate of Pitch Angle change	Inertial Reference System 2
70. Roll IRS-1 (deg)	Roll Angle	Inertial Reference System 1
71. Roll IRS-2 (deg)	Roll Angle	Inertial Reference System 2
72. Roll IRS-3 ASCB (deg)	Roll Angle	Inertial Reference System 3 via ASCB-D
73. Roll Rate IRS-1 (deg/sec)	Rate of Roll Angle change	Inertial Reference System 1
74. Roll Rate IRS-2 (deg/sec)	Rate of Roll Angle change	Inertial Reference System 2
75. Rudder FCC1 (deg)	Rudder Position	Flight Control Computer 1
76. Rudder Ped Force FCC-1 (lbf)	Rudder Pedal Force	Flight Control Computer 1
77. Rudder Ped Force FCC-2 (lbf)	Rudder Pedal Force	Flight Control Computer 2
78. Rudder Ped Pos FCC-1 (deg)	Rudder Pedal Position	Flight Control Computer 1
79. Rudder Ped Pos FCC-2 (deg)	Rudder Pedal Position	Flight Control Computer 2
80. Spoiler-LIB FCC (deg)	Left Inboard Spoiler Position	Flight Control Computer 1
81. Spoiler-LMB FCC (deg)	Left Midboard Spoiler Position	Flight Control Computer 1
82. Spoiler-LOB FCC (deg)	Left Outboard Spoiler Position	Flight Control Computer 1
83. Spoiler-RIB FCC (deg)	Right Inboard Spoiler Position	Flight Control Computer 1
84. Spoiler-RMB FCC (deg)	Right Midboard Spoiler Position	Flight Control Computer 1
85. Spoiler-ROB FCC (deg)	Right Outboard Spoiler Position	Flight Control Computer 1
86. Stab-HSCU 1 (deg)	Horizontal Stabilizer Position	Horizontal Stabilizer Control Unit 1
87. Stall-Shaker Active FCC1 (discrete)	Stick Shaker Active Command	Flight Control Computer 1
88. Stall-Shaker Active FCC2 (discrete)	Stick Shaker Active Command	Flight Control Computer 2
89. Temp SAT-ADS1 (degC)	Static Air Temperature	Air Data System 1
90. Temp TAT-ADS1 (degC)	Total Air Temperature	Air Data System 1
91. Wind Dir-Wx St (deg)	Weather Station Wind Direction	Weather Station
92. Wind Spd-Wx St (kts)	Weather Station Wind Speed	Weather Station
93. Yaw Rate Body-IRS1 (deg/sec)	Body Yaw Rate	Inertial Reference System 1
94. Yaw Rate Body-IRS2 (deg/sec)	Body Yaw Rate	Inertial Reference System 2

NOTE: Pressure altitude 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.

Table A-2. Unit abbreviations.

Units Abbreviation	Description
deg	degrees
kts	knots
g	G
discrete	discrete
deg	degrees
deg/sec	degrees per seconds
degC	degrees Celsius
in	inches
ft	feet
hrs	hours
lbf	pounds-force
min	minutes
pph	pounds per hour
sec	seconds
%rpm	percent revolutions per minute

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.

APPENDIX B

This appendix describes the FDR parameters provided and verified in this report. Table B-1 lists the parameters and table B-2 describes the unit abbreviations used in this report.

Table B-1. Verified and provided FDR parameters.

Parameter Name	Parameter Description
1. Accel Long (g)	Longitudinal Acceleration
2. Accel Vert (g)	Vertical Acceleration
3. Airspeed Cal (kts)	Calibrated Airspeed
4. Altitude Radio-1 (deg)	Radio Altitude-1
5. Altitude Radio-2 (deg)	Radio Altitude-2
6. Gear WOW-L (discrete)	Left Gear Weight On Wheels
7. Gear WOW-R (discrete)	Right Gear Weight On Wheels
8. Ground Spd (kts)	Ground Speed
9. Heading Mag (deg)	Magnetic Heading
10. Pitch (deg)	Pitch Angle
11. Roll (deg)	Roll Angle

Table B-2. Unit abbreviations.

Units Abbreviation	Description
deg	degrees
discrete	discrete
ft	feet
g	g
kts	knots

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.