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

May 14, 2012

Flight Data Recorder and Fault History Database - 10

Group Chairman's Factual Report
By Cassandra Johnson

1. EVENT SUMMARY

Location: Appleton, Wisconsin
Date: February 14, 2011
Aircraft: Gulfstream G550
Registration: N535GA
Operator: Gulfstream Aerospace
NTSB Number: CEN11FA193

On February 14, 2011, about 1315 central standard time CST, a Gulfstream Aerospace Corporation GV-SP airplane, N535GA, owned and operated by Gulfstream Aerospace Corporation, incurred substantial left wing damage during a landing overrun on runway 30 (6,501 feet by 150 feet, dry grooved concrete) at the Outagamie County Regional Airport (ATW), near Appleton, Wisconsin. The flight crew reported a loss of a hydraulic system. The two certificated airline transport pilots and one passenger were not injured. The maintenance test flight was conducted under the provision of Title 14 *Code of Federal Regulations* (CFR) Part 91. Visual meteorological conditions prevailed and an activated instrument flight rules flight plan was on file for the flight. The local flight departed from ATW about 1010 CST.

2. FLIGHT DATA RECORDER GROUP

A flight data recorder (FDR) group was convened on March 8, 2011 and completed on March 10, 2011.

Chairman:	Cassandra Johnson Mechanical Engineer National Transportation Safety Board
Member:	Michael Bauer Aerospace Engineer National Transportation Safety Board
Member:	Anna Cushman Aerospace Engineer Federal Aviation Administration
Member:	Frank Manochio Electrical Systems Engineer Gulfstream Aerospace

Member: Gary Schoonover
Service Engineering
Gulfstream Aerospace

3. FDR Carriage Requirements

The event aircraft, N535GA, was manufactured in 2010, and was operating such that it was required to be equipped with an FDR that recorded, at a minimum, 18 parameters, as cited in 14 CFR Part 91.609(c)(1).

4. DETAILS OF FLIGHT DATA RECORDER INVESTIGATION

The NTSB's Vehicle Recorder Division received the following FDR:

Recorder Manufacturer/Model: **Universal Avionics 1607**
Recorder Serial Number: **152**

4.1. Universal Avionics Description

This model 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 (for example, 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.

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 73.5 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 3 hours.

The parameters evaluated for the purpose of this report appeared to be in accordance with the federal FDR carriage requirements, except Relative Time and Pressure Altitude. There appears to be a discrepancy between the sampling rate requirements in 14 CFR Part 91 and the sampling requirements for 14 CFR Part 135 and 14 CFR Part 121. The accident aircraft recorded Relative Time once every 4 seconds and Pressure Altitude once every second, which meet the requirements for 14 CFR Part 135 and 14 CFR Part 121; whereas Appendix E to 14 CFR Part 91 specifies the sampling interval for Relative Time to be once per second and Pressure Altitude to be 11 per second.

4.1.3. FDR Documentation

FDR data frame correlation documentation is required in 14 CFR Part 121.343(j), 14 CFR Part 121.343a(d) and 14 CFR Part 135.152(f)(2). In contrast, FDR data frame correlation documentation is not required for 14 CFR Part 91.609. However, FDR data frame documentation is essential for decoding FDR data (for example, changing the raw binary data into engineering units). Upon request, Gulfstream provided the FDR documentation to the NTSB but the documentation was insufficient to decode the data and difficult to understand. Therefore, it was necessary to have Gulfstream's assistance in decoding and verifying the data.

Gulfstream was provided a detailed list of the insufficiencies of their FDR data frame correlation documentation. In general, some of the problems with the FDR data frame correlation document were:

- The FDR document did not reflect the recorded parameters originally delivered with the aircraft.
- The FDR document did not explain it contained both 256-word intervals data frame information and 512-word intervals data frame information.
- The states for 1-bit discrete parameters and the states for multiple bit discrete parameters (for example, auto throttles, NAV modes, etc.) were not provided.
- The definitions of column titles were not provided which made the document difficult to understand.
- Some parameter names did not accurately reflect the parameter definition. For example, the message parameter should reflect the actual warning or add the message in the parameter name.
- Parameters that are a combination of multiple words (for example, more than 12 bits) were not defined as to how to combine the words.
- The FDR document did not provide mathematical conversions for translating raw decimal counts into engineering units.
- Sign conventions were not defined (for example, rudder surface position to the right is nose right, pitch up is positive, etc.).
- For some parameters, the subframe column did not reflect the actual recorded subframes.
- Parameters were listed multiple times because there were many virtual sources, thus making it difficult to figure out what parameters were recorded.
- The source of each parameter was not defined.
- For some parameters, multiple revisions were noted but no information was provided of what the multiple revisions meant.

Subsequent to the FDR group meeting, Gulfstream submitted a revised FDR data frame correlation document to address the above issues. Upon review, some of the issues listed above were addressed but not all. Additionally, there were many editorial errors and inconsistencies throughout the document which made the document confusing and difficult to follow. Some examples include:

- Appendix G was referenced when there was not an appendix G.
- Cert Echo is referenced when the document does not define Cert Echo.
- The page numbers for both appendix A and C use the letter E.

- Certification F is referenced as transmitting at 512 wps but the FDR data frame information in appendix B shows 256 wps.

4.1.4. Parameter Conversions

The FDR group systematically determined the conversions of the parameters verified and provided in this report as listed in table A-1 of appendix A. Additionally, table A-2 of appendix A describes the unit and discrete state abbreviations used in this report. Where applicable, the conversions have been changed to ensure that the parameters conform to the NTSB's standard sign convention that climbing right turns are positive (CRT=+).[1]

4.1.4.1. Gear WOW-L and Gear WOW-R

The source of the Gear WOW-L is from the left engine Full Authority Digital Engine Control (FADEC) and the source of the Gear WOW-R is from the right engine FADEC. Both the Gear WOW-L and Gear WOW-R will indicate ground when all three gears (left main landing gear, right main landing gear, and nose gear) are on the ground.

4.2. Data Drop Outs

There were two data drop outs during the flight and one data drop out after the landing. The two data drop outs during the flight were expected due to the nature of the test flight. The data drop out after the landing is most likely attributed to the landing event.

4.3. Time Correlation

Due to the data drop outs and that SRN is elapsed seconds based on the FDR data stream, the timing (x-axis) for figures 1 to 9 were kept in SRN. However, recorded GMT[2] Hours, GMT Minutes, and GMT Seconds are provided when each SRN is cited in this report.

4.4. Aircraft Fault History Database (FHDB)

In addition to the FDR, Gulfstream provided to the FDR group the Crew Advisory System (CAS)[3] messages recorded in the Fault History Database (FHDB) from the February 14, 2011 event aircraft. In general, the FHDB collects maintenance messages and CAS messages at a 1 hertz rate logged by the Central Maintenance Computer (CMC) during the event flight. Each FHDB message is time stamped with the date and time. The clock source for the FHDB CAS messages is the same clock source for the recorded FDR times (GMT Hours, GMT Minutes and GMT Seconds).

Table 1 contains the recorded FHDB CAS messages along with the timestamps and the severity of each message during the final approach from 263,800 SRN (19:08:52 GMT) until the FDR data drop out at 264,125 SRN (19:14:17 GMT). Since the FHDB CAS messages' timestamps have the same time source as the recorded FDR times, SRN was added to the table to assist in correlating the FHDB CAS messages to the FDR data.

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[1] CRT=+ means that for any parameter recorded that indicates a climb or a right turn, the sign for that value is positive. Also, for any parameter recorded that indicates an action or deflection, if it induces a climb or right turn, the value is positive. Examples: Right Roll = +, Pitch Up = +, Elevator Trailing Edge Up = +, Right Rudder = +.

[2] GMT is Greenwich Mean Time which is also known as Coordinated Universal Time (UTC).

[3] There is a time delay before CAS messages are displayed to the crew.

Table 1. FHDB CAS messages final approach to data drop out.

FDR SRN	Date Timestamp	FHDB CAS Message	FHDB Message Severity
263,937	02/14/2011 19:11:09	L HYDRAULIC QUANTITY LOW	CAUTION
263,964	02/14/2011 19:11:36	YAW DAMPER 1 FAIL	CAUTION
263,964	02/14/2011 19:11:36	YAW DAMPER 1 FAIL	CAUTION
263,966	02/14/2011 19:11:38	L HYDRAULIC SYSTEM FAIL	CAUTION
263,969	02/14/2011 19:11:41	SINGLE SPEED BRAKE	ADVISORY
263,994	02/14/2011 19:12:06	FLAP/STAB MAINT REQD A-B	ADVISORY
264,001	02/14/2011 19:12:13	FLAP/STAB MAINT REQD A-B	ADVISORY
264,074	02/14/2011 19:13:26	AUX HYDRAULIC FAIL	CAUTION
264,086	02/14/2011 19:13:38	L THRUST REVERSER FAIL	CAUTION
264,089	02/14/2011 19:13:41	L THRUST REVERSER MAINT	CAUTION
264,089	02/14/2011 19:13:41	L TR SWITCH MISCOMPARE	ADVISORY
264,095	02/14/2011 19:13:47	AIRCRAFT CONFIGURATION	WARNING
264,105	02/14/2011 19:13:57	L THRUST REVERSER FAIL	CAUTION
264,110	02/14/2011 19:14:02	L TR SWITCH MISCOMPARE	ADVISORY
264,121	02/14/2011 19:14:13	AUX HYDRAULIC FAIL	CAUTION
264,121	02/14/2011 19:14:13	L HYDRAULIC QUANTITY LOW	CAUTION
264,121	02/14/2011 19:14:13	L HYDRAULIC SYSTEM FAIL	CAUTION
264,121	02/14/2011 19:14:13	L THRUST REVERSER FAIL	CAUTION
264,121	02/14/2011 19:14:13	L THRUST REVERSER MAINT	CAUTION
264,121	02/14/2011 19:14:13	L TR SWITCH MISCOMPARE	ADVISORY
264,121	02/14/2011 19:14:13	SINGLE SPEED BRAKE	ADVISORY
264,123	02/14/2011 19:14:15	WOW FAULT	ADVISORY
264,124	02/14/2011 19:14:16	A/T WOW FAULT	ADVISORY

4.5. FDR Plots and Corresponding Tabular Data

Figures 1 to 9 contain select FHDB CAS messages listed in table 1 and FDR data from the event aircraft recorded during the February 14, 2011 event. Table A-1 lists all of the parameters plotted except GMT Hours, GMT Minutes, GMT Seconds, Latitude and Longitude. Figures 1 to 4 cover the entire flight from 252,220 SRN (15:56:12 GMT) until the FDR data ends at 264,476 SRN (19:21:09 GMT). Figures 5 to 9 cover 4.8 minutes of the final approach and then 93 seconds after the Gear WOW-L and Gear WOW-R transitioned from “Air” to “Gnd” thus indicating all three landing gear (left main landing gear, right main landing gear, and nose gear) are on the ground[4]. The x-axis scale for figures 5 to 9 are from 263,800 SRN (19:08:52 GMT) to 264,180 SRN (19:15:04 GMT). Figures 1, 2, 3, and 4 have the same parameters plotted as figures 5, 6, 7, and 8, respectively. Figure 9 has select FDR parameters and select FHDB CAS messages from table 1. The FHDB CAS messages were added as text where each FHDB CAS message has an arrow pointing to a vertical line associated to the time it occurred.

Figures 1 to 9 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] For more details, see Section 4.1.4.1 Gear WOW-L and Gear WOW-R.

In summary, the FDR data indicated the following:

- At 263,914 SRN (19:10:46 GMT) during the final approach, Gear Up-L, Gear Up-R and Gear Up-N transitioned from “Up” to “Not Up” while descending through a pressure altitude of 2,721 ft.
- At 263,916 SRN (19:10:48 GMT), the Battery Contactor-L and Battery Contactor-R transitioned from “Not Closed” to “Closed” and 4 seconds later at 263,920 SRN (19:10:52 GMT) transitioned back to “Not Closed”[5]. During this time, the Hyd Sys Press-Aux increased from 120 psi to 1,300 psi and then decreased to 444 psi.
- At 263,937 SRN (19:11:09 GMT), the FHDB CAS message L HYDRAULIC QUANTITY LOW was recorded. At this time, the pressure altitude had decreased to about 2,433 ft.
- At 263,954 SRN (19:11:26 GMT), the Hyd Sys Press-L decreased from 2,952 psi to 2,688 psi.
- At 263,956 SRN (19:11:28 GMT), the Hyd Press 1Left transitioned from “GT EQ 2400 psi” to “-” indicating loss of left hydraulic pressure. At this time, the Hyd Sys Press-L decreased to 2,060 psi and the pressure altitude had decreased to 2,182 ft.
- At 263,962 SRN (19:11:34 GMT), the Hyd Sys Press-L decreased to 164 psi and remained below 200 psi for the rest of the landing.
- At 263,966 SRN (19:11:38 GMT), the FHDB CAS message L HYDRAULIC SYSTEM FAIL was recorded.
- At 263,985 SRN (19:11:57 GMT) while descending through the pressure altitude of 1,786 ft, the Flap Hndl increased from 20 deg to 39 deg. At this time, the Flap-L and Flap-R remained at 20 deg. About 6 seconds later at 263,991 SRN (19:12:03 GMT), the Flap Hndl decreased back to 20 deg.
- At 264,060 SRN (19:13:12 GMT), the Battery Contactor-L and Battery Contactor-R transitioned from “Not Closed” to “Closed”. At this time, the pressure altitude decreased to approximately 800 feet.
- At 264,066 SRN (19:13:18 GMT), the Eng1 TRA and Eng2 TRA decreased from about 5 degrees to 0 degrees.
- At 264,074 SRN (19:13:26 GMT), the FHDB CAS message AUX HYDRAULIC FAIL was recorded. At this time, the pressure altitude decreased to about 684 ft.
- At 264,079 SRN (19:13:31 GMT), the Eng1 TRA and Eng2 TRA decreased to about -5 deg.[6]
- At 264,081 SRN (19:13:33 GMT), the Eng2 Rvrsr Deploy transitioned from “Not Dep” to “Deployed”; whereas Eng1 Rvrsr Deploy remained “Not Dep” and remained “Not Dep” during the landing.
- At 264,082 SRN (19:13:34 GMT), the Brake Pedal-R and Brake Pedal-L transitioned from “Not Appl” to “Applied”. At this time, the ground speed was about 122 kts and the calibrated airspeed was about 124 kts. All recorded brake pressures remained below 208 psi during the entire landing event.
- At 264,086 SRN (19:13:38 GMT), the FHDB CAS message L THRUST REVERSER FAIL was recorded. At this time, the Gear WOW-L and Gear WOW-R transitioned from “Air” to “Gnd” thus indicating all three landing gear (left main landing gear, right

[5] Battery contactor closed indicates that the Aux hydraulic pump was selected ON.

[6] Eng TRA at 39 deg is maximum forward thrust, Eng TRA at 0 deg is forward thrust, Eng TRA at -5 deg is thrust reverser selected to deploy with idle reverse thrust, and Eng TRA at -22 deg is maximum reverse thrust.

main landing gear, and nose gear) are on the ground. At this time, the ground speed was about 112 kts and the calibrated airspeed was about 117 kts. Additionally at this time, Brake Press-LOB, Brake Press-LIB, Brake Press-RIB, and Brake Press-ROB recorded below 100 psi and remained below 100 psi until the data dropped out at 264,124 SRN (19:14:16 GMT).

- At 264,087 SRN (19:13:39 GMT), the Eng2 TRA decreased to -22 deg and Eng1 TRA remained at -6 deg.
- At 264,092 SRN (19:13:44 GMT), Eng1 TRA and Eng2 TRA increased to about 39 deg and Eng2 Rvrsr Deploy transitioned to “Not Dep”. At this time, the ground speed was approximately 100 kts and the calibrated airspeed was 102 kts.
- At 264,097 SRN (19:13:49 GMT), Eng1 TRA and Eng2 TRA decreased to 0 deg. At this time, the ground speed was 98 kts and the calibrated airspeed was 101 kts.
- At 264,099 SRN (19:13:51 GMT), Brake Ped-L and Brake Ped-R transitioned from “Not Appl” to “Appl” and Eng1 TRA and Eng2 TRA decreased to -5 deg.
- At 264,120 SRN (19:14:12 GMT), the Gear WOW-L and Gear WOW-R transitioned to “Air” thus indicating at least one gear was not on the ground and was in the “Air” mode. At this time, the ground speed was 26 kts.
- At 264,124 SRN (19:14:16 GMT), the data dropped out.

The corresponding tabular data used to create figures 1 to 9 including GMT Hours, GMT Minutes, GMT Seconds, Latitude, and Longitude are provided in electronic comma separated value (*.csv) format as attachment 1 to this report.

Figure 1. Basic parameters during entire flight.

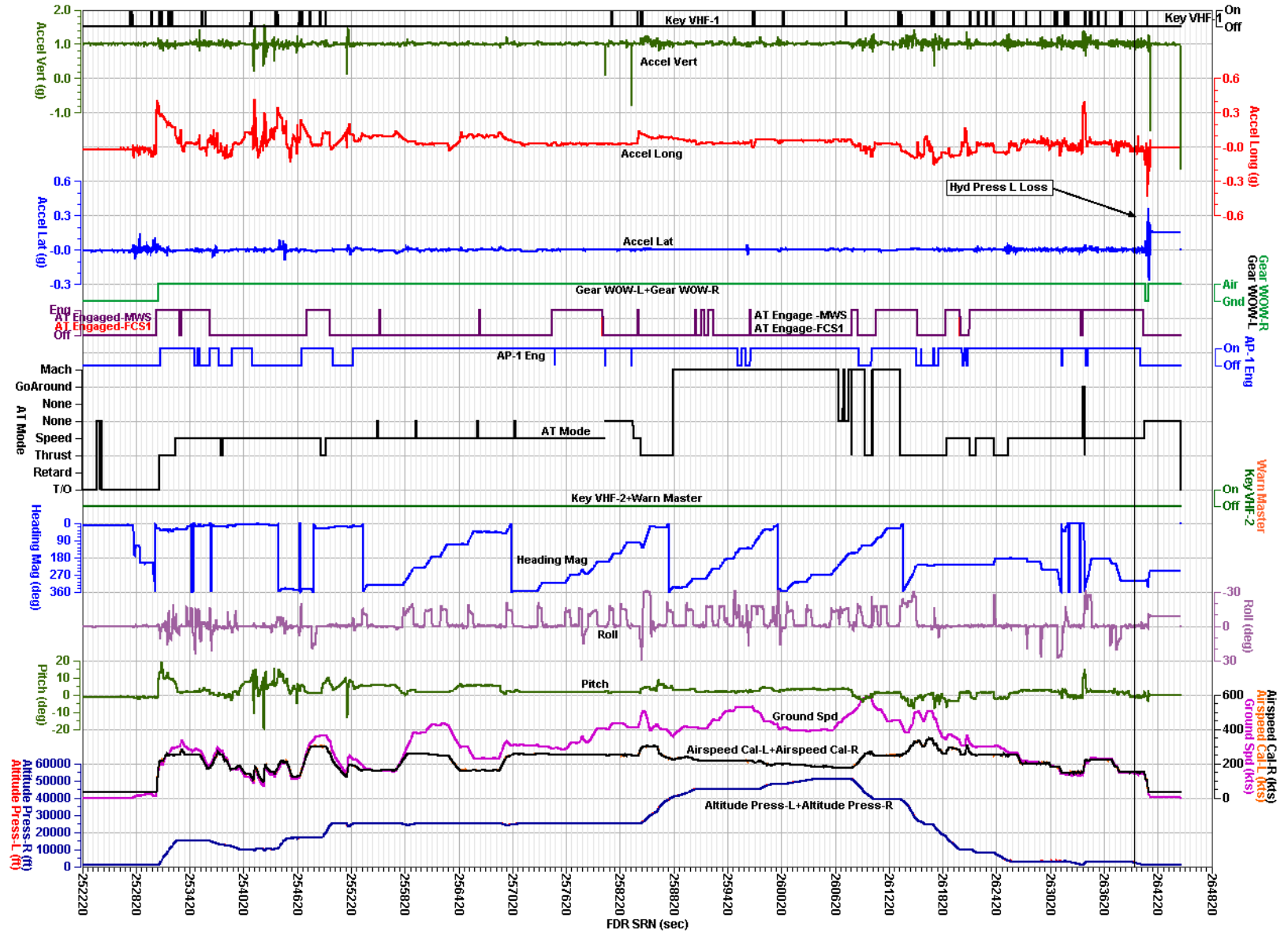

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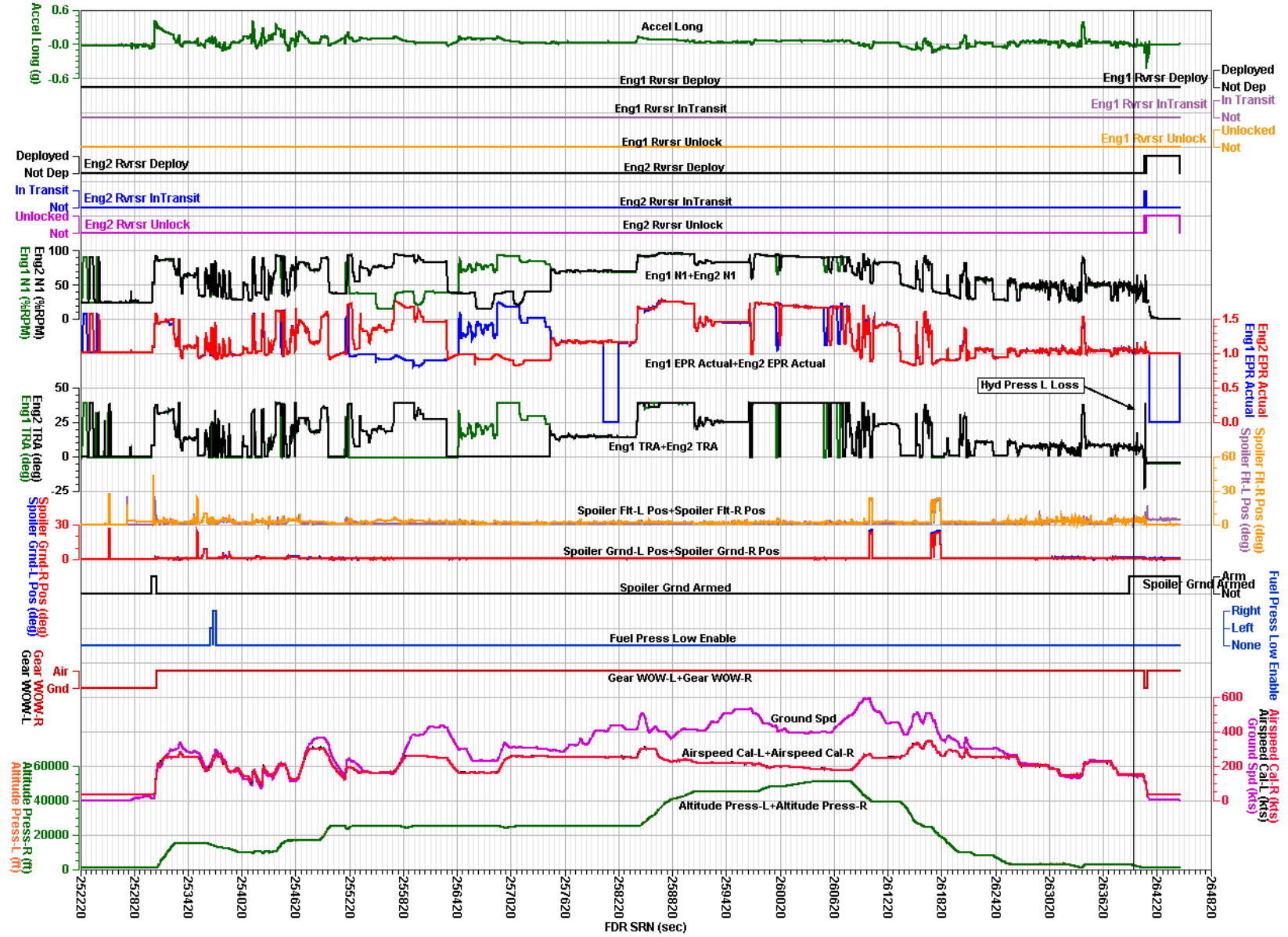
Figure 2. Engine and spoiler parameters during entire flight.



Revised: 27 April 2012 | Engine/Spoilers Parameters-Entire Flight | National Transportation Safety Board

Figure 3. Hydraulic and brake parameters during entire flight.

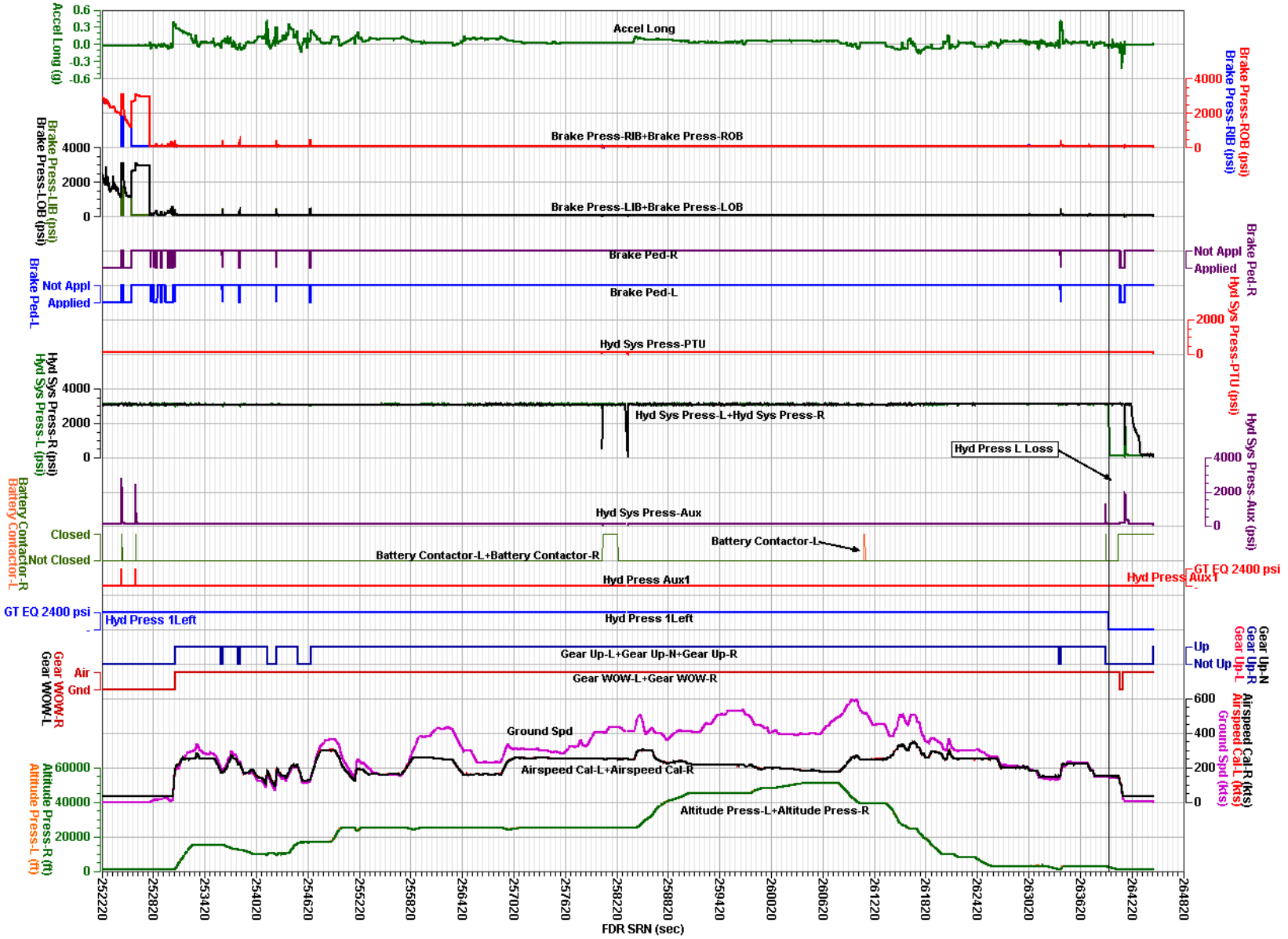


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Figure 4. Control surface parameters during entire flight.

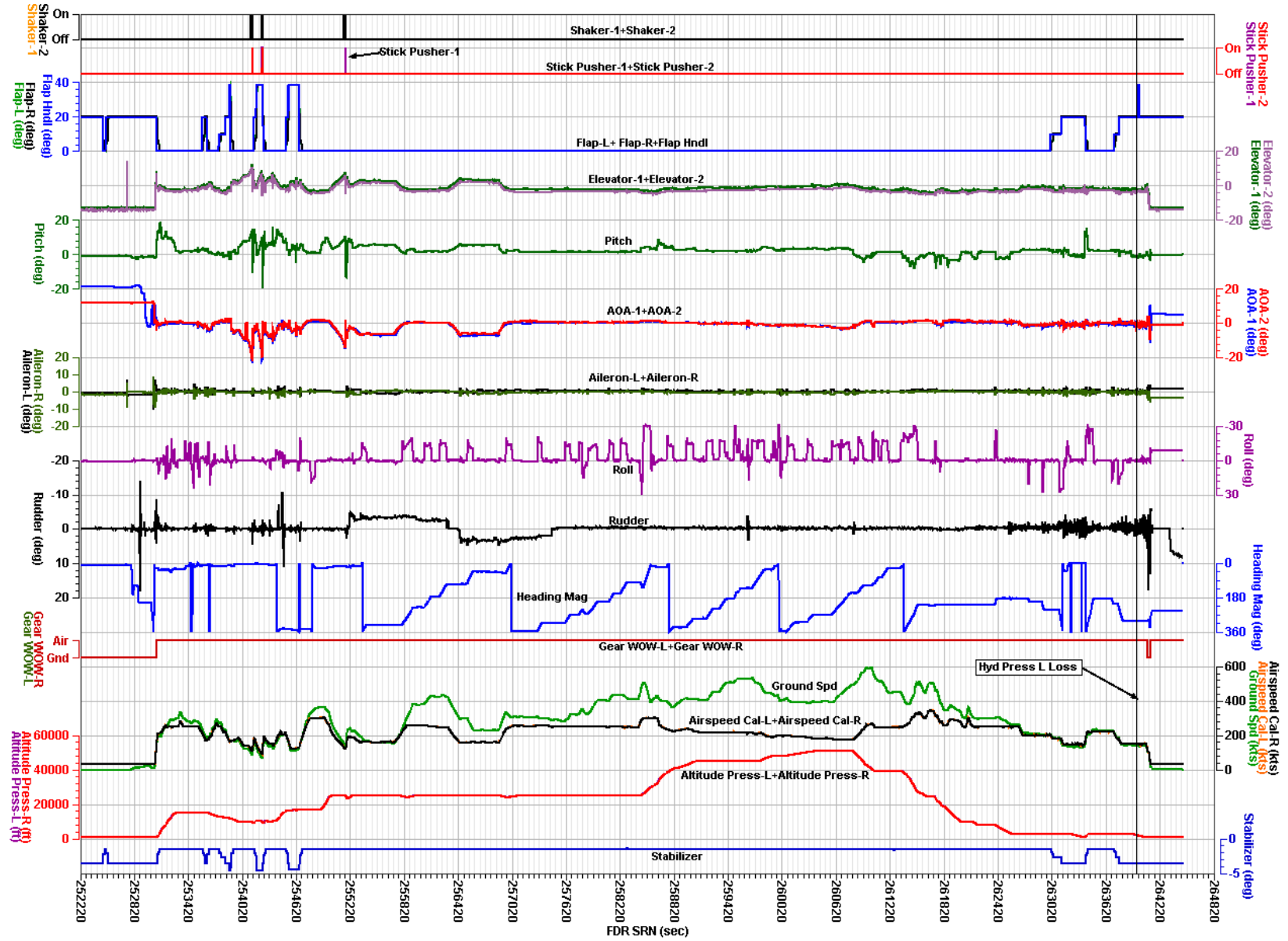

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Figure 5. Basic parameters during approach to landing.

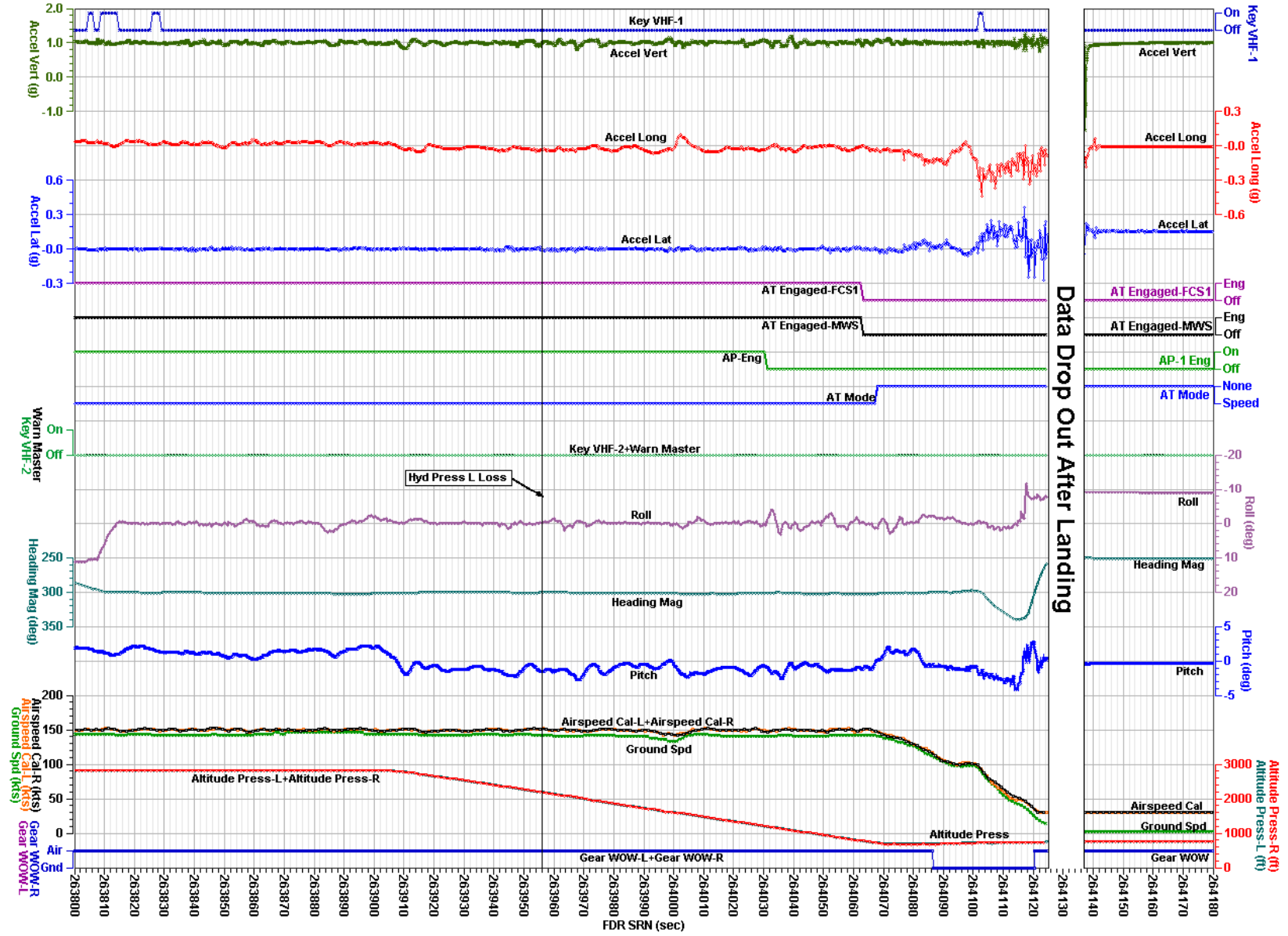

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Figure 6. Engine and spoiler parameters during approach to landing.

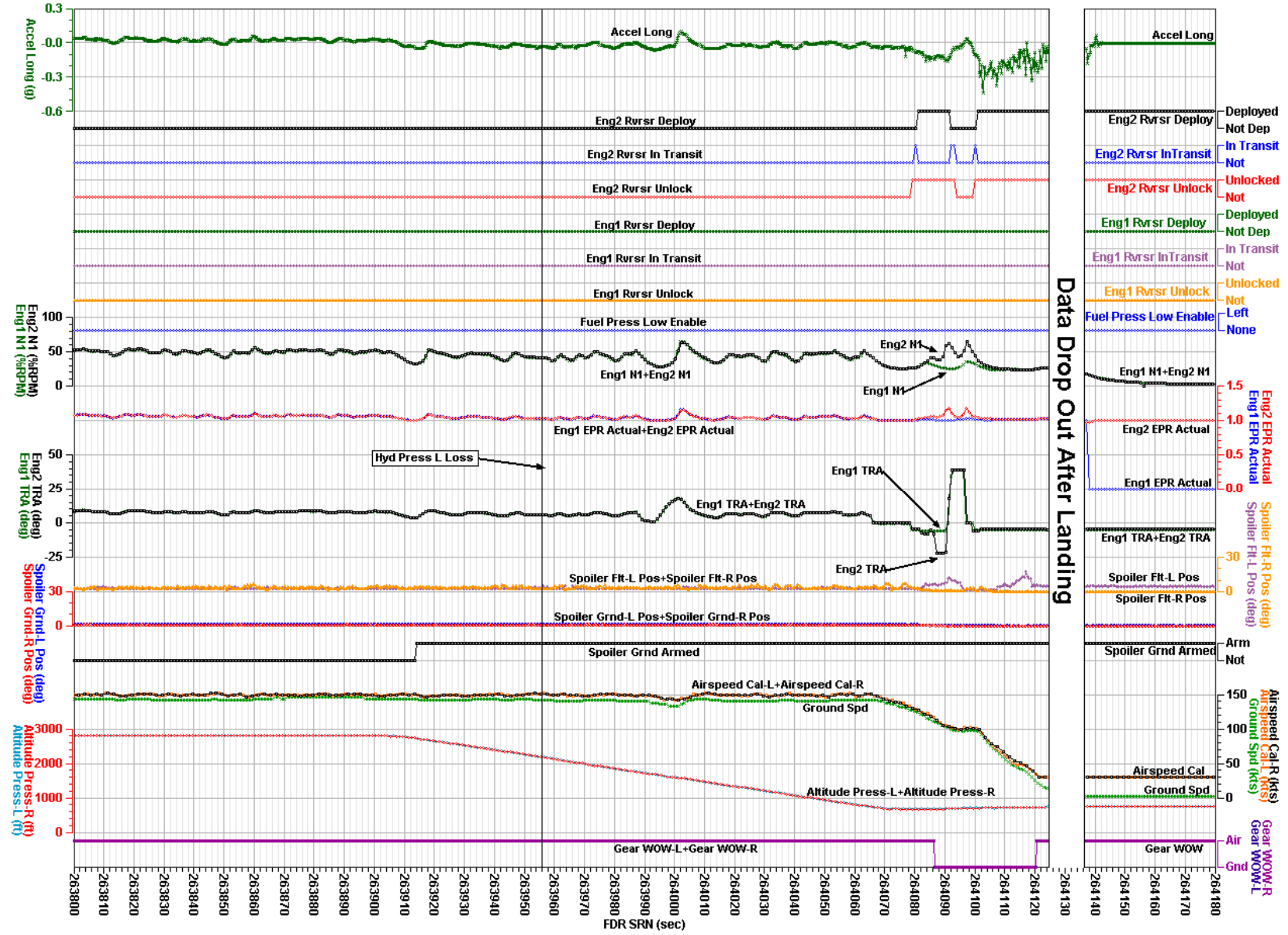

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Figure 7. Hydraulic and brake parameters during approach to landing.

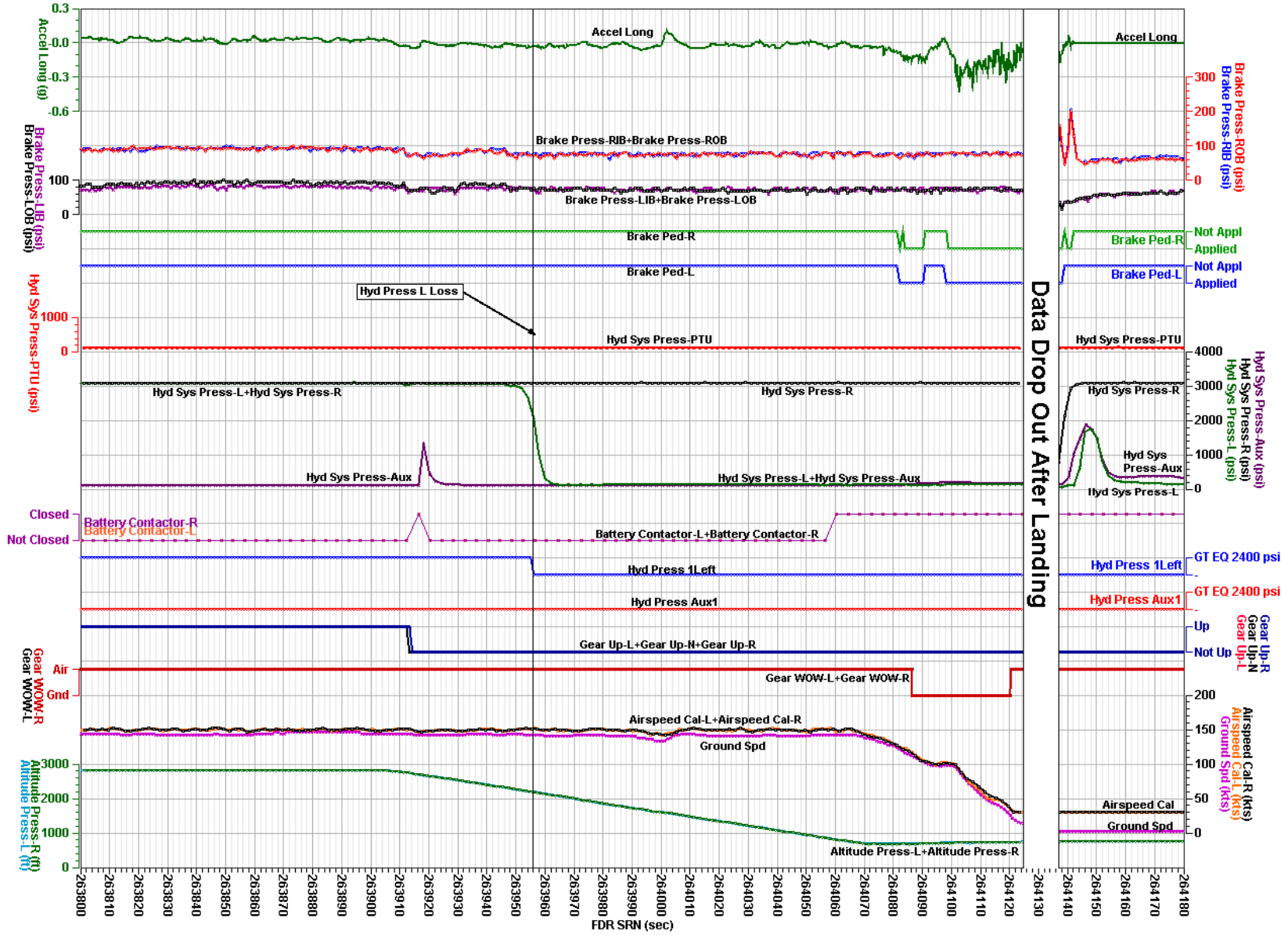

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Figure 8. Control surface parameters during approach to landing.

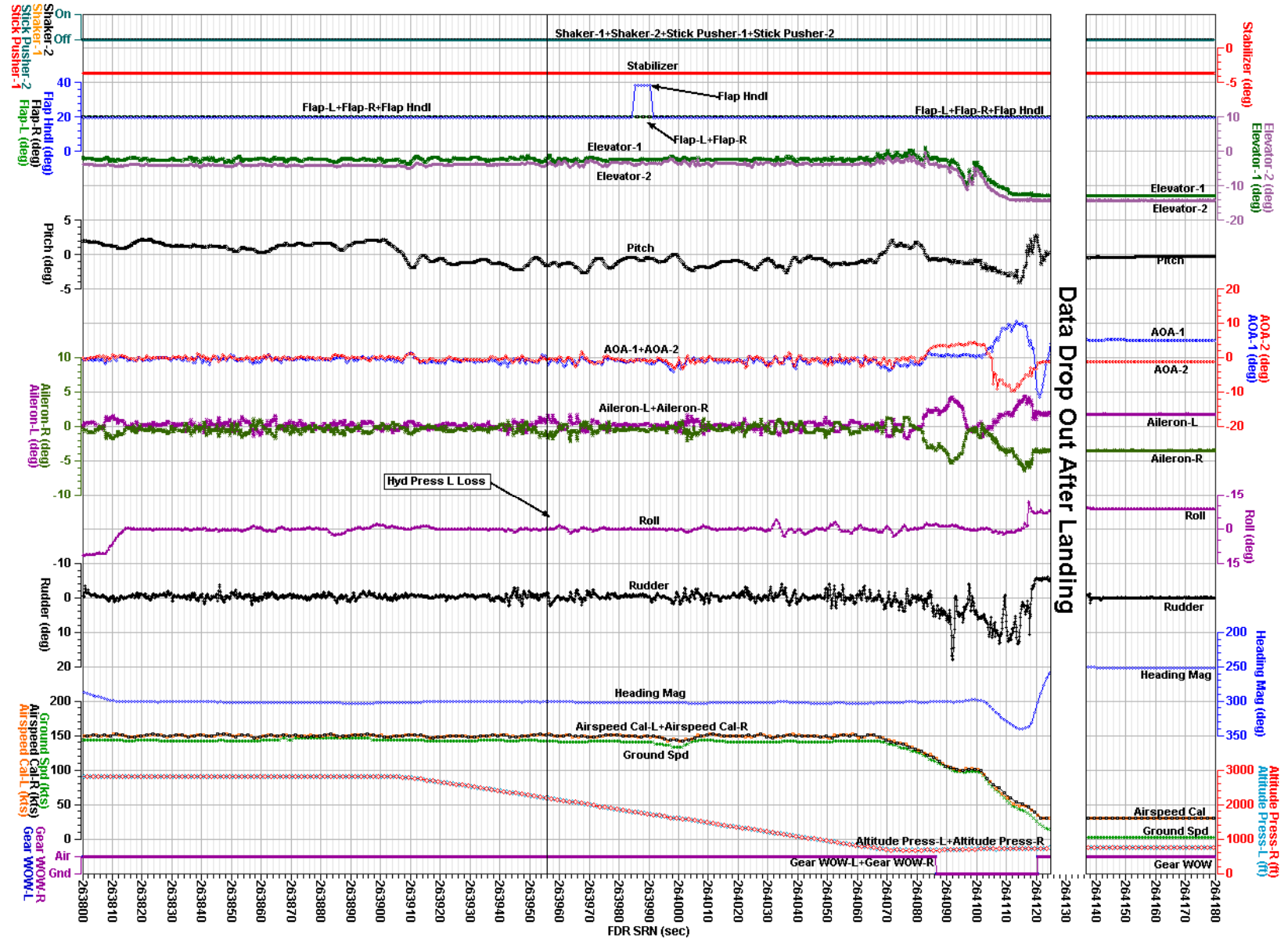

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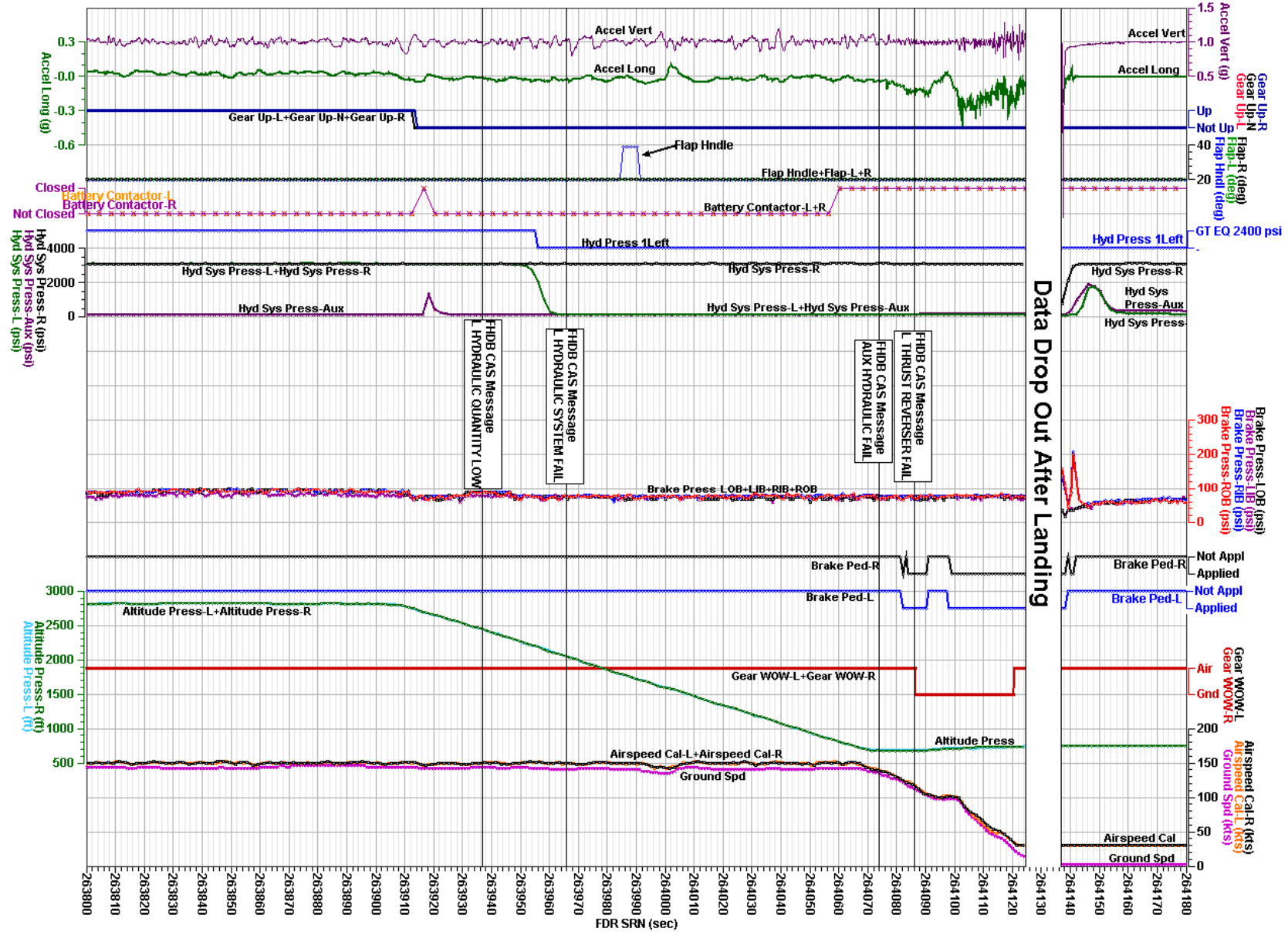
Figure 9. Select parameters and select FHDB messages during approach to landing.



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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 and discrete state abbreviations used in this report.

Table A-1. Verified and provided FDR parameters.

Parameter Name	Parameter Description
1. Accel Lat (g)	Lateral Acceleration
2. Accel Long (g)	Longitudinal Acceleration
3. Accel Vert (g)	Vertical Acceleration
4. Aileron-L (deg)	Left Aileron Position
5. Aileron-R (deg)	Right Aileron Position
6. Airspeed Cal-L (kts)	Left Calibrated Airspeed
7. Airspeed Cal-R (kts)	Right Calibrated Airspeed
8. Altitude Press-L (ft)	Left Pressure Altitude
9. Altitude Press-R (ft)	Right Pressure Altitude
10. AOA-1 (deg)	Angle of Attack-1
11. AOA-2 (deg)	Angle of Attack-2
12. AP-1 Eng (discrete)	Autopilot 1 Engage
13. AT Engaged-FCS1 (discrete)	Auto Throttle Engaged-Flight Control System 1
14. AT Engaged-MWS (discrete)	Auto Throttle Engaged-Monitor Warning System
15. AT Mode (discrete)	Auto Throttle Mode
16. Battery Contactor-L	Left Battery Contactor
17. Battery Contactor-R	Right Battery Contactor
18. Brake Ped-L (discrete)	Left Brake Pedal
19. Brake Ped-R (discrete)	Right Brake Pedal
20. Brake Press-LIB (psi)	Left Inboard Brake Pressure
21. Brake Press-LOB (psi)	Left Outboard Brake Pressure
22. Brake Press-RIB (psi)	Right Inboard Brake Pressure
23. Brake Press-ROB (psi)	Right Outboard Brake Pressure
24. Elevator-1 (deg)	Elevator-1 Position
25. Elevator-2 (deg)	Elevator-2 Position
26. Eng1 EPR Actual	Engine 1 Actual Engine Pressure Ratio
27. Eng1 N1 (%RPM)	Engine 1 N1
28. Eng1 Rvrsr Deploy (discrete)	Engine 1 Reverser Deploy
29. Eng1 Rvrsr InTransit (discrete)	Engine 1 Reverser In Transit
30. Eng1 Rvrsr Unlock (discrete)	Engine 1 Reverser Unlock
31. Eng1 TRA (deg)	Engine 1 Throttle Resolver Angle
32. Eng2 EPR Actual	Engine 2 Actual Engine Pressure Ratio
33. Eng2 N1 (%RPM)	Engine 2 N1
34. Eng2 Rvrsr Deploy (discrete)	Engine 2 Reverser Deploy
35. Eng2 Rvrsr InTransit (discrete)	Engine 2 Reverser In Transit
36. Eng2 Rvrsr Unlock (discrete)	Engine 2 Reverser Unlock
37. Eng2 TRA (deg)	Engine 2 Throttle Resolver Angle
38. Flap Hndl (deg)	Flap Handle Position
39. Flap-L (deg)	Left Flap Position

Parameter Name	Parameter Description
40. Flap-R (deg)	Right Flap Position
41. Fuel Press Low Enable (discrete)	Fuel Pressure Low Enable
42. Gear Up-L (discrete)	Left Gear Up
43. Gear Up-N (discrete)	Nose Gear Up
44. Gear Up-R (discrete)	Right Gear Up
45. Gear WOW-L (discrete)	Gear Weight On Wheels from Left FADEC
46. Gear WOW-R (discrete)	Gear Weight On Wheels from Right FADEC
47. Ground Spd (kts)	Ground Speed
48. Heading Mag (deg)	Magnetic Heading
49. Hyd Press 1Left (discrete)	Hydraulic Pressure 1 Left
50. Hyd Press Aux1 (discrete)	Hydraulic Pressure Auxiliary 1
51. Hyd Sys Press-Aux (psi)	Hydraulic System Pressure Auxiliary
52. Hyd Sys Press-L	Left Hydraulic System Pressure
53. Hyd Sys Press-PTU	Power Transfer Unit Hydraulic System Pressure
54. Hyd Sys Press-R	Right Hydraulic System Pressure
55. Key VHF-1 (discrete)	VHF-1 Keying
56. Key VHF-2 (discrete)	VHF-2 Keying
57. Latitude (deg)	Latitude Position
58. Longitude (deg)	Longitude Position
59. Pitch (deg)	Pitch Angle
60. Roll (deg)	Roll Angle
61. Rudder (deg)	Rudder Position
62. Shaker-1 (discrete)	Shaker-1
63. Shaker-2 (discrete)	Shaker-2
64. Spoiler Flt-L Pos (deg)	Left Flight Spoiler Position
65. Spoiler Flt-R Pos (deg)	Right Flight Spoiler Position
66. Spoiler Grnd Armed (discrete)	Ground Spoiler Armed
67. Spoiler Grnd-L Pos (deg)	Left Ground Spoiler Position
68. Spoiler Grnd-R Pos (deg)	Right Ground Spoiler Position
69. Stabilizer (deg)	Horizontal Stabilizer Position
70. Stick Pusher-1 (discrete)	Stick Pusher-1
71. Stick Pusher-2 (discrete)	Stick Pusher-2
72. Time GMT Hrs (hrs)	GMT Hours
73. Time GMT Min (min)	GMT Minutes
74. Time GMT Sec (sec)	GMT Seconds
75. Warn Master	Master Warning

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.

Table A-2. Unit and discrete state abbreviations.

Unit/Discrete Abbreviation	Description
%RPM	percent revolutions per minute
Appl	Applied
deg	degrees
Dep	Deployed

Unit/Discrete Abbreviation	Description
discrete	discrete
Eng	Engaged
ft	feet
g	g
Gnd	Ground
GT EQ	Greater Than or Equal to (≥)
hrs	hours
in	inches
kts	knots
min	minutes
psi	pounds per square inch
sec	seconds

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.