NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

AIRWORTHINESS GROUP FACTUAL REPORT ADDENDUM 4
IN-SERVICE EVALUATION

May 30, 2008

A. ACCIDENT DCA06FA058

Location:	Memphis, Tennessee
Date:	July 28, 2006
Time:	1125 Central Daylight Time (CDT)
Aircraft:	FedEx Express Flight 630, McDonnell-Douglas (Boeing) MD-10-10F, N391FE

B. AIRWORTHINESS GROUP

Chairman:	Clinton R. Crookshanks National Transportation Safety Board Denver, Colorado
Member:	Steve Cole FedEx Memphis, Tennessee
Member:	Vikki Anderson Federal Aviation Administration Washington, District of Columbia
Member:	Joe Bracken Air Line Pilots Association Herndon, Virginia
Member:	Neal Gilleran The Boeing Company Long Beach, California

Member: Sunil Jinadasa
The Boeing Company
Long Beach, California

C. DETAILS OF THE INVESTIGATION

1.0 Overview

The Airworthiness Group proposed an In-Service Evaluation (ISE) of the main landing gear (MLG) loads on a FedEx MD-10-10F airplane similar to the accident airplane. The main purpose of the evaluation was to accurately determine the loads imparted to the MLG during the landing sequence and to validate the finite element model of the MLG that was being developed[1]. In October 2006, the group presented FedEx management with a flight test proposal for the in-evaluation and aircraft N357FE was selected as the candidate airplane[2]. The MLG instrumentation was installed on the airplane in December 2006 during a scheduled C-check at the FedEx maintenance facility in Los Angeles, CA. Each landing gear was instrumented with 8 linear strain gages, 3 rosette strain gages, 1 tri-axial accelerometer, and 1 brake pressure transducer. The airplane was instrumented with 1 tri-axial accelerometer near the center-of-gravity, 2 brake pressure transducers, one each on the left and right brake systems, and two string potentiometers, one each on the left and right dual brake control valves (DBCV). All of the data was fed to a recording device in the central avionics compartment where it was recorded at 200 Hz. The airplane was routed through Memphis periodically so that the data card could be swapped out and downloaded. The airplane entered revenue service on January 5, 2007 and continued gathering data until May 17, 2007.

2.0 Calibration

Prior to the airplane being released for revenue service, the instrumentation was calibrated according to the procedures outlined in the proposal. Basically, the airplane performed static run ups of the two wing engines to specified N1 percentage settings. At each setting the recording equipment was activated for several seconds to capture the strain, pressure and acceleration readings. A string potentiometer was temporarily installed on the left MLG for the engine runs in order to measure the strut extension. After the engine runs the airplane was jacked up so that the struts were fully extended and there was no weight on the wheels. The recording equipment was activated for several seconds to obtain the no-load reading for all of the instrumentation. This zero offset value for the strain gages was used to adjust the in-service strain values since the gages were installed while the airplane was resting on its wheels.

3.0 Data Gathering and Reduction

During the four plus months of data gathering the instrumentation recorded 314 revenue flights and 4 special test flights, and the data was downloaded 13 times[3]. The flight log lists the

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[1] See the Airworthiness Group Factual Report Addendum 6 – Finite Element Model for the details.
[2] See Attachment 1 to this report for the flight test proposal.
[3] See Attachment 2 to this report for the flight log.

following parameters by column:

1. FLT Count – Incremental count of the total number of flights not including the test flights after the instrumentation was installed or the special test flights on March 29. Only those flights where data was recorded are counted.
2. LNDG Count – Incremental count of the flights where valid landing data was obtained and used for the analysis.
3. BRKG Count – Incremental count of the flights where valid braking data was obtained and used for the analysis.
4. Flight ID – Number assigned for file identification purposes.
5. FLT No. – FedEx flight number.
6. Blank – Flight leg for continuing flights.
7. Date – The date the flight occurred.
8. ORIG – Origination point of the flight.
9. DEST – Destination point of the flight.
10. ZULU – Coordinated Universal time of the landing.
11. CST – Time converted to Central Standard Time.
12. FLT TIME HRS – Flight time in hours and minutes.
13. Braking, S,U,E – Relative appearance of the brake pedal data; Symmetric, Unsymmetric, or Erratic.
14. Braking, L Level – Brake pressure level; L 0-600psi, M 600-1200 psi, H 1200-1800 psi.
15. Braking, R Level – Brake pressure level; L 0-600psi, M 600-1200 psi, H 1200-1800 psi.
16. Bad Parameter – Sensors producing erroneous data.
17. Comments – Notable comments about the data.

In addition to the instrumentation data, the group received the flight data recorded by the airplane Auxiliary Data Acquisition System (ADAS). Within about 5 days of each download the data was in the hands of the group for analysis. During a look at the first set of data it was noted that the trigger to the recording system was not operating as expected. The data acquisition began after the airplane had touched down and began braking. The triggering signal was taken from the airplane ADAS and was initially set to activate when the radio altitude on the approach reached 50 feet. On January 23, 2007, after two data downloads, the trigger was set to activate the recording system at a radio altitude of 300 feet. A look at the third and fourth sets of data revealed that the trigger point was still off, some flights would capture the touchdown and some would not. On February 6, the trigger point was set to a radio altitude of 600 feet, where it remained for the duration of the ISE. Due to this triggering issue, the group elected not to include the first two downloaded data sets in the analysis. Data sets 3 through 5 still had some triggering issues so the group elected to use only those flights where valid data was recorded for the analysis of the braking and landing loads. Data sets 6 through 13 were used for both the landing and braking analysis since these data sets captured both. The special test flights were not included in either analysis. In the end, 266 flights were included in the braking analysis and 237 flights were included in the landing analysis.

Boeing was tasked with using the airplane data from the ADAS to determine, at the time of touchdown, gross weight, sink rate, and pitch angle. Due to the excessive amount of time to document these parameters and the limited use of them, this was discontinued after the 8th download on March 9.

Within the first month of acquiring data, the data for P3 and LL2 was erroneous. P3 was the pressure transducer on the RMLG and was deemed to be an important parameter. Since there were so many strain gages installed and due to the brittle nature of the gages, loss of strain gages was expected during the evaluation period. On February 12, the airplane was in Denver as part of its regular schedule so the pressure transducer was repaired. During disassembly of the P3 connector it was noted that the interior of the connector was extensively charred due to the shorting of the power and ground wires. The connector was replaced and the system checked out. On March 14, 2007, the data for P4, the pressure on the LMLG went bad and remained that way until the end of the evaluation. By the end of the evaluation period at least 6 strain gages, one pressure gage, and three accelerometer channels were providing inaccurate data.

On 3 occasions, the airplane returned to the gate for unknown reasons and no data was recorded. In two of the cases, flight 329 on January 6 and flight 3153 on February 2, the airplane departed a second time on the same date and completed the original flight number. In the third case, flight 533 on February 17, the airplane departed one-day later and completed flight 593. On 6 occasions a flight was completed yet there was no data for the flight on the data card due to unknown reasons. The flights where this happened were flight 593 on February 18, flight 906 on March 30, flight 1256 on March 31, flight 693 on May 9, flight 1704 on May 17, and flight 625 on May 17.

In 10 instances the system recorded data but some or all of the data was not usable for the reasons listed below.

1. Flight 3852, February 7, ID 3.07 – The system stopped recording at about 38 seconds elapsed time. Valid touchdown data was captured but valid braking data was not.
2. Flight 621, February 9, ID 3.15 – The system stopped recording at about 19 seconds elapsed time. Valid touchdown data was captured but valid braking data was not.
3. Flight 904, March 7, ID 6.21 - The system stopped recording at about 38 seconds elapsed time. Valid touchdown data was captured but valid braking data was not.
4. Flight 568, March 14, ID 7.15 - The system stopped recording at about 38 seconds elapsed time. Valid touchdown data was captured but valid braking data was not.
5. Flight 1255, March 20, ID 8.04 – The system stopped recording at about 42 seconds elapsed time. Valid landing and braking data was not captured.
6. Flight 1247, March 21, ID 8.08 - The system stopped recording at about 34 seconds elapsed time. Valid touchdown data was captured but valid braking data was not.
7. Flight 1241, April 4, ID 10.11 – The system stopped recording at about 34 seconds elapsed time. Valid touchdown data was captured but valid braking data was not.
8. Flight 1420, April 5, ID 10.16 – The system triggered late and valid touchdown data was not captured.
9. Flight 2711-a, April 28, ID 12.10 – The system stopped recording at about 16 seconds elapsed time. Valid landing and braking data was not captured.
10. Flight 1426-1, May 4, ID 12.28 – The system stopped recording at about 55 seconds elapsed time. Valid landing and braking data was not captured.

On two occasions the flight crews reported grabbing brakes on the ISE airplane; Flight 3018 on April 6 and flight 1205 on April 7. The brakes system was examined after each report with no faults found.

4.0 In-Service Evaluation Data

Some examples of the data are presented below. For each flight, the brake pedal position, the pressure out of the dual brake control valve (DBCV) going into the Anti-Skid Manifold (ASM), the pressure out of the ASM going into the brake, the L5 strain on the forward side of the MLG opposite the L6 location, and the L6 strain on the aft side of the MLG beneath the air filler valve is plotted versus time for the LH and RH MLG. For most of the flights the brake pedal position and resulting ASM and brake pressures on the LMLG was higher than the RMLG.

Figure 1 shows Flight 910 on February 14 (Flight ID 4.05). This flight is an example of unsymmetric brake application by the flight crew and the resulting pressures and MLG response. Note the initial spike and immediate decrease in the LH brake pressure that indicates activation of the anti-skid feature of the system. The LH brake pressure is classified as medium due to peak pressures in the 600-1200 psi range and the RH brake pressure is classified as light due to peak pressures in the 0-600 psi range. The oscillation in the L5 and L6 strain for both MLG around 15 seconds shows the airplane touchdown and gear response. Note that the L6 data is essentially a mirror image of L5. The positive nature of L5 represents a tension stress on the forward side of the MLG and the negative nature of L6 represents a compressive stress on the aft side of the MLG as expected.

Figure 2 shows Flight 1627 on February 23 (flight ID 5.10). This flight is an example of symmetric brake application by the flight crew and the resulting pressures and MLG response. Note the initial spike and immediate decrease in the LH brake pressure that indicates activation of the anti-skid feature of the system. The same thing to a lesser degree can be seen in the RH brake pressure and there is a lag in the response of the RH brake pressure. The LH and RH brake pressures are classified as medium due to peak pressures in the 600-1200 psi range. The oscillation in the L5 and L6 strain for both MLG around 9 seconds shows the airplane touchdown and gear response. Note the oscillation in the L5 and L6 strain at the point of initial brake application on both the LH and RH MLG.

Figure 3 shows Flight 1728 on March 2 (flight ID 6.05). This flight is an example of erratic brake application by the flight crew and the resulting pressures and MLG response. Note the oscillating nature of the inputs to both brakes that are unsymmetrical. Again, there is an initial spike and immediate decrease in the LH brake pressure that indicates activation of the anti-skid feature of the system. The LH and RH brake pressures are classified as medium due to peak pressures in the 600-1200 psi range. The oscillation in the L5 and L6 strain for both MLG around 17 seconds shows the airplane light touchdown and minimal gear response. The oscillation in the L5 and L6 strains at the point of initial brake application is more pronounced for the RH MLG.

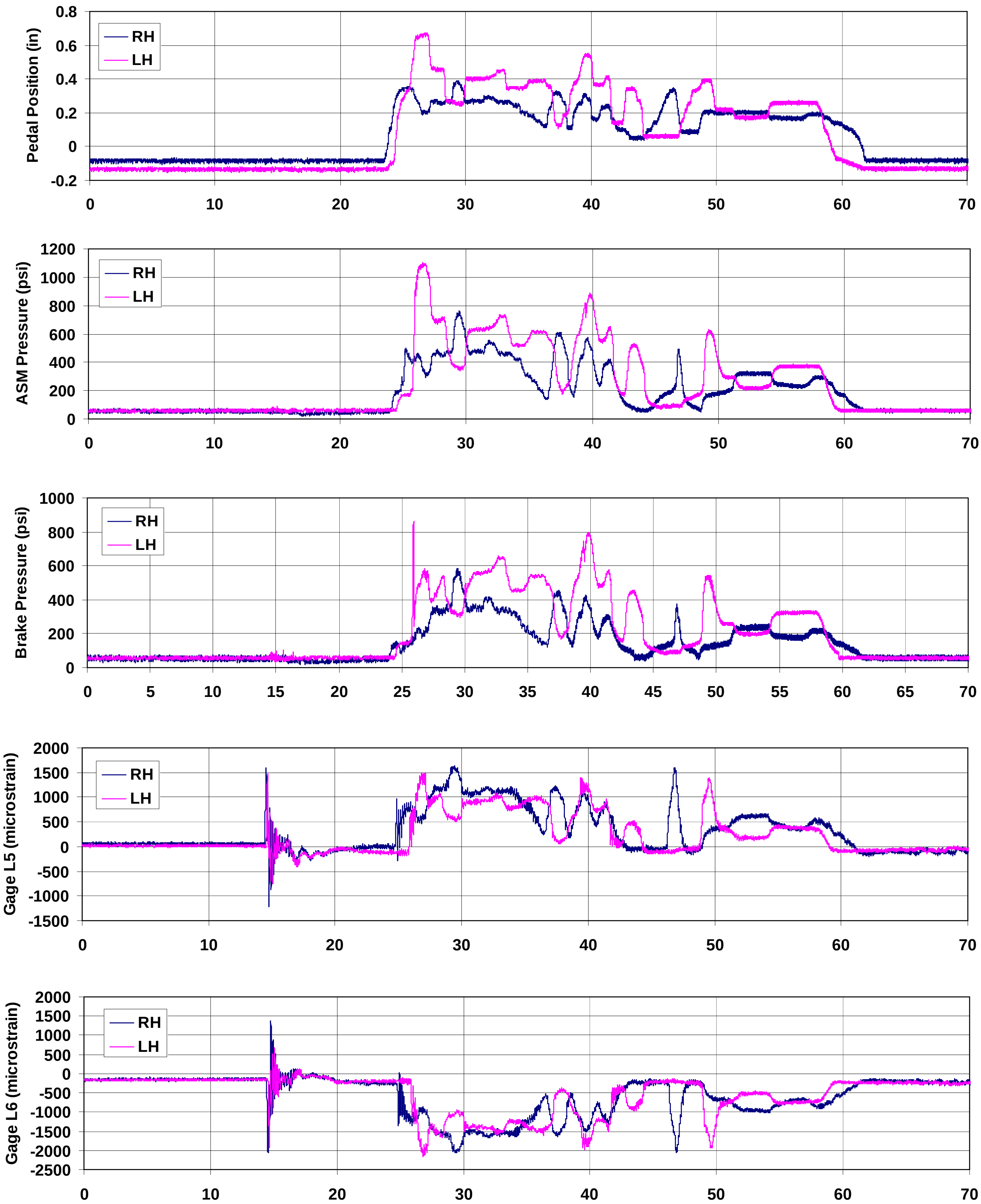

Figure 1 – Flight 910 (Flight ID 4.05)

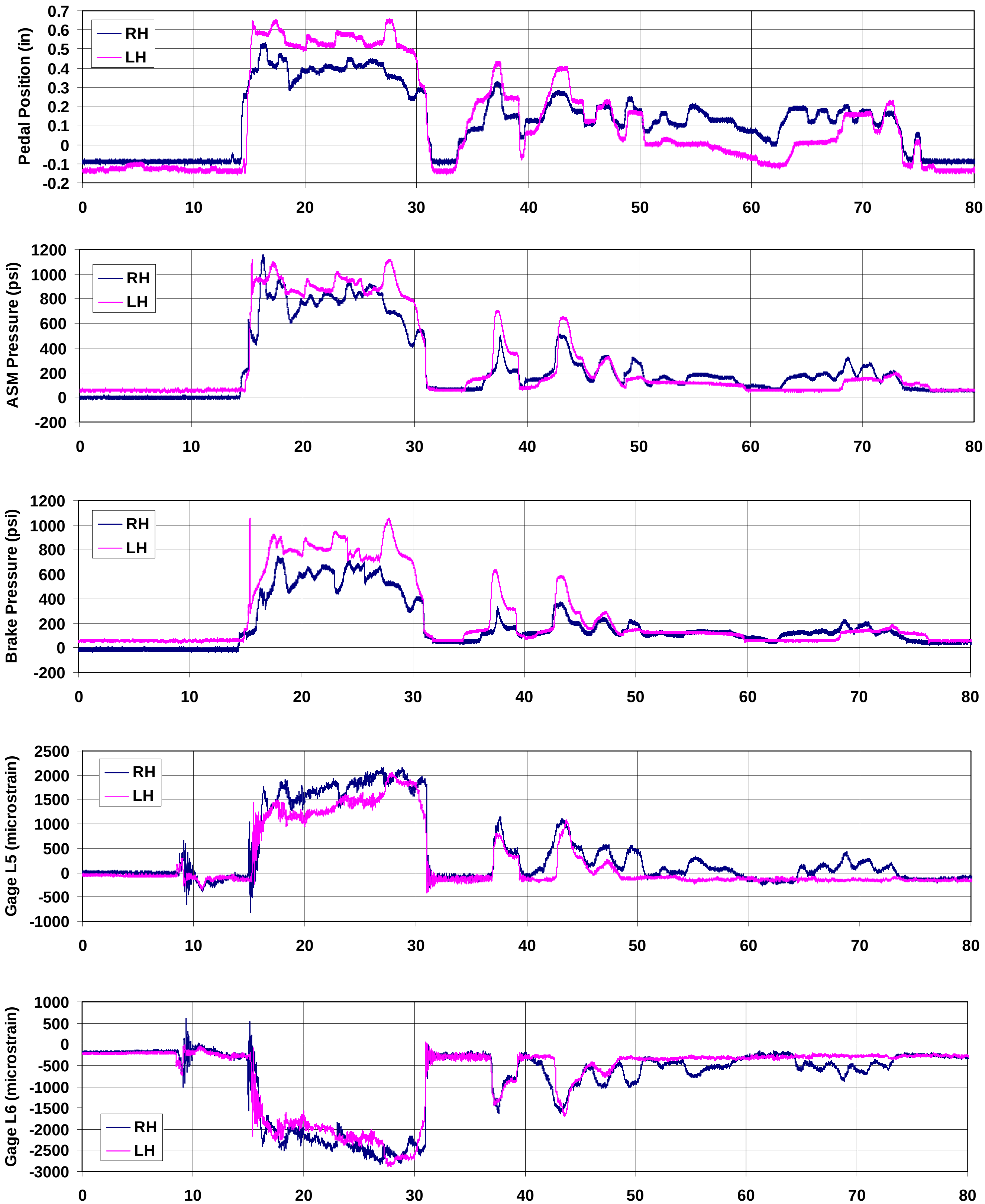

Figure 2 – Flight 1627 (Flight ID 5.10)

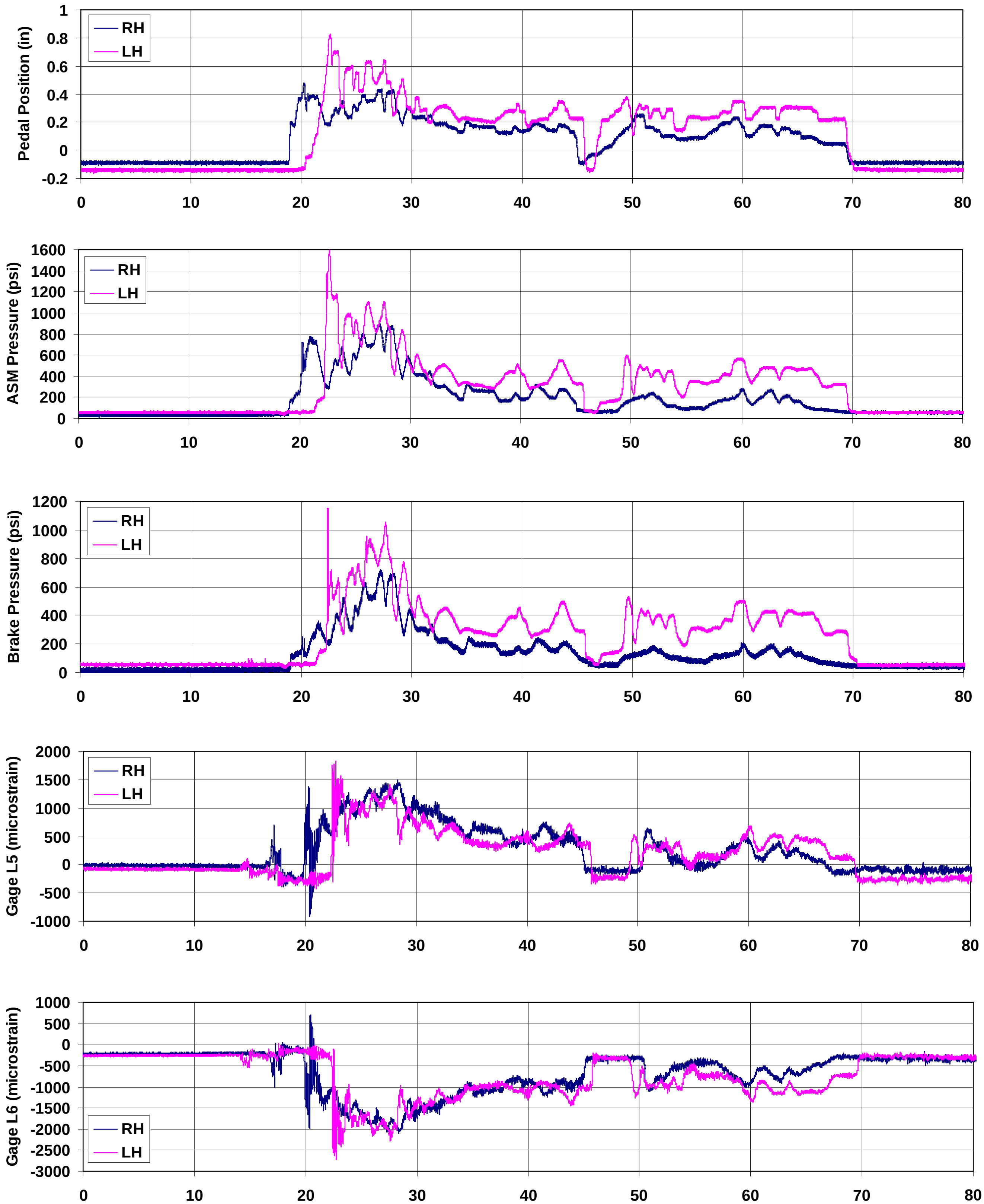

Figure 3 – Flight 1728 (Flight ID 6.05)