NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, DC

November 30, 2006

AIRCRAFT PERFORMANCE STUDY

A. ACCIDENT

Location: Memphis, TN
Date: July 28, 2006
Time: 1125 Central Daylight Time (CDT[1])
Aircraft: Boeing MD-10-10F, N391FE Federal Express
NTSB Accident No.: DCA06FA058

B. GROUP

Chairman: Abdullah Kakar
NTSB, RE-60
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Members: Dave Yingling
The Boeing Company
Long Beach, CA

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Pierre Huggins
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[1] All future time reference will be in CDT unless otherwise specified.

C. SUMMARY

On July 28, 2006, about 1125 central daylight time, FedEx Express (FedEx) flight 630, a Boeing MD-10-10F (MD-10), N391FE, crashed while landing at Memphis International Airport (MEM), Memphis, Tennessee. The left main landing gear collapsed after touchdown on runway 18R, and the airplane came to rest on the runway. After the gear collapsed, a fire developed on the left side of the airplane. The two flight crewmembers received minor injuries during the evacuation, and one non-revenue FedEx pilot was not injured. The post crash fire substantially damaged the airplane's left wing and portions of the left side of the fuselage. Flight 630 departed from Seattle-Tacoma International Airport (SEA), Seattle, Washington, and was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 on an instrument flight rules flight plan.

Data available pertaining to the accident included Flight Data Recorder (FDR), radar data from the Memphis Airport Surveillance Radar (ASR-9) and atmospheric data from the Memphis Automated Surface Observing System (ASOS).

This study used the available data to determine the aircraft's landing performance. The flight's descent rate, and the loads on the left main gear were calculated. Plots of various parameters such as, altitude, speeds, accelerations, and angles were presented to illustrate the findings.

D. RESULTS

The FDR data indicated that the airplane landed with 122 knots (kts) airspeed at time 1124:23. The winds were reported at about 8 kts from the west. At touchdown the descent rate was calculated to be approximately -2 to -3 feet per second (fps) and the drift angle was about -2 degrees (deg), (airplane heading right of ground track). The calculated track angle (direction of flight relative to runway heading) was about 0 deg. About 1.5 seconds after touchdown the track angle increased to 3 deg (tracking to right of runway heading) and then decreased to -2 deg (tracking to left of runway heading) by 1124:28. During this time period the rudder position angle showed a change in deflection angle of approximately 16 deg trailing edge left. At approximately 1124:30 the data indicated that the landing gear began to fail (collapse), which was coincident with the location of the ground scar marks on the runway. Figure 1 is an overlay of the flight's ground track.

Calculations were performed to determine the magnitude of the loads imposed on the left gear during the landing. Comparing the accident flight's data with the previous landing, the longitudinal and vertical loads appeared to be consistent with the exception of the lateral loads. The accident flight data showed that about 1 second after touchdown the lateral load increased to about 0.3 G, which was coincident with the deflection of the rudder mentioned above. The increase in the load was within the design load limits of the landing gear.

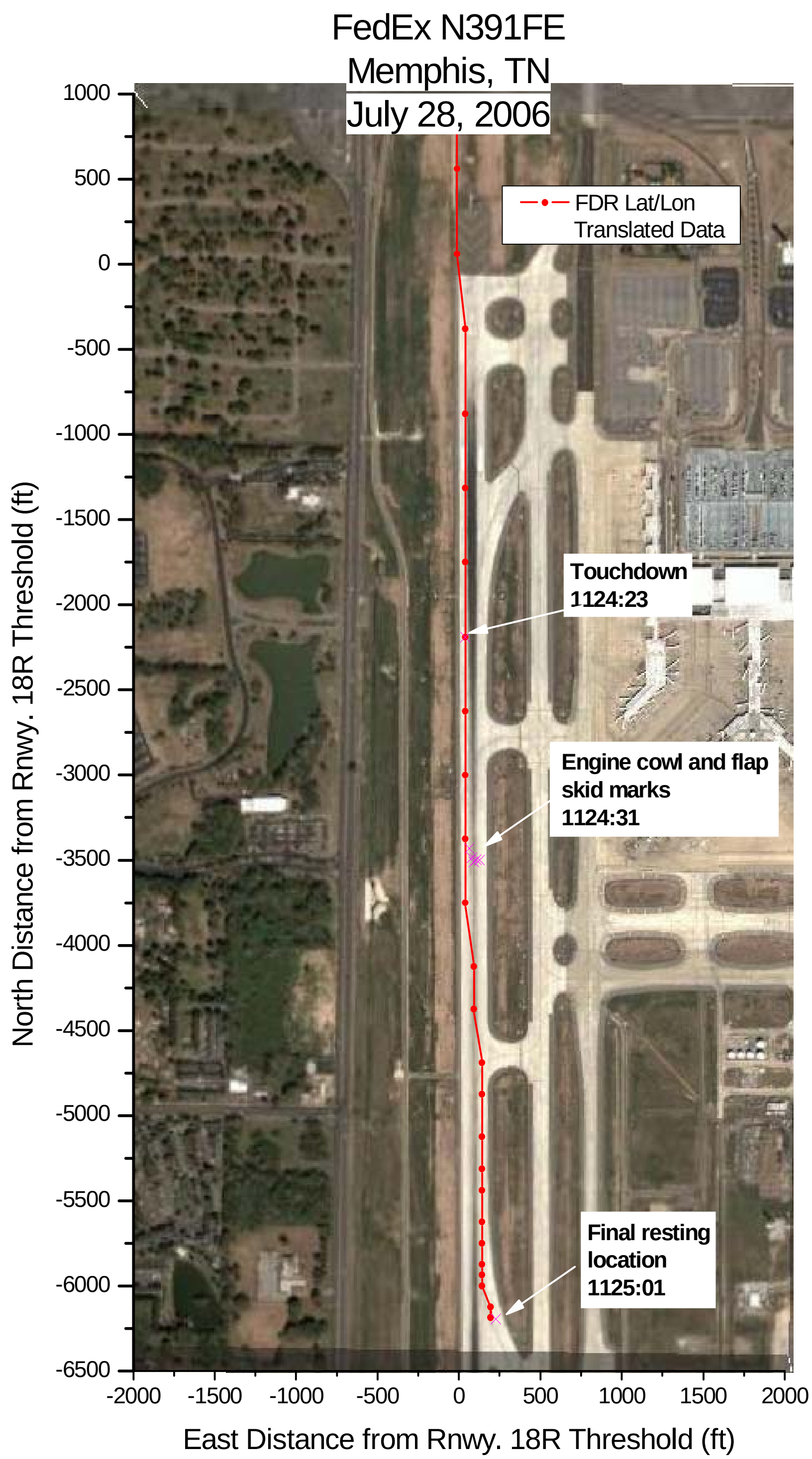

Figure 1. Ground Track Overlay (with key events and time annotations)

E. DETAILS OF INVESTIGATION

1) Time Correlation of Data Sources

The time stamps of the data recorded on the FDR and by the radar were in different time base and format. To use these data sources together their times were synchronized to a common time reference. The pressure altitude data was common to both the FDR and radar data and it was used to perform the correlation of the FDR time to radar time. The FDR altitude time was then shifted to match the radar data or at least fit through the ±50 ft uncertainty bands. The shifting amounted to 95,625 seconds, which was the offset value to correct FDR data to radar time. Equation 1 shows the FDR to CDT time correlation and depicted graphically in figure 2.

11:16:1.93 CDT = 95,625 FDR SRN   eq. 1

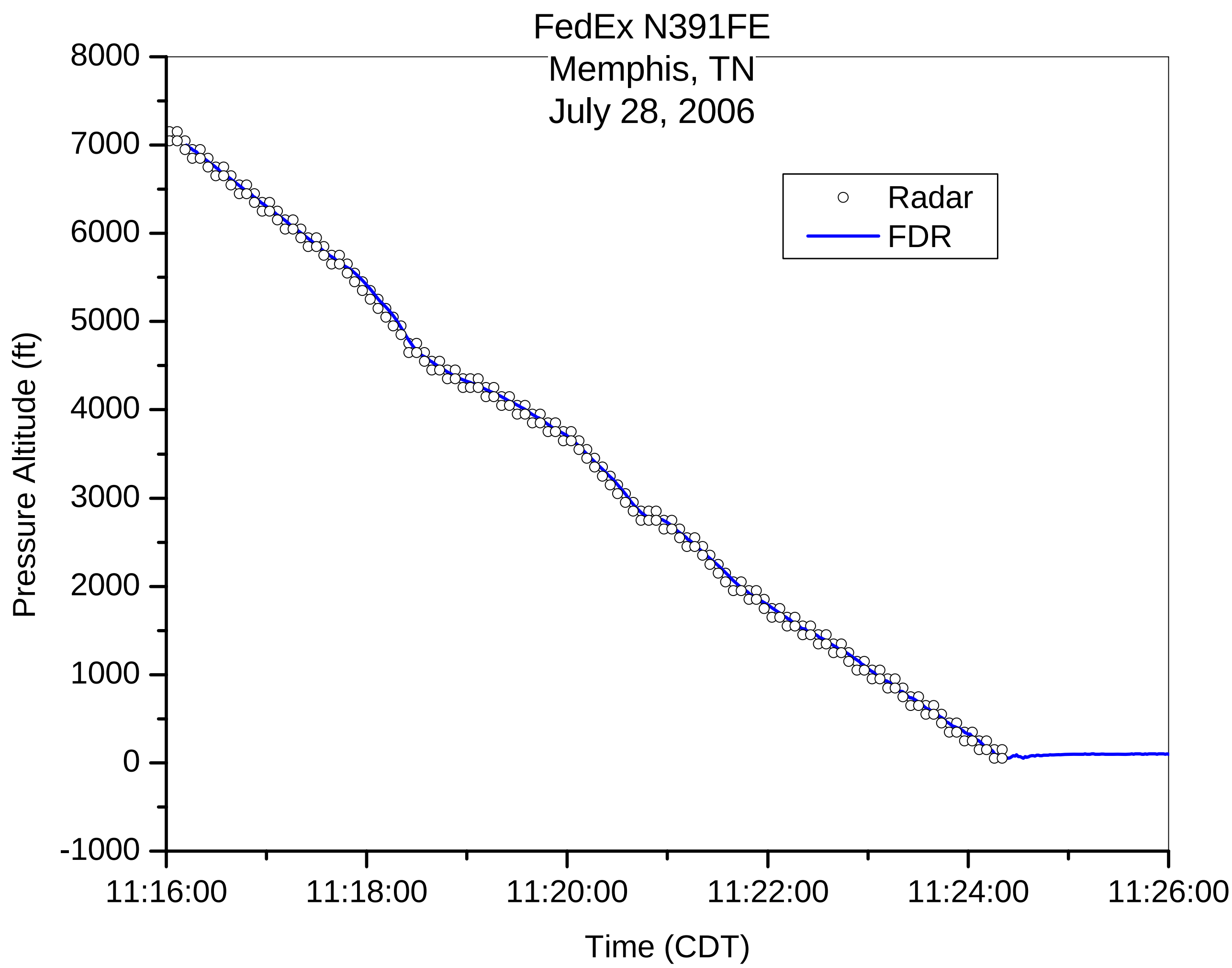

Figure 2. FDR and Radar Time Correlation

2) Data Source

I. Radar Data

The radar data was used as a supplement for this study and included Standard Terminal Automation Replacement System (STARS) data from the MEM ASR-9 radar station located at Memphis Airport, 35 degrees, 01 minute, 19.60 seconds latitude and 089 degrees, 58 minutes, 50 seconds longitude. Beacon code 3776 was assigned to N391FE for identification and tracking purposes. The time range of data used was from 1116:01.3 to 1124:20.4. The ASR-9 antenna has the capability of tracking targets up to 60 nautical miles (nm). The antenna rotates at about 13.0 revolutions per minute therefore providing a status of the range, azimuth, mode C altitude and a time stamp of the returns every 4.6 seconds. The resolution of the range, azimuth, and altitude are, ± 1/16 nm (~ ± 380 ft), ± 0.176 deg, and ± 50 ft, respectively. The MEM radar data is included in table 1A of the appendix.

II. FDR Data

The FDR was the primary source of data for performance calculations. Details of the FDR read-out are explained in the FDR Group Chairman’s Factual report. The relevant FDR data, vertical, lateral, and longitudinal accelerations are shown in figure 3, pitch, roll, heading in figure 4, speed and altitude in figure 5, elevator. rudder and drift angle in figure 6, wind direction and speed in figure 7, and brake pedal position in figure 8. All plots in this report are plotted versus local time unless otherwise specified.

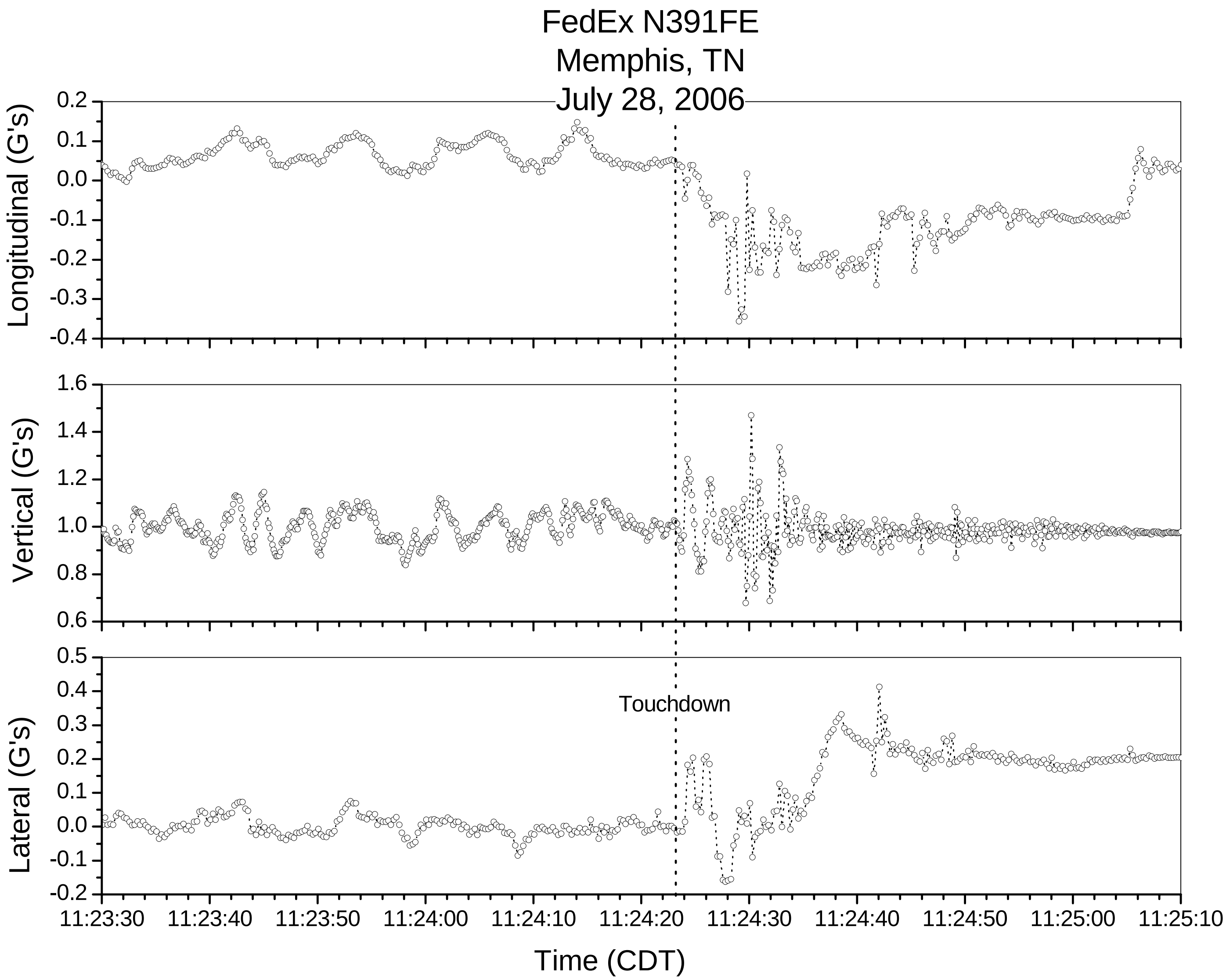

Figure 3. FDR Accelerations

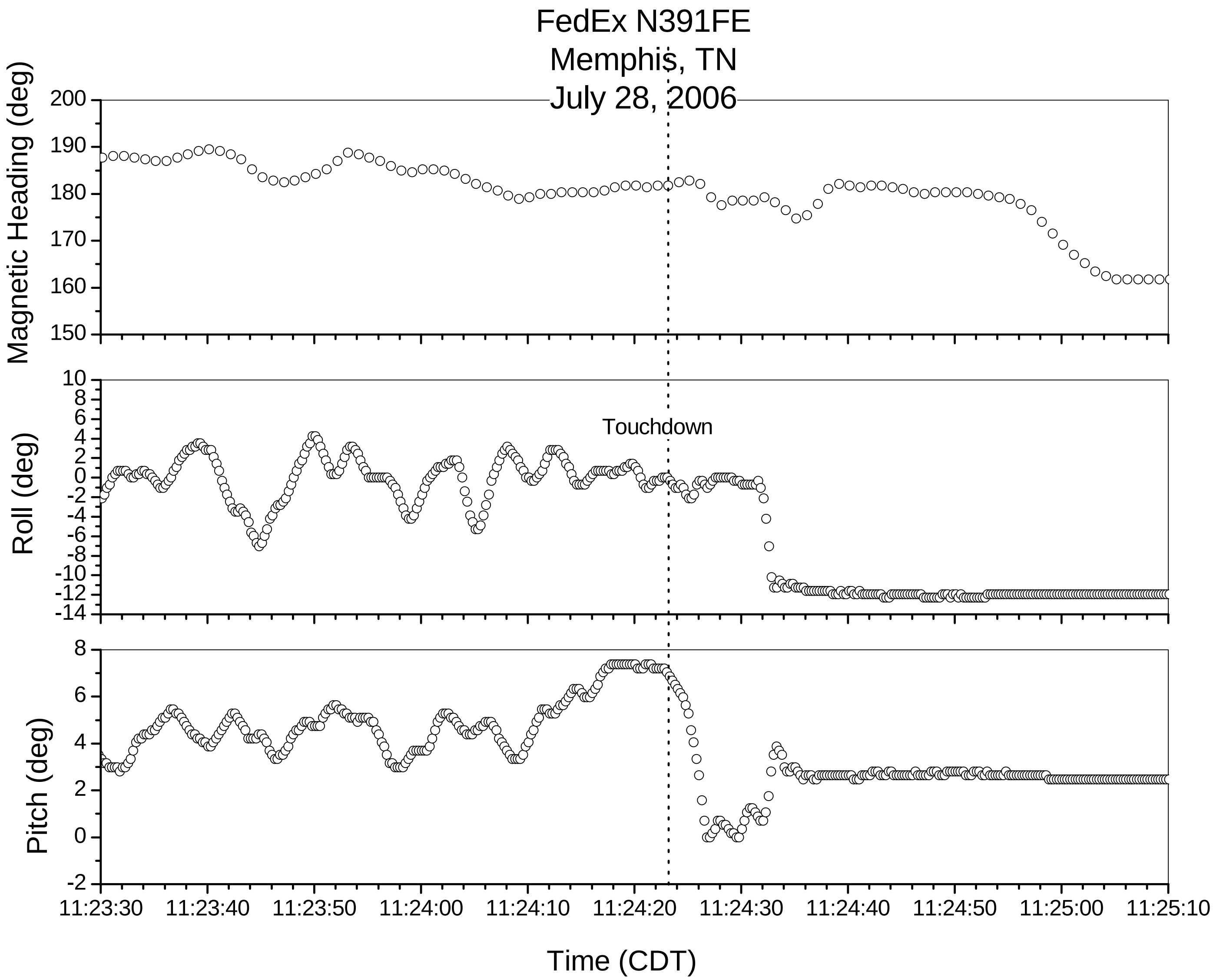

Figure 4. FDR Pitch, Roll, and Heading

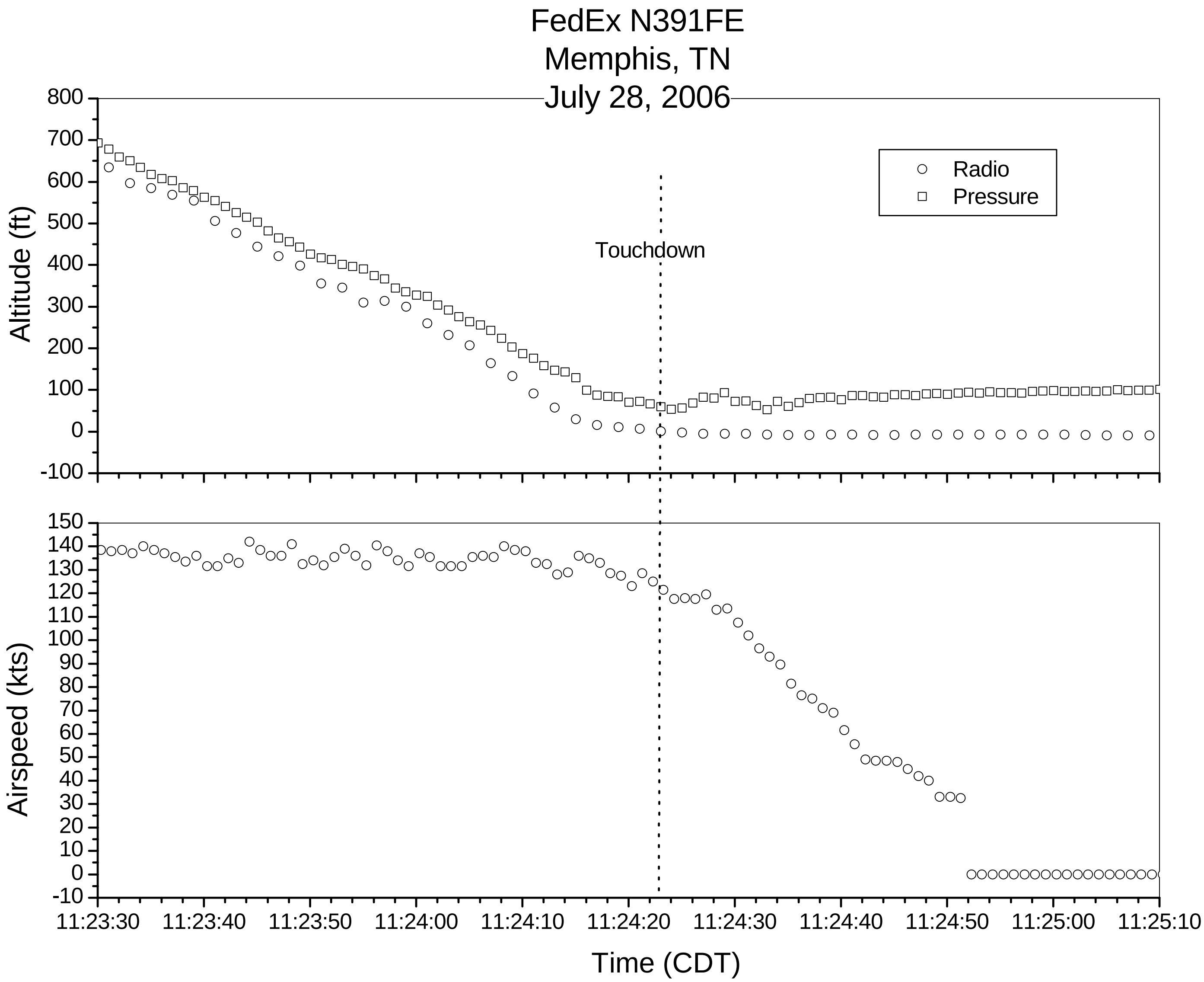

Figure 5. FDR Altitude and Airspeed

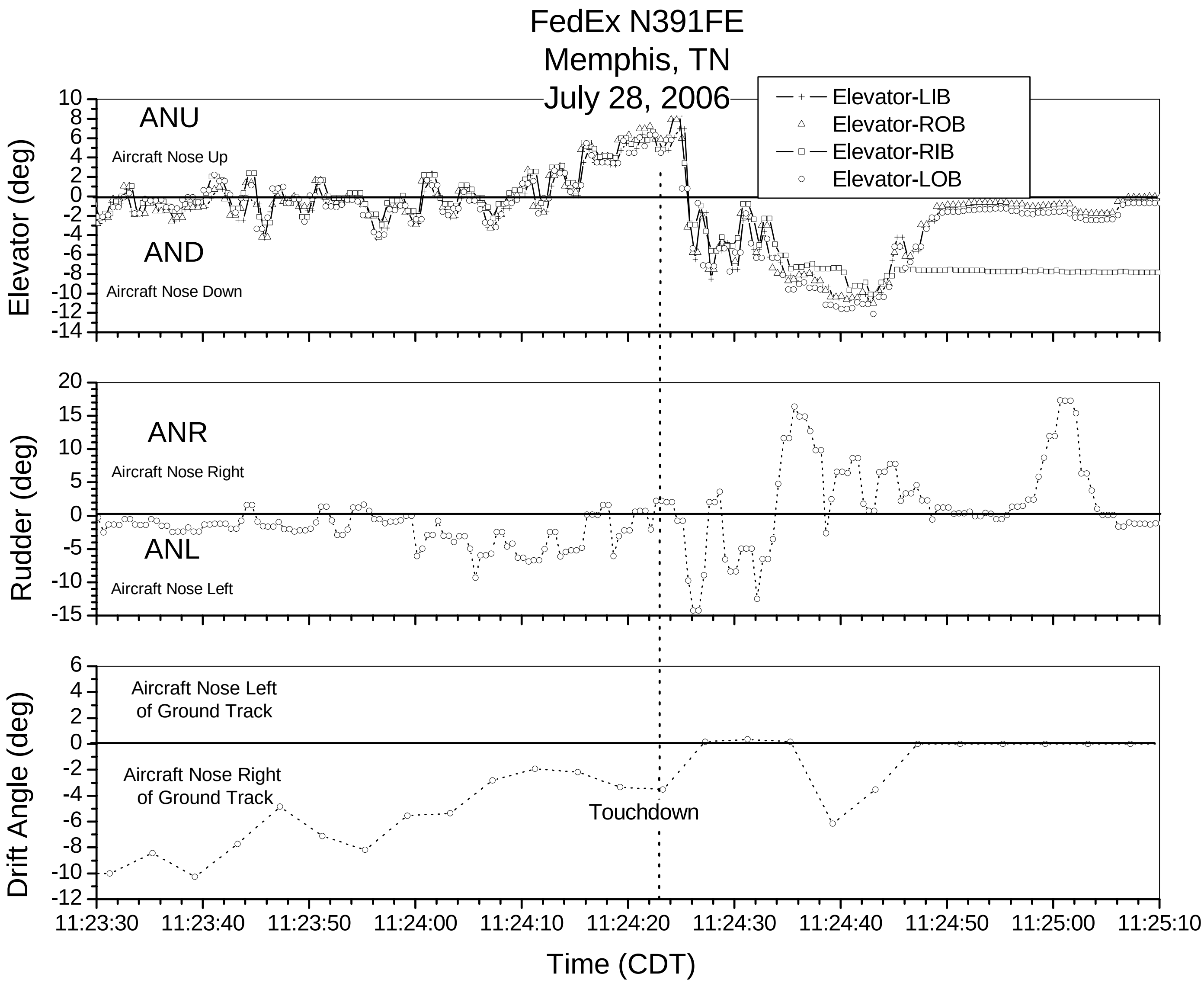

Figure 6. FDR Elevator, Rudder and Drift Angle

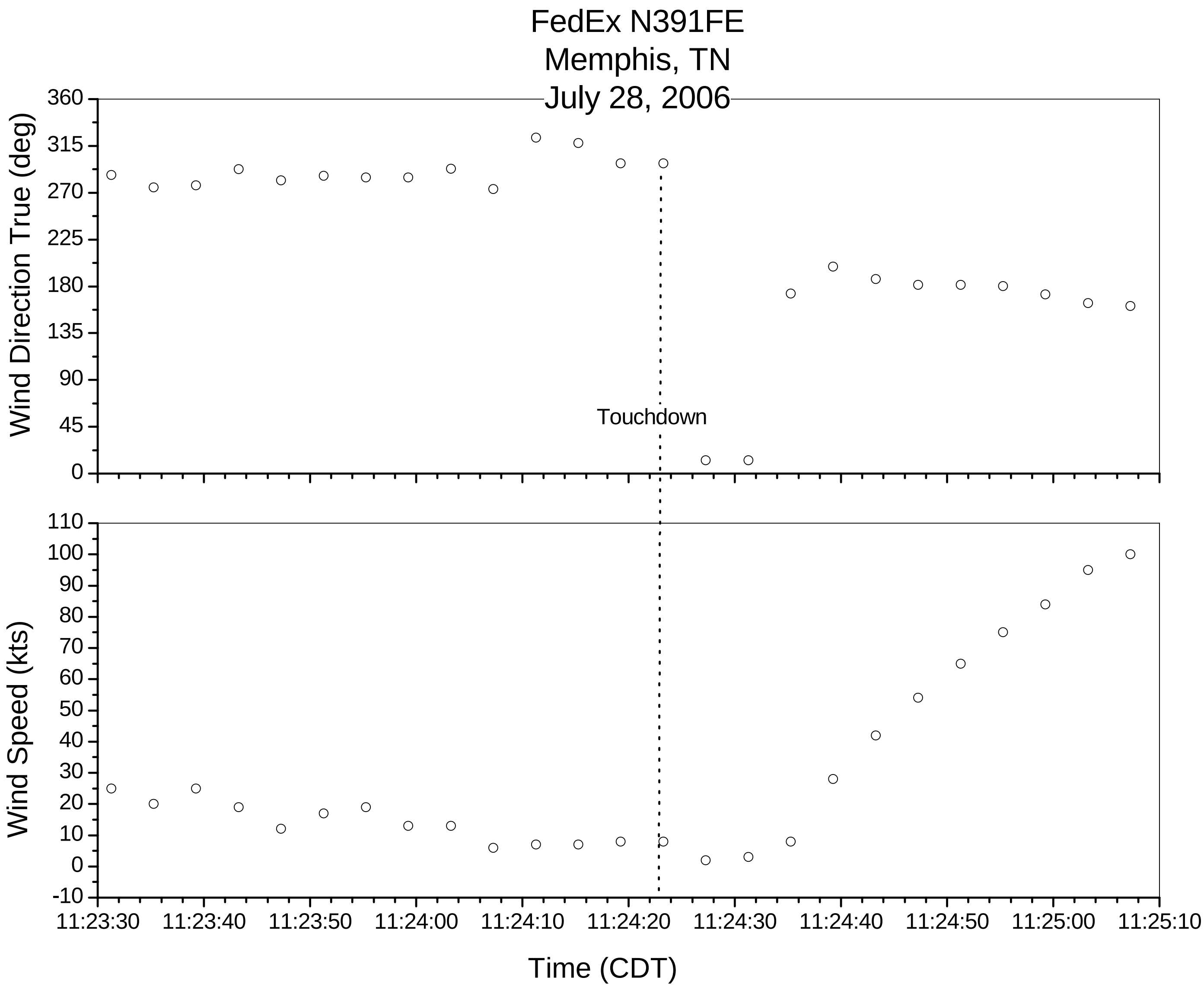

Figure 7. FDR Wind Speed and Direction

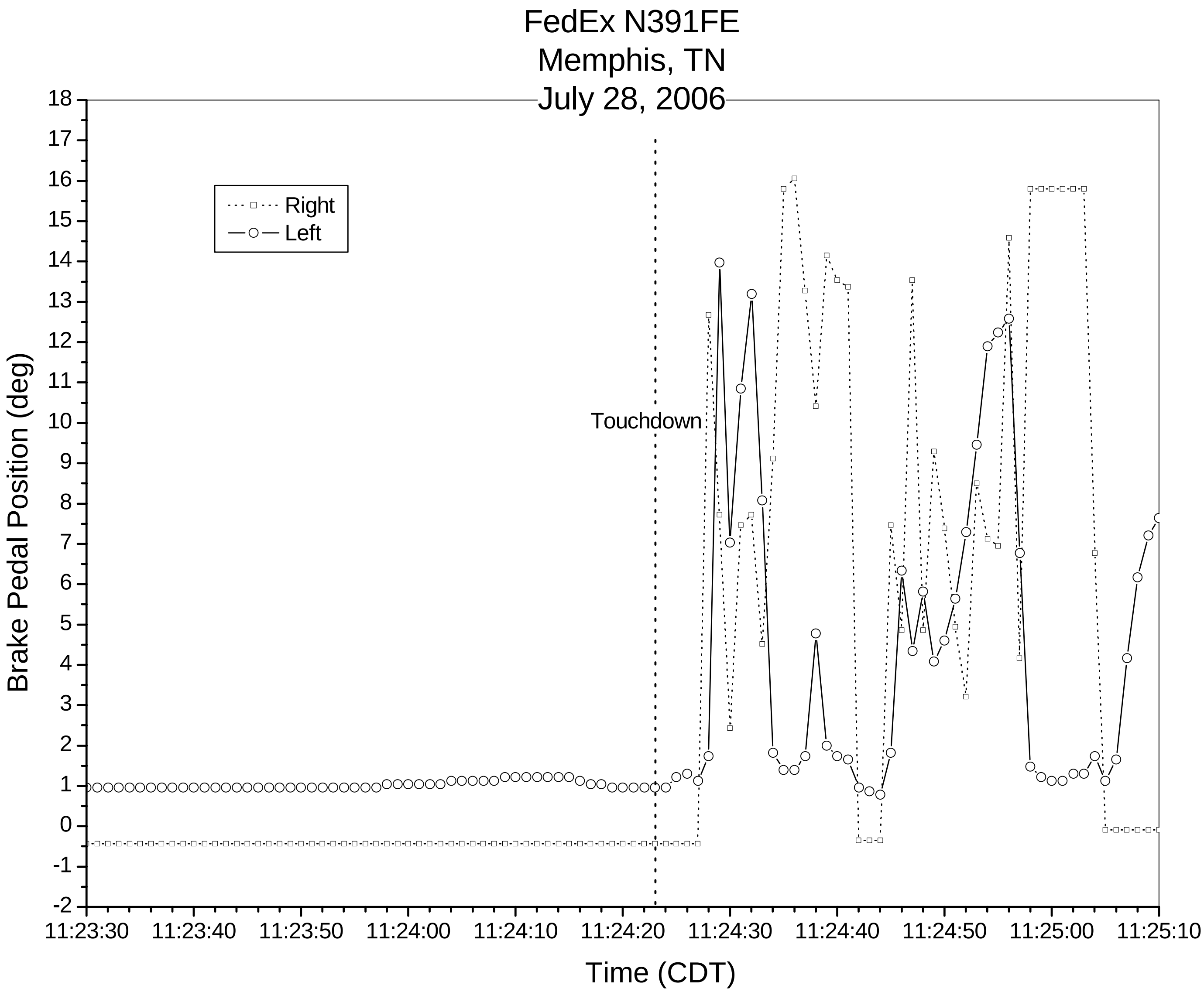

Figure 8. FDR Brake Pedal Position

III. Wreckage Survey and Runway Data

The wreckage diagram is included in the Structures Group Chairman's factual report and excerpts from the report used by the Performance Group are included in table 1. Figure 9, obtained from the Structures Group, is an aerial photograph of the witness marks and the wreckage scene. According to the Structures Group Chairman the locations and distances of the witness marks were recorded using a hand held Global Positioning System.

The Memphis Airport Authority provided the runway 18R-36L gradient, which is listed in table 2.

Table 1. Witness Marks and Airplane Resting Location

Airplane Points	**Distance from Runway 18R End (feet)**	**Distance Left of Centerline (feet)**
Engine Cowl	3,486	16.8
Outboard Flap Outboard Hinge	3498	43.2
Outboard Flap Inboard Hinge	3512	30
Wingtip	3,499	66.4
Nose Wheel of Airplane*	6,194	227

* Distance calculated from Latitude/Longitude measurements

Figure 9. Accident Scene Photograph

Table 2. Runway 18R/36L Gradient

Beginning Station (feet)	**Ending Station** (feet)	**Grade** (%)
0	6234.55	0.21
6234.55	6984.55	Vertical Curve (Transition point)
6984.55	9320	0.68

3) <u>Ground Track, Load and Wind Calculations</u>

I. Ground Track

To precisely determine the aircraft's ground track and its corresponding time history, the FDR recorded load factors (vertical, longitudinal, and lateral) were integrated. Using these acceleration components along with the Euler angles (pitch, roll, heading) the position of the aircraft for the chosen time frame was determined. FDR radio altitude and ground speed, as well as radar data, and location of the physical evidence were used as constraints to bound the calculations.

The FDR parameters may not always show the precise state of the parameter because of calibration or measurement errors. Small errors can compound to larger errors during the ground track calculation. Offsets to the recorded parameters are applied to correct for the biases. The initial set of offsets is determined from FDR data when the airplane is at rest prior to the accident. The offsets are then varied until the derived trajectory satisfies all the bounded conditions.

The integration was performed starting from where the airplane came to rest and calculated backwards in time. This approach eliminated numerous initial conditions that needed to be identified such as angle of attack, sideslip, and ground speed, thus simplifying the integration process. The integration was divided into two parts, first part spanned from time 1123:57 to 1124:32 and the second part from 1124:32 to 1125:12. The second part was a forward in time integration. The division was required because when the left main gear collapsed, the initial set of offsets were no longer effective in meeting the constraints. As a result, two sets of offsets were required, one for each part of the integration.

For the second part, the initial conditions, ground speed, and altitude were specified. All integration calculations were based on the center of gravity of the aircraft. Once the trajectory was satisfactorily determined and all the constraints were satisfied with the offsets and initial conditions from table 2 for the respective parts of the integration, FDR events were then correlated to a location on the runway.

Table 2. FDR Offsets and Initial Conditions for Part One Integration

Longitudinal Accel. (g's)	**Lateral Accel.** (g's)	**Vertical Accel.** (g's)	**Roll** (degree)	**Pitch** (degree)	**Heading** (degree)	**East*** (feet)	**North*** (feet)
0.018	0.02395	-0.0027	-0.865	-.1	0	193	-6187

* North and East position converted from FDR data

Table 2a. Initial Conditions for Part Two Integration

East (feet)	**North** (feet)	**Radio Altitude** (feet)	**Ground Speed** (knots)	**Airplane Angle of Attack (**degree**)**	**Airplane Side Slip Angle (**degree**)**
-63	3809	315	142	5	-2.95

Table 2b. FDR Offsets for Part Two Integration

Longitudinal Acceleration (g's**)**	**Lateral Acceleratio n (**g's**)**	**Vertical Acceleratio n (**g's**)**	**Roll (**degree**)**	**Pitch (**degree**)**	**Heading (**degree**)**
-0.017	0.0155	0.00843	0.11	-0.78	0

Figure 10 shows the calculated altitude and ground speed match with FDR data. The FDR recorded latitude and longitude data to the sixth decimal place (0.000001 degrees). This high resolution data was translated to north and east position relative to the runway threshold and used for matching the calculated north and east position versus time, shown in figure 11. Figure 12 depicts the calculated ground track plotted along with the radar data, FDR (translated) data and the ground witness mark locations. Figure 13 is a plot of the calculated altitude versus distance along runway 18R. Note that in figure 13 the dip in altitude at approximately 4,000 feet is likely due to the collapse of the left main gear.

The calculated ground track and drift angle and FDR rudder position angle are shown in figure 14 to illustrate the angle at touchdown and during the landing roll. The track angle is the angle between true north and the airplane ground track while the drift angle is defined as the angle between the ground track and the heading of the airplane. For comparison purposes the ground track angle was converted to magnetic north and relative to runway heading. The track angle was approximately 0 at touchdown and the drift angle was about -2 deg, aircraft heading right of ground track. After touchdown about 3 seconds later the drift angle was 0 deg, but the track angle had increased to a maximum of approximately 3 deg (airplane tracking right of runway heading) and then decreased to a minimum of -2 deg (airplane tracking left of runway heading) a change of 5 deg in 5 seconds. During this same time period the rudder position increased to about 16 deg trailing edge left, and then decreased to about 2 deg trailing edge right.

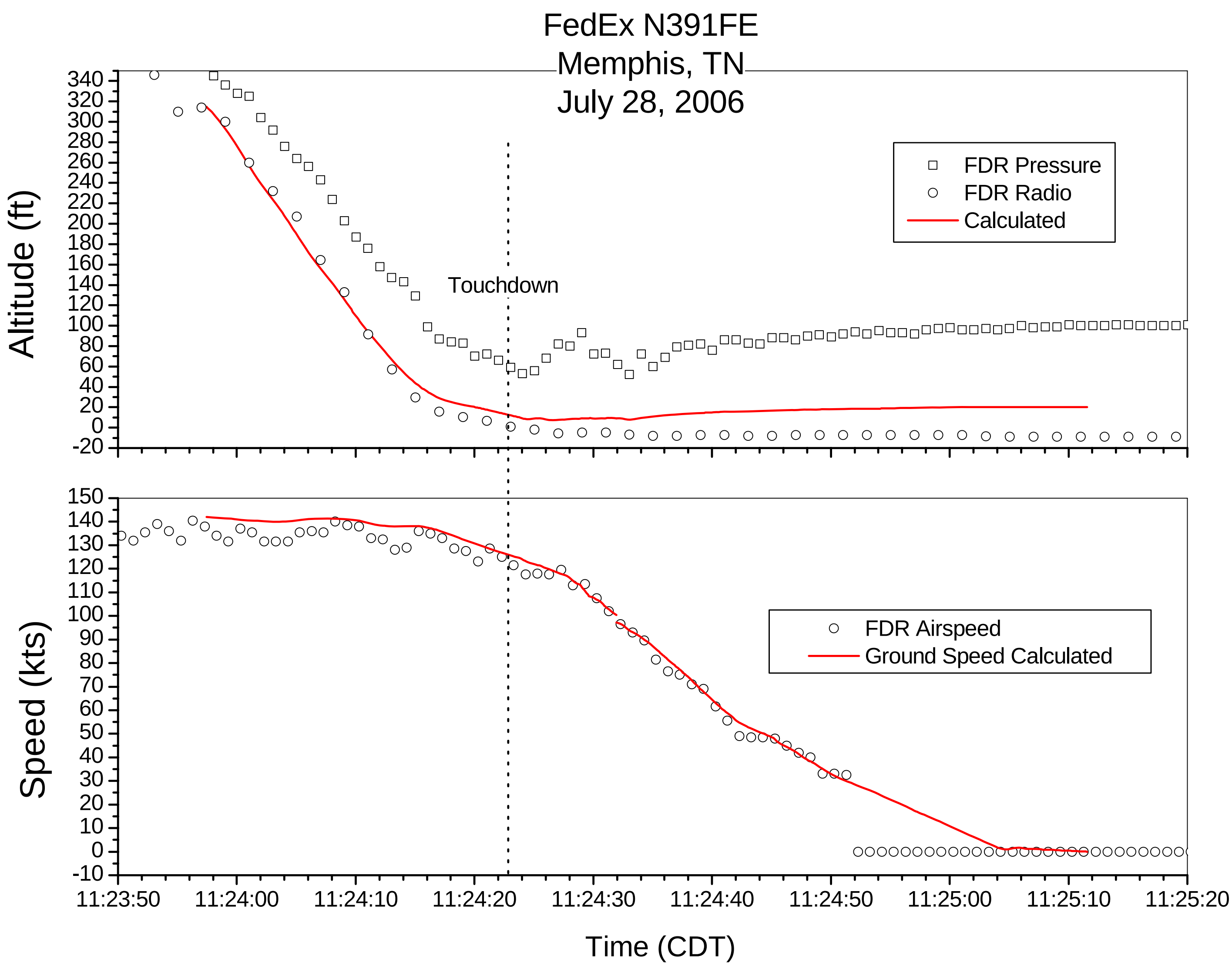

Figure 10. Altitude and Speed Match

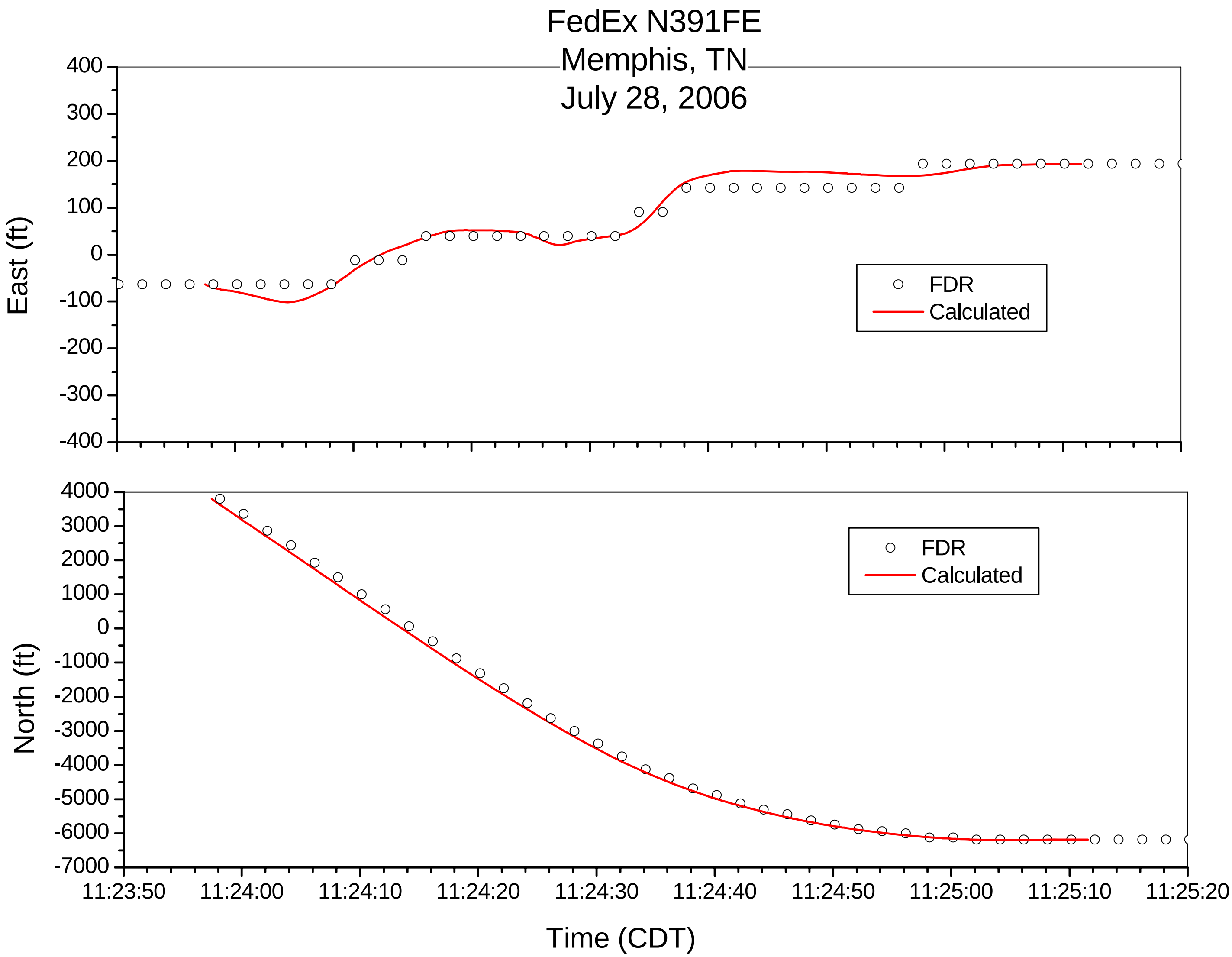

Figure 11. North and East Position Match

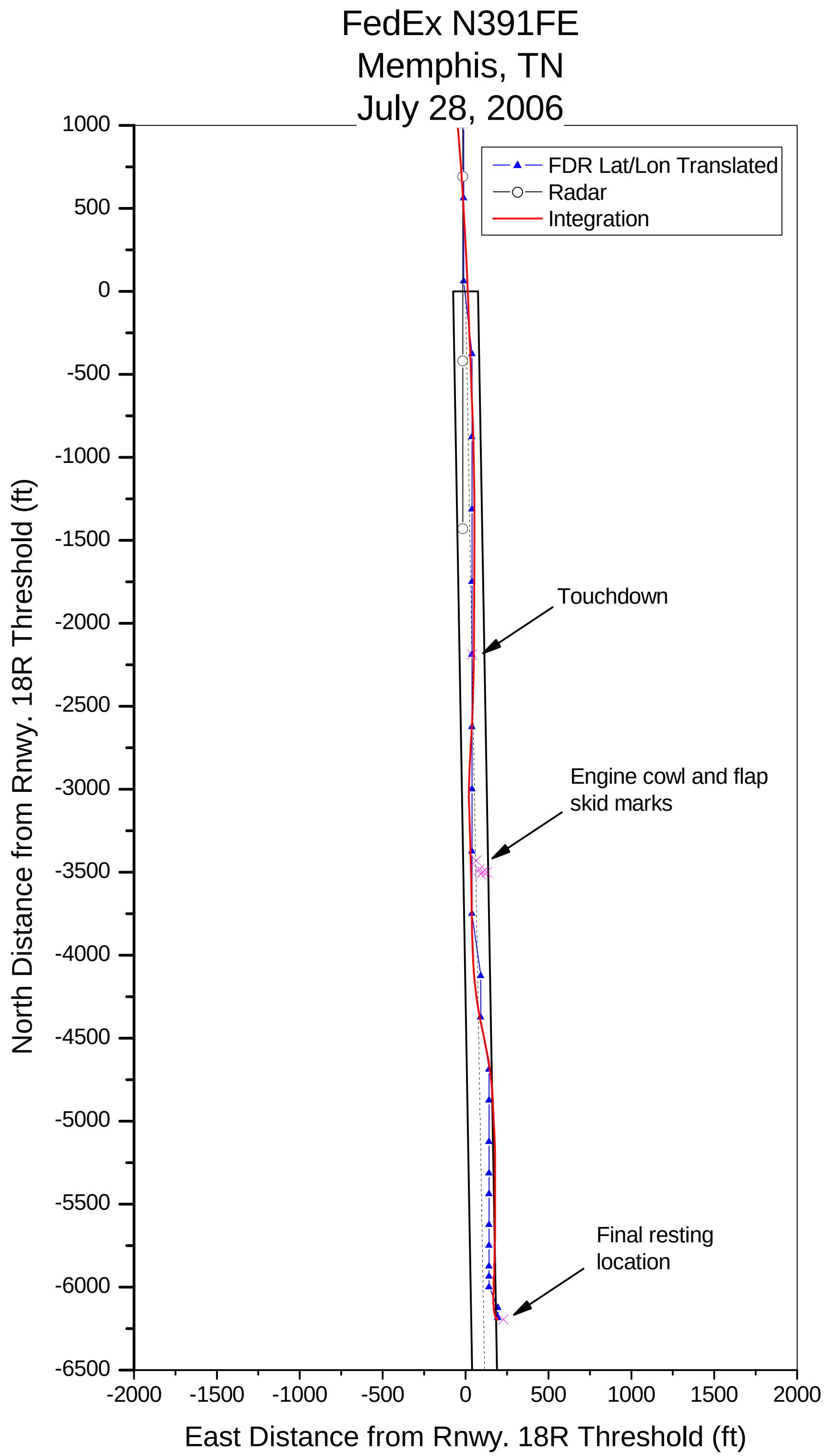

Figure 12. Ground Track Match

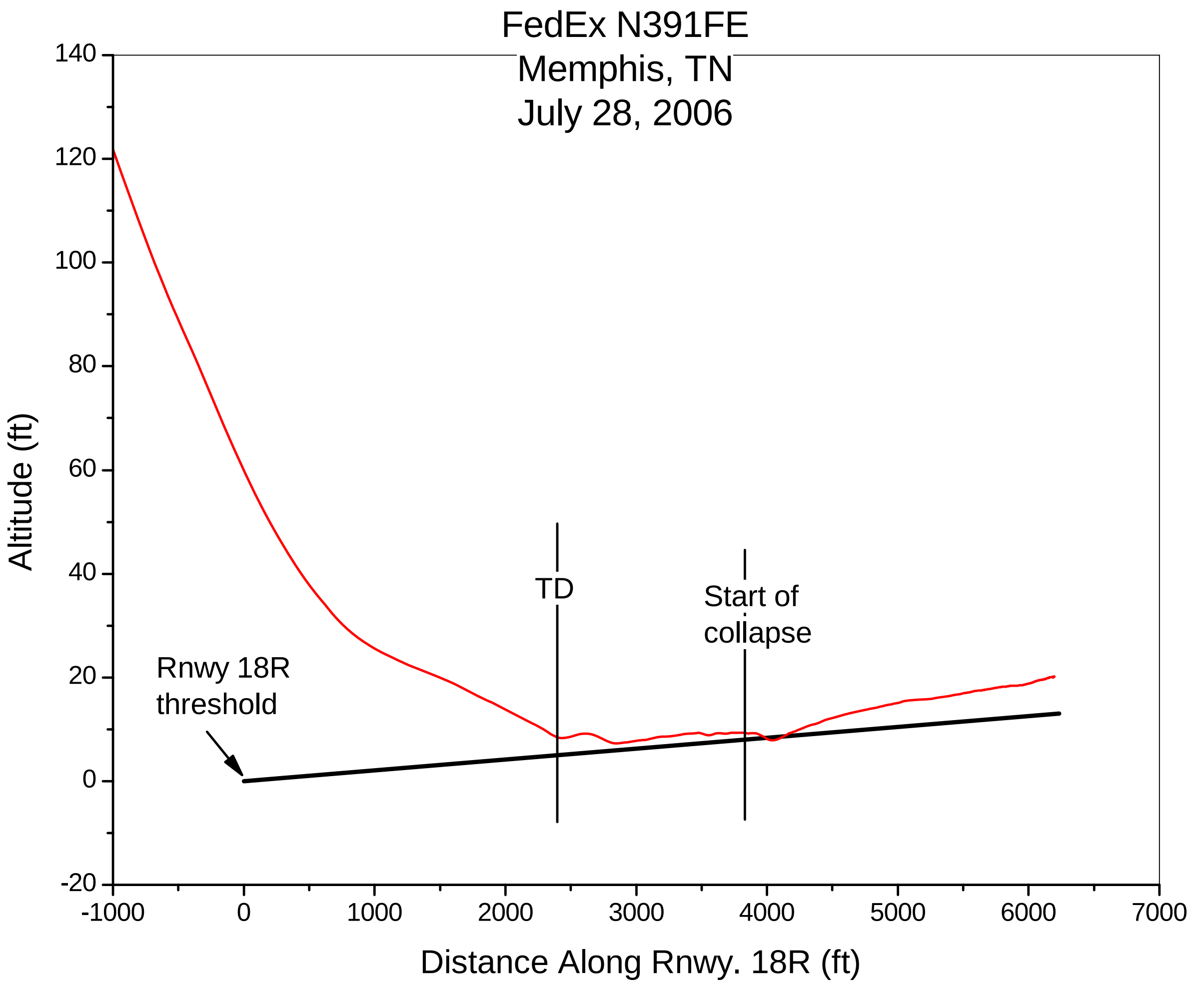

Figure 13. Calculated Altitude versus Distance

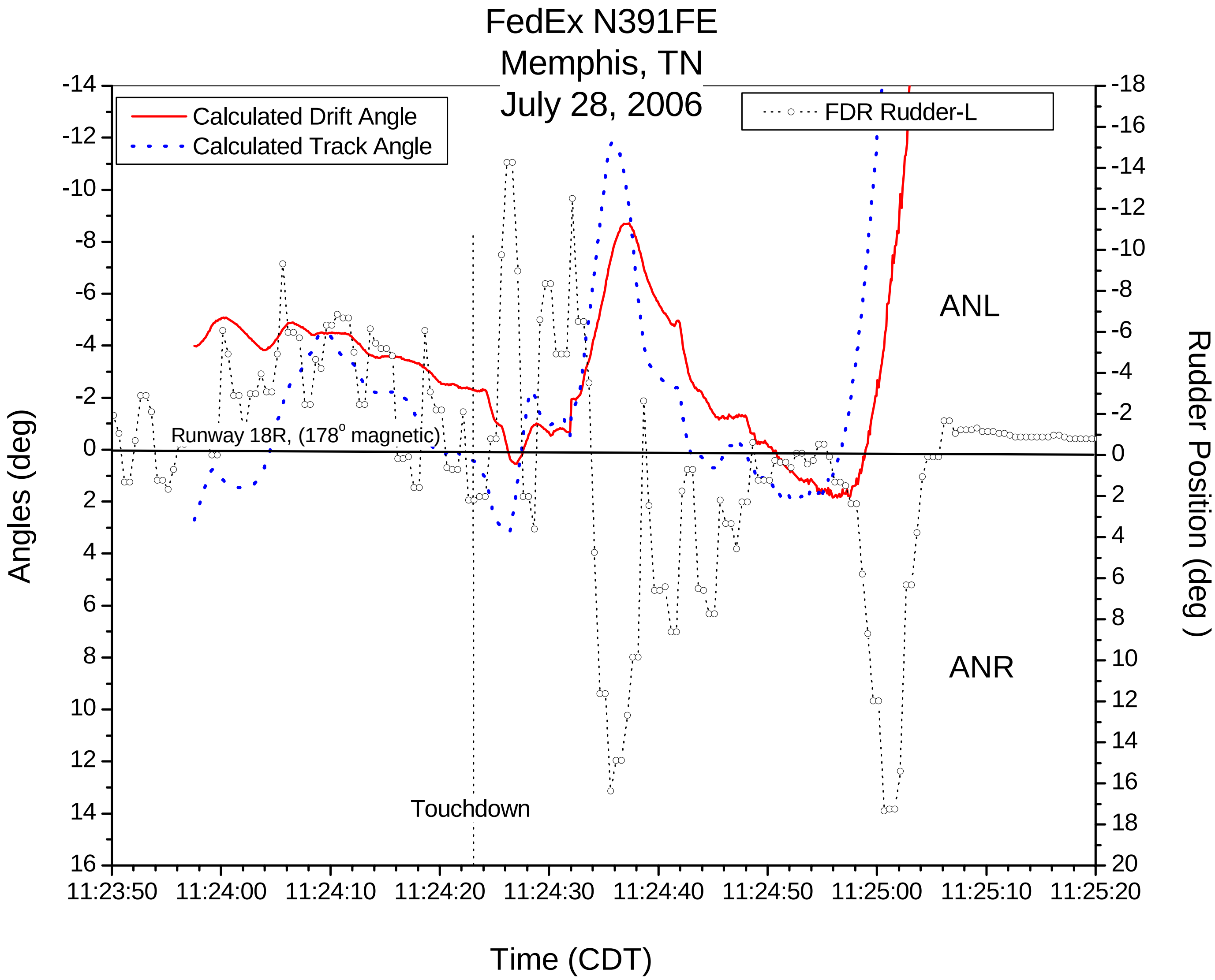

Figure 14. Drift, Track, and Rudder Position Angle

II. Load Calculation Results

Due to the failure of the left main gear after touchdown, the magnitude of the loads imposed on the gear was desired. The FDR recorded the load factors in the three directions at the sensor, but the loads at the gear can vary depending on the orientation and angular rates of the airplane. The loads at the left main gear were resolved using the transformation equations 2 through 4 listed below. The results of the calculated loads are shown in figure 15.

$$Nz_{leftgear} = Nz_{sensor} + (X_{gear} * (\dot{q}_b - r_b * p_b) + Y_{gear} * (\dot{p}_b + q_b * r_b) + Z_{gear} * (p_b^2 + q_b^2))/g \qquad \text{eq. 2}$$

$$Nx_{leftgear} = Nx_{sensor} + (-X_{gear} * (r_b^2 + q_b^2) + Y_{gear} * (\dot{r}_b - p_b * q_b) + Z_{gear} * (\dot{q}_b + r_b * p_b))/g \qquad \text{eq. 3}$$

$$Ny_{leftgear} = Ny_{sensor} + (X_{gear} * (\dot{r}_b + p_b * q_b) + Y_{gear} * (p_b^2 + r_b^2) - Z_{gear} * (\dot{p}_b - q_b * r_b))/g \qquad \text{eq. 4}$$

where:

Nz : vertical load factor, positive down towards ground, G's
Nx : longitudinal load factor, positive towards aft of airplane, G's
Ny : lateral load factor, positive along right wing, G's
$Ny_{leftgear}$: positive along right wing, G's
$Nx_{leftgear}$: positive towards aft of airplane, G's
$Nz_{leftgear}$: positive down towards ground, G's
X_{gear} : 4.29 longitudinal distance from sensor to left gear, positive aft, feet
Y_{gear} : 14.875 lateral distance from sensor to left gear, positive left, feet
Z_{gear} : 11.85 vertical distance from sensor to left gear, positive down, feet
p_b : body axis roll rate, rad/sec
q_b : body axis pitch rate, rad/sec
r_b : body axis yaw rate, rad/sec
$\dot{p}_b$: body axis roll acceleration, rad/sec^2
$\dot{q}_b$: body axis pitch acceleration, rad/sec^2

$\dot{r}_b$: body axis yaw acceleration, rad/sec^2
g : 32.174 gravitational acceleration, ft/sec^2

The FDR pitch, roll, and heading data were transformed to body axis and differentiated to produce the angular rates used in equations 2 to 4.

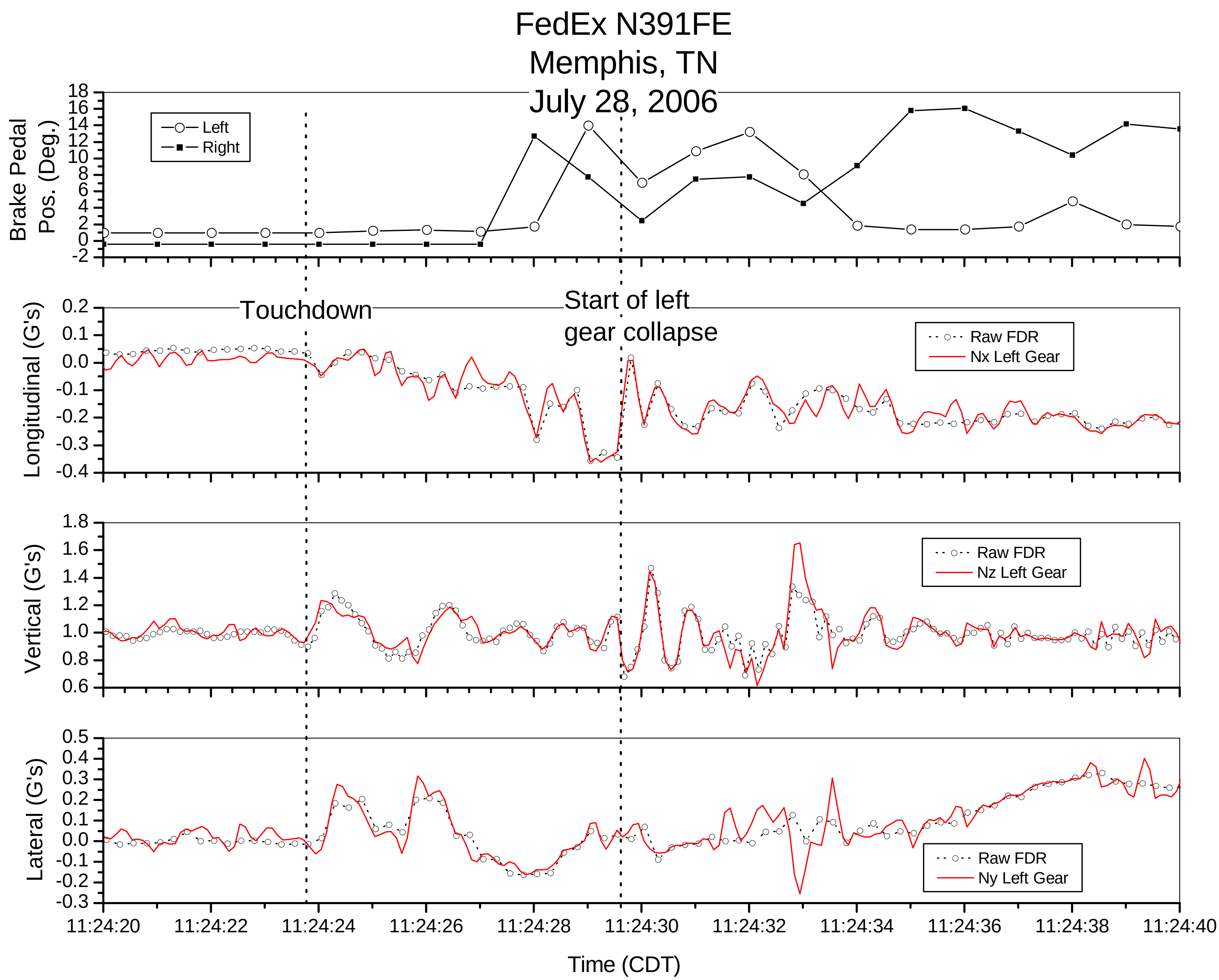

Figure 15. FDR Load Factor at Sensor and Calculated Loads at Left Gear (expanded scale)

Observing figure 15, at about 1124:30 the vertical load factor decreased to about 0.6 G and then 1 second later increased to about 1.7 G's. This was most likely a result of failure (collapse) of the left gear and was consistent with the location of the ground strike marks of the engine cowling and wing tip. The maximum lateral load of approximately 0.3 G during the landing roll was determined to be within the design and ultimate load limits[2].

Figure 16 illustrates the calculated vertical speed (descent rate). It shows that the flight landed with a sink rate between -2 and -3 fps. The body center descent rate was calculated by differentiating the altitude time history. The left and right gear descent rates were calculated using equations 5 and 6.

$$\dot{h}_{leftgear} = \dot{h}_{cg} + \cos(pitch) * Y_{gear} * p_b \quad \text{eq. 5}$$

$$\dot{h}_{rightgear} = \dot{h}_{cg} - \cos(pitch) * Y_{gear} * p_b \quad \text{eq. 6}$$

where:

$\dot{h}_{leftgear}$: descent rate calculated at left gear

$\dot{h}_{rightgear}$: descent rate calculated at right gear

$\dot{h}_{cg}$: body center descent rate calculated at center of gravity

p_b : body axis roll rate, rad/sec

Y_{gear} : 14.875 lateral distance from sensor to left gear, positive left, feet

[2] Boeing provided design limit data.

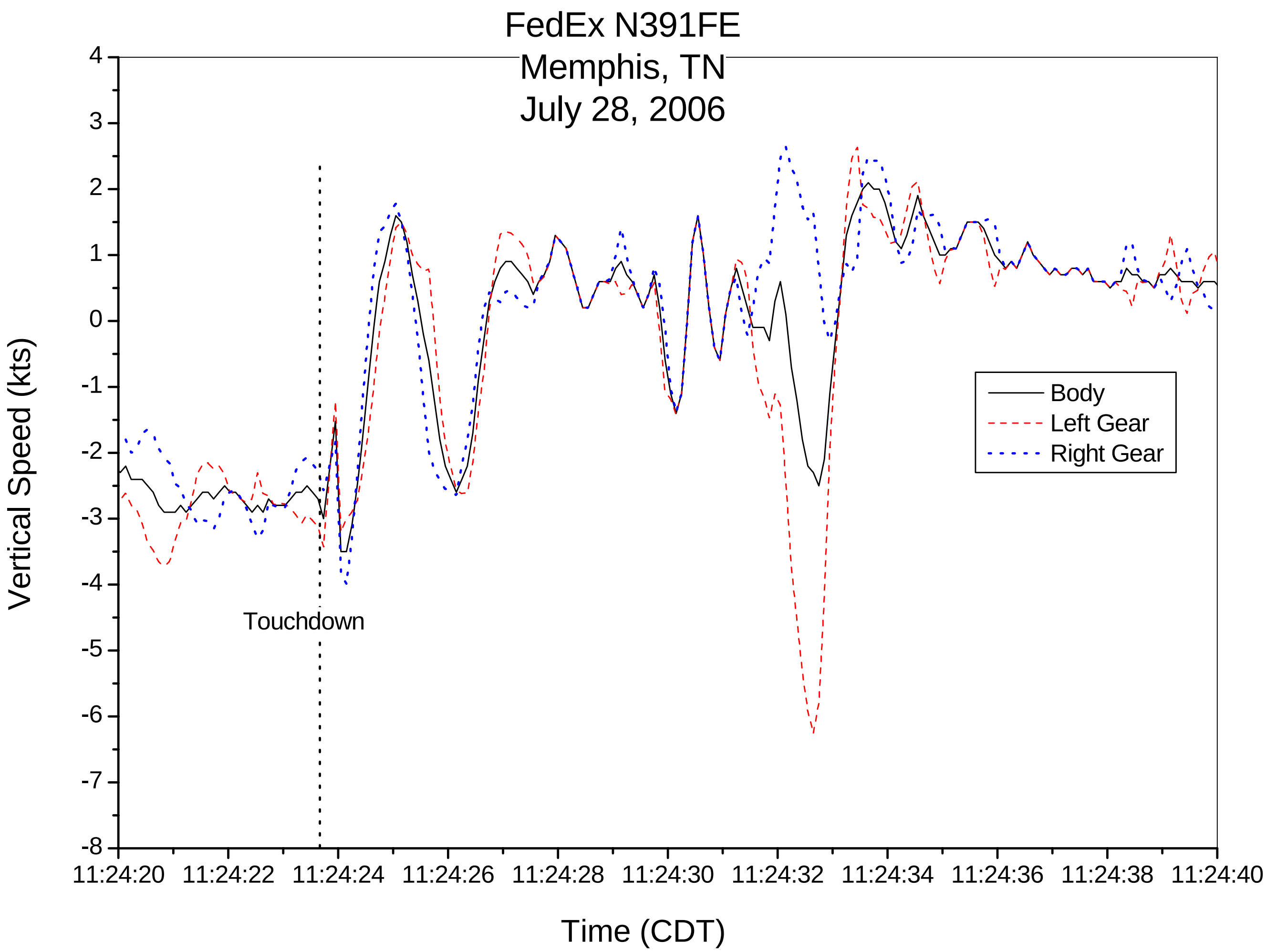

Figure 16. Calculated Vertical Speed (expanded scale)

III. Wind Calculation

The calculated altitude and position over time plus the FDR pressure altitude, airspeed, and heading over time were used to derive the wind velocity and direction profile (figure 17). This derivation is based on a point mass system in a quasi steady state, and is invalid for times when the airplane is in contact with the ground. The calculated wind speed during touchdown was about 8 knots from 280 deg.

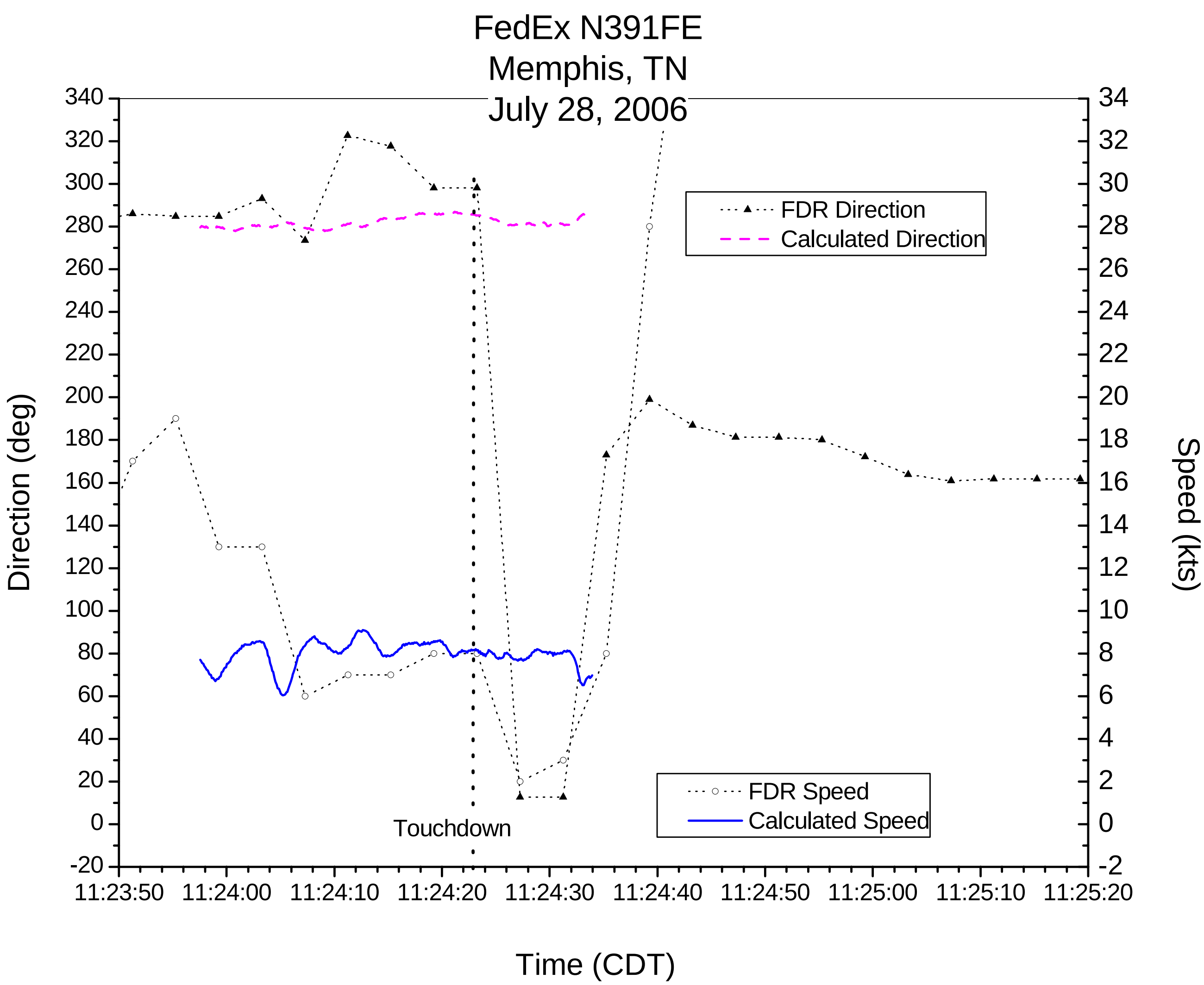

Figure 17. Wind Direction and Speed

F. CONCLUSION

The FedEx flight landed on runway 18R with a descent rate of about -2 to -3 fps and with a -2 deg drift angle (airplane heading right of ground track). The winds were reported at about 8 kts from the west. About 1 second after touchdown the drift angle decreased to 0 deg and the track angle increased to 3 deg (airplane ground track right of runway heading) and then decreased to -2 deg (ground track left of runway heading). During this 5 second time period the rudder deflection angle changed by about 16 deg trailing edge left. The loads on the left gear during landing and roll out were calculated and showed that the design limits were not exceeded.

Abdullah Kakar
Aerospace Engineer

Appendix

Memphis (MEM) ASR-9
Radar Data
July 28, 2006

1116:01.3 to 1124:20.4 CDT

Table 1A. MEM ASR-9 Radar Data

Time (CDT) hh:mm:ss	Pressure Altitude (feet)	Range (nautical miles)	Azimuth (ACPS)
11:16:01.3	7100	27.41	3589
11:16:01.9	7100	27.41	3621
11:16:06.0	7100	27.08	3593
11:16:06.6	7100	27.08	3625
11:16:10.6	7000	26.75	3599
11:16:11.2	7000	26.75	3631
11:16:15.2	6900	26.42	3603
11:16:15.7	6900	26.42	3635
11:16:19.9	6900	26.11	3609
11:16:20.4	6900	26.11	3641
11:16:24.5	6800	25.78	3611
11:16:25.0	6800	25.78	3643
11:16:29.1	6700	25.47	3618
11:16:29.7	6700	25.47	3650
11:16:33.7	6700	25.14	3623
11:16:34.3	6700	25.14	3655
11:16:38.2	6600	24.83	3629
11:16:38.8	6600	24.83	3661
11:16:43.0	6500	24.5	3635
11:16:43.6	6500	24.5	3667
11:16:47.6	6500	24.19	3639
11:16:48.1	6500	24.19	3671
11:16:52.2	6400	23.88	3645
11:16:52.8	6400	23.88	3677
11:16:56.8	6300	23.56	3651
11:16:57.4	6300	23.56	3683
11:17:01.4	6300	23.27	3657
11:17:01.9	6300	23.27	3689
11:17:06.1	6200	22.95	3664
11:17:06.6	6200	22.95	3696
11:17:10.7	6100	22.64	3670
11:17:11.2	6100	22.64	3702
11:17:15.3	6100	22.34	3676
11:17:15.9	6100	22.34	3708
11:17:20.0	6000	22.05	3682
11:17:20.5	6000	22.05	3714
11:17:24.5	5900	21.75	3689
11:17:25.0	5900	21.75	3721
11:17:29.2	5900	21.45	3697
11:17:29.8	5900	21.45	3729
11:17:33.8	5800	21.16	3704

Table 1A. MEM ASR-9 Radar Data Cont'd.

Time (CDT) hh:mm:ss	Pressure Altitude (feet)	Range (nautical miles)	Azimuth (ACPS)
11:17:34.3	5800	21.16	3736
11:17:38.4	5700	20.88	3711
11:17:39.0	5700	20.88	3743
11:17:43.1	5700	20.59	3718
11:17:43.6	5700	20.59	3750
11:17:47.7	5600	20.31	3726
11:17:48.3	5600	20.31	3758
11:17:52.3	5500	20.05	3734
11:17:52.9	5500	20.05	3766
11:17:57.0	5400	19.78	3742
11:17:57.6	5400	19.78	3774
11:18:01.6	5300	19.52	3751
11:18:02.1	5300	19.52	3783
11:18:06.2	5200	19.25	3759
11:18:06.7	5200	19.25	3791
11:18:10.9	5100	18.98	3767
11:18:11.4	5100	18.98	3799
11:18:15.4	5000	18.73	3777
11:18:16.0	5000	18.73	3809
11:18:20.1	4900	18.48	3785
11:18:20.7	4900	18.48	3817
11:18:24.7	4700	18.2	3793
11:18:25.2	4700	18.2	3825
11:18:29.4	4700	17.91	3801
11:18:30.0	4700	17.91	3833
11:18:34.0	4600	17.61	3807
11:18:34.5	4600	17.61	3839
11:18:38.6	4500	17.31	3814
11:18:39.1	4500	17.31	3846
11:18:43.2	4500	17.02	3822
11:18:43.8	4500	17.02	3854
11:18:47.8	4400	16.73	3830
11:18:48.4	4400	16.73	3862
11:18:52.5	4400	16.47	3838
11:18:53.1	4400	16.47	3870
11:18:57.1	4300	16.2	3846
11:18:57.7	4300	16.2	3878
11:19:01.8	4300	15.94	3856
11:19:02.2	4300	15.94	3888
11:19:06.4	4300	15.67	3862
11:19:06.9	4300	15.67	3894

Table 1A. MEM ASR-9 Radar Data Cont'd.

Time (CDT) hh:mm:ss	Pressure Altitude (feet)	Range (nautical miles)	Azimuth (ACPS)
11:19:11.0	4200	15.42	3871
11:19:11.5	4200	15.42	3903
11:19:15.6	4200	15.17	3882
11:19:16.2	4200	15.17	3914
11:19:20.2	4100	14.94	3890
11:19:20.8	4100	14.94	3922
11:19:24.9	4100	14.69	3900
11:19:25.5	4100	14.69	3932
11:19:29.5	4000	14.47	3910
11:19:30.1	4000	14.47	3942
11:19:34.2	4000	14.23	3919
11:19:34.8	4000	14.23	3951
11:19:38.8	3900	14.02	3930
11:19:39.3	3900	14.02	3962
11:19:43.4	3900	13.8	3940
11:19:43.9	3900	13.8	3972
11:19:48.0	3800	13.58	3951
11:19:48.6	3800	13.58	3983
11:19:52.6	3800	13.33	3958
11:19:53.1	3800	13.33	3990
11:19:57.3	3700	13.08	3967
11:19:57.7	3700	13.08	3999
11:20:01.8	3700	12.83	3975
11:20:02.4	3700	12.83	4007
11:20:06.5	3600	12.59	3983
11:20:07.0	3600	12.59	4015
11:20:11.1	3500	12.36	3991
11:20:11.7	3500	12.36	4023
11:20:15.8	3400	12.11	4002
11:20:16.3	3400	12.11	4034
11:20:20.4	3300	11.89	4010
11:20:21.0	3300	11.89	4042
11:20:25.0	3200	11.66	4020
11:20:25.6	3200	11.66	4052
11:20:29.6	3100	11.42	4028
11:20:30.3	3100	11.42	4060
11:20:34.2	3000	11.14	4034
11:20:34.8	3000	11.14	4066
11:20:38.9	2900	10.89	4037
11:20:39.4	2900	10.89	4069
11:20:43.5	2800	10.62	4037

Table 1A. MEM ASR-9 Radar Data Cont'd.

Time (CDT) hh:mm:ss	Pressure Altitude (feet)	Range (nautical miles)	Azimuth (ACPS)
11:20:44.1	2800	10.62	4069
11:20:48.2	2800	10.38	4035
11:20:48.7	2800	10.38	4067
11:20:52.7	2800	10.12	4034
11:20:53.4	2800	10.12	4066
11:20:57.4	2700	9.89	4032
11:20:57.9	2700	9.89	4064
11:21:02.0	2700	9.66	4031
11:21:02.5	2700	9.66	4063
11:21:06.6	2600	9.42	4030
11:21:07.2	2600	9.42	4062
11:21:11.2	2500	9.17	4027
11:21:11.8	2500	9.17	4059
11:21:15.9	2500	8.95	4028
11:21:16.5	2500	8.95	4060
11:21:20.4	2400	8.72	4028
11:21:21.0	2400	8.72	4060
11:21:25.0	2300	8.48	4028
11:21:25.5	2300	8.48	4060
11:21:29.7	2200	8.27	4026
11:21:30.3	2200	8.27	4058
11:21:34.3	2100	8.05	4027
11:21:34.9	2100	8.05	4059
11:21:38.9	2000	7.83	4027
11:21:39.4	2000	7.83	4059
11:21:43.5	2000	7.61	4026
11:21:44.1	2000	7.61	4058
11:21:48.1	1900	7.39	4024
11:21:48.7	1900	7.39	4056
11:21:52.7	1900	7.19	4024
11:21:53.2	1900	7.19	4056
11:21:57.4	1800	6.98	4024
11:21:57.9	1800	6.98	4056
11:22:02.0	1700	6.8	4021
11:22:02.5	1700	6.8	4053
11:22:06.6	1700	6.61	4021
11:22:07.2	1700	6.61	4053
11:22:11.2	1600	6.42	4019
11:22:11.7	1600	6.42	4051
11:22:15.8	1600	6.25	4017
11:22:16.3	1600	6.25	4049

Table 1A. MEM ASR-9 Radar Data Cont'd.

Time (CDT) hh:mm:ss	Pressure Altitude (feet)	Range (nautical miles)	Azimuth (ACPS)
11:22:20.4	1500	6.06	4016
11:22:21.0	1500	6.06	4048
11:22:25.1	1500	5.89	4016
11:22:25.6	1500	5.89	4048
11:22:29.7	1400	5.72	4014
11:22:30.3	1400	5.72	4046
11:22:34.3	1400	5.53	4013
11:22:34.9	1400	5.53	4045
11:22:38.9	1300	5.36	4013
11:22:39.4	1300	5.36	4045
11:22:43.5	1300	5.19	4013
11:22:44.1	1300	5.19	4045
11:22:48.1	1200	5.02	4011
11:22:48.6	1200	5.02	4043
11:22:52.8	1100	4.83	4010
11:22:53.4	1100	4.83	4042
11:22:57.4	1100	4.66	4007
11:22:57.9	1100	4.66	4039
11:23:02.0	1000	4.47	4006
11:23:02.5	1000	4.47	4038
11:23:06.6	1000	4.28	4004
11:23:07.2	1000	4.28	4036
11:23:11.2	900	4.09	4002
11:23:11.8	900	4.09	4034
11:23:15.9	900	3.92	3999
11:23:16.3	900	3.92	4031
11:23:20.5	800	3.72	3996
11:23:21.0	800	3.72	4028
11:23:25.0	700	3.55	3995
11:23:25.6	700	3.55	4027
11:23:29.7	700	3.36	3992
11:23:30.3	700	3.36	4024
11:23:34.2	600	3.17	3986
11:23:34.8	600	3.17	4018
11:23:38.9	600	3	3982
11:23:39.4	600	3	4014
11:23:43.5	500	2.81	3980
11:23:44.1	500	2.81	4012
11:23:48.1	400	2.62	3975
11:23:48.7	400	2.62	4007
11:23:52.7	400	2.45	3968

Table 1A. MEM ASR-9 Radar Data Cont'd.

Time (CDT) hh:mm:ss	Pressure Altitude (feet)	Range (nautical miles)	Azimuth (ACPS)
11:23:53.2	400	2.45	4000
11:23:57.4	300	2.28	3961
11:23:57.9	300	2.28	3993
11:24:02.0	300	2.11	3951
11:24:02.5	300	2.11	3983
11:24:06.6	200	1.92	3945
11:24:11.2	200	1.75	3933
11:24:15.7	100	1.58	3920
11:24:20.4	100	1.41	3904