

DOCKET NO. **SA - 510**

EXHIBIT NO. **13 A**

**NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.**

Performance Group Chairman's Report of Investigation

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C.

January 17, 1994

Performance Group Chairman's Report of Investigation

A. ACCIDENT DCA-94-MA-076

Location: Aliquippa, Pennsylvania
Date : September 8, 1994
Time : 1904 Eastern Daylight Time
Aircraft: Boeing 737-300, N513AU

B. GROUP IDENTIFICATION

The group met at the accident site on September 8 through 15, 1994 and at the Boeing Company, Seattle, Washington on September 21-22, October 12-13, and November 3, 1994. The following group members participated in the investigation:

Chairman: Thomas R. Jacky
 National Transportation Safety Board
 Washington, D.C.

Member: Steven E. O'Neal
 Federal Aviation Administration
 Renton, WA

Member: Bob McCullough
 USAir, Inc.
 Pittsburgh, PA

Member: Keakini Kaulia
 Air Line Pilots Association
 Herndon, VA

Member: James Kerrigan
 Boeing Commercial Airplane Company
 Seattle, Washington

Additionally, the following persons participated in the investigative effort:

John Clark,	NTSB
Keith McGuire,	NTSB
Marty Ingham,	Boeing
Mike Carriker,	Boeing
Paul Sturpe,	USAir
Les Berven,	FAA
Keith Hagy,	ALPA
John Delisi,	NTSB
Jim Wilborn,	Boeing
Jim Vasatka,	Boeing
Paul Sturpe,	USAir
George Greene,	NASA
Dan Vicroy,	NASA

C. SUMMARY

On September 8, 1994 at 1904 Eastern Daylight Time USAir Flight 427, a Boeing 737-3B7, N513AU, crashed while maneuvering to land at Pittsburgh International Airport, Pittsburgh, Pennsylvania. The airplane was being operated on an instrument flight rules (IFR) flight plan under the provisions of Title 14, code of Federal Regulation (CFR), Part 121, on a regularly scheduled flight from Chicago O'Hare International Airport, Chicago, Illinois, to Pittsburgh. The airplane was destroyed by impact forces and fire near Aliquippa, Pennsylvania. All 132 persons on board the airplane were fatally injured.

D. DETAILS OF INVESTIGATION

The Airplane Performance Group used available data, including data from the FDR, CVR, and ATC radar facilities to define the motion of the accident airplane. The group also examined the effects that various malfunctions, failures, and wake vortex encounters would have on the motion of the airplane.

Recorded Radar Data

Printouts of USAir Flight 427's (transponder code 6255) recorded radar tracking data (TD) of Automated Radar Terminal System (ARTS) III data from the Pittsburgh Terminal Radar Approach Control (TRACON) were acquired and processed by the National Transportation Safety Board. In addition, a Continuous Disc/Time Sequenced Output (CDTSO) extractor tape of ARTS III data was processed and hand-carried to Washington, D.C. where the tape was read by Vehicle Performance Division personnel. Data were also extracted for the preceding airplane, Delta Airlines Flight 1083, and for another airplane

in the area, Blue Ridge Flight 425. The final 6 USAir 427 returns were plotted onto a United States Geological Service (USGS) topographical map of the accident area (Attachment 1).

The data for USA427, DL1083, and BLR were plotted relative to the Pittsburgh ASR. Mode C altitude (100s of MSL feet) were annotated onto selected TD returns. The resultant plot is included in Attachment 1.

The USA427, DL1083, and BLR425 TD data were then used to calculate lateral distance between USA427 and DL1083 and USA427 and BLR425. Radar returns at similar times were used for the calculations. Results of the calculations are included in Attachment 1.

Two additional plots for USA427 and DL1083 are included in Attachment 1 and shows the Mode C altitude in 100's of MSL feet for each return.

Simulator Testing

First session -- The group met at Seattle, Washington to review simulator data provided by Boeing and to develop a preliminary list of possible failure scenarios to investigate using Boeing's simulator capability. Forty five simulator runs were attempted on September 22, 1994, with seven runs either aborted or not recorded. The group used the Boeing Multipurpose Engineering Cab (MCAB) Simulator with the Aerodynamic Data and Control System Description for the 737-300 Flight Simulator (Document D6-37908, rev C).

The primary objective of the study was to attempt to replicate USAir 427's flight data recorder data through the accident sequence. Most specifically, the group intended to match the initial heading change rate found at the beginning of the accident sequence or initial upset. In addition, the group intended to simulate initial failure or malfunction scenarios, record the simulator aircraft's response to the input, and then compare the resultant data to FDR data.

Attachment 2 lists the failure or malfunction scenarios examined and lists the simulator runs and a summary of the simulator scenario. The resultant data from the simulator runs were not included in this report but will be provided the docket.

Second session -- Examination of radar and flight data recorder data plots indicated the possibility that USA427 may have flown into the wake of the aircraft preceding USA427, identified as Delta Airlines Flight 1083, a B-727.

A wake vortex model, along with a visual identifiers of

the vortices, of Delta 1083's wake vortex was developed by Boeing. Additionally, a distributed lift model was developed to determine local angle of attack values over the airplane wings and integrate the resultant lift and rolling moments caused by wake vortex interaction.

Information received from Delta Airlines estimated the B-727's weight at the time of interest as 126,400 lbs, and that the aircraft would have been in a "clean", or no flaps, configuration.

Delta Airlines Flight 1083's wake was modeled using the Rankine potential vortex model. Vortex core diameters used were 17 feet and 4 feet. Span distance between the vortex cores used was 85 feet. Vortex circulation values (or Γ) used ranged between 500 ft²/sec and 2125 ft²/sec. Vortex "flight path angles" of 0.0°, 3.5°, and -3.5° were used.

To visualize the wake vortices, two cylinders were used to depict the vortex cores, with a red line used to indicate the vortex pair center-line.

To validate the simulation, the group's pilot participants first flew the simulator's distributed lift model and the wake vortex model. The pilots agreed that the models were accurate. Then different scenarios developed regarding wake vorticity, sink rate, position, core size, wake angle, and aircraft intercept angle were run. A listing of the simulator runs is included in Attachment 3.

One hundred and five simulator runs were attempted on October 12 and 13, 1994. The group used the Boeing Multipurpose Engineering Cab (MCAB) Simulator with the Aerodynamic Data and Control System Description for the 737-300 Flight Simulator (Document D6-37908, rev. C).

Third session -- Refinements were made to the vortex model to further examine possible wake vortex encounter participation in the accident sequence. The Rankine potential vortex model developed by Boeing was used to represent the wake from the Delta Airlines B-727. The B-737 distributed lift model, was adjusted to include wake encounter effects to the vertical and horizontal tails. Forty-four simulator runs were attempted on November 2, 1994.

The model of Delta Airlines Flight 1083's wake vortex core diameter was 4 feet. Span distance between the vortex cores was 85 feet. The vortex circulation (or Γ) value used was 1500 ft²/sec. A vortex "flight path angle" of 0.0° was used. To generate roll angles and rates similar to USA427 FDR's, the left vortex's circulation was dropped to zero, and the right vortex's circulation kept at $\Gamma=1500$ ft²/sec.

The pilot participants first flew the simulator's distributed lift and tail effects model through a series of maneuvers. The pilots agreed that the models were accurate. The auto-pilot was used to make a 140° to 100° heading turn, with the yaw damper on and off. The same turn was attempted using control wheel steering (CWS). In another series of runs, the auto-throttles were manipulated in order to note throttle movement and rate. Finally, a series of runs were made by flying the aircraft into the wake vortex, followed by a $3^{\circ}/\text{sec}$ rudder pedal input. A listing of the simulator runs is included in Attachment 4.

Backdrive Model and Kinematic Study

During the course of the investigation, two efforts were made to derive airplane control surface positions from the Flight Data Recorder data taken from USAir Flight 427.

1. Backdrive of Boeing Simulator to Match FDR Data

The Boeing full motion engineering development simulator configured as a B-737-300 was used to extract aerodynamic coefficients required to closely match FDR time data traces. Aircraft rates and accelerations were obtained by differentiating FDR data. The rates and accelerations were then used to determine the control surface position necessary to drive the simulator to recreate the FDR traces. The derived control input positions, rates, and angles were recorded and plotted. Plots of control surface positions producing the best match to the FDR data are included in Exhibit 13G.

It is noted that the derived control positions are not necessarily indicative of the actual positions, since forces other than those calculated by the simulation may have been acting on the airplane.

2. Kinematic Study of the FDR Data

In a separate Boeing study, USA427's FDR attitude data were used to determine the forces, moments and aerodynamic coefficients that were required to be acting on the airplane's roll, pitch, and yaw axes. The aerodynamic coefficient associated to the aircraft's attitude without control surface deflection was subtracted from the total aerodynamic coefficient described by the FDR data. The resultant "delta-aerodynamic-coefficient" was then used to define control surface positions necessary to produce the equivalent aerodynamic coefficient, or resultant motion. However, the "delta-aerodynamic-coefficient" may have resulted from forces and moments other than those produced solely by control surface inputs. For example, forces and moments associated

6

with turbulence or aerodynamic wing stall may produce similar motion with different control surface inputs. In the case of the airplane's yaw axis, the resultant delta yaw moment coefficient may have resulted from a combination of rudder surface deflection, turbulence from a wake vortex, and/or other event that would produce yawing moments. The results of the study are included in Exhibit 13G.

Time Correlation of Data

FDR and CVR microphone keying information were used to help establish a time correlation between the Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR) on Flight 427. The CVR transcript gives the beginning of each radio transmission in local time (EDT). The FDR records whether the microphone is "keyed" (on) or "not keyed" (off) once each second.

For the purposes of this study, power to the FDR and CVR was assumed to be removed simultaneously. The CVR transcript identifies this time as 31:02.6 Elapsed Time. The FDR indicates this time as 32:39.9 Elapsed Time. Therefore:

CVR Elapsed Time + 0001:37.3 yields FDR Elapsed Time

The 97.3 second offset added to CVR Elapsed Time produced the FDR's Elapsed Time, to the nearest second. The time correlation was used to further compare the FDR and CVR data.

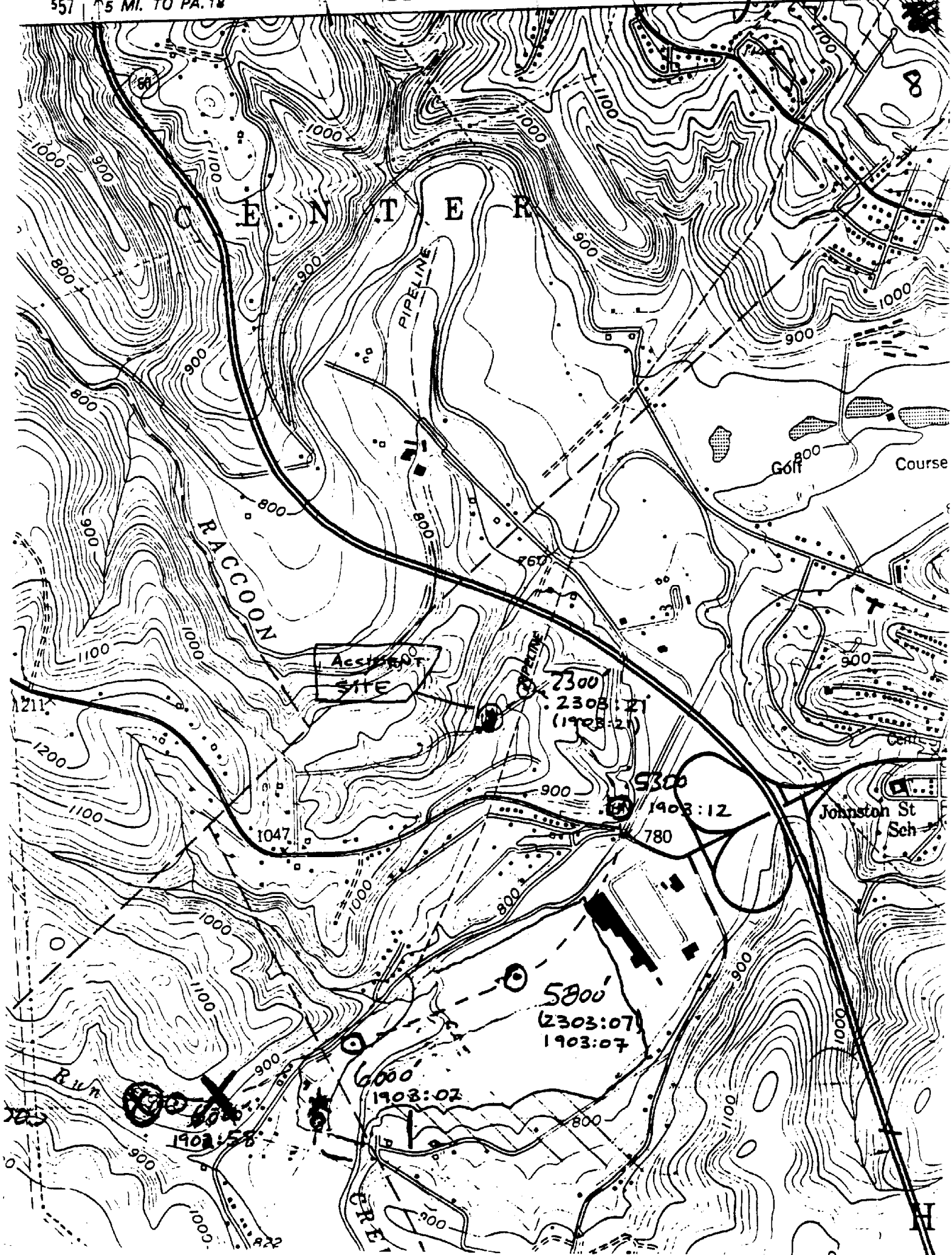
A plot of USA427 FDR data overlayed with selected CVR excerpts is included in Attachment 5. The plot covers the time from 130 to 160 FDR elapsed time.


Tom Jacky
Aerospace Engineer

Attachments

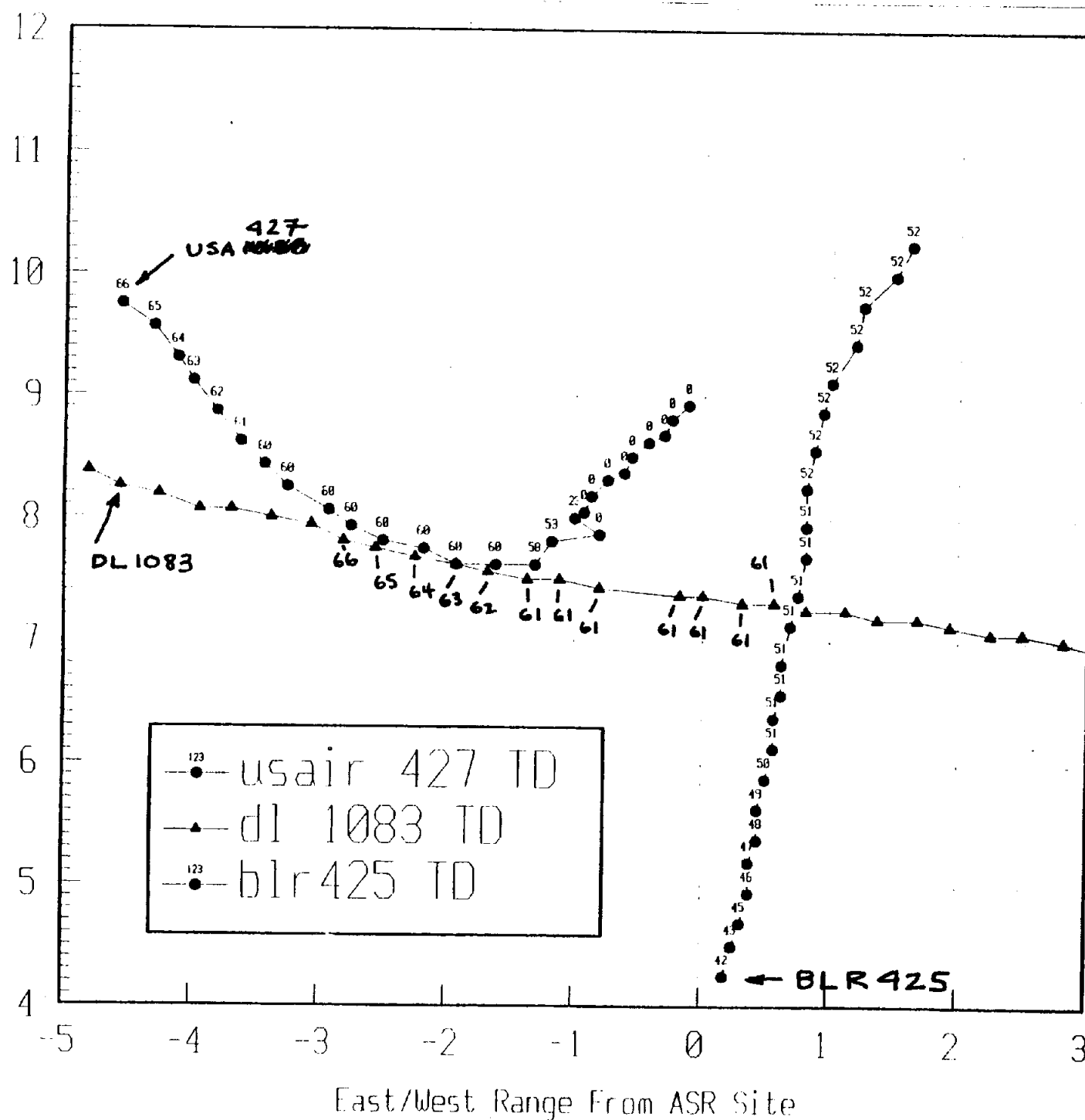
1. Recorded Radar Data
2. First Simulator Session
3. Second Simulator Session
4. Third Simulator Session
5. CVR Correlation

ATTACHMENT 1**Recorded Radar Data**



X & Y
positions
plotted
are
"X" & "Y"
From
Tracking
Data
Sets
& extracted
from
extractor
tapes

North/South Range from ASR site



USAir 427 & Delta 1083 Separation Table

Aircraft	Radar Return UCT	X - Position (n.m.)	Y - Position (n.m.)	Mode C Alt (100s of Ft)	Vertical Separation (Feet)	Lateral Separation (n.m.)
USAir 427 Delta 1083	2301:30.01 2301:30.09	-5.875 -3.063	11.188 7.938	72 66	600	4.3
USAir 427 Delta 1083	2301:34.59 2301:34.70	-5.688 -2.813	10.938 7.813	72 66	600	4.2
USAir 427 Delta 1083	2301:39.17 2301:39.45	-5.500 -2.583	10.750 7.750	71 65	600	4.2
USAir 427 Delta 1083	2301:43.78 2301:43.95	-5.313 -2.250	10.375 7.688	70 64	600	4.2
USAir 427 Delta 1083	2301:48.45 2301:48.57	-5.125 -1.938	10.375 7.625	69 63	600	4.2
USAir 427 Delta 1083	2301:53.06 2301:53.16	-4.938 -1.688	10.125 7.563	68 62	600	4.1
USAir 427 Delta 1083	2301:57.65 2301:57.95	-4.750 -1.375	9.938 7.500	67 61	600	4.2
USAir 427 Delta 1083	2302:02.32 2302:02.54	-4.563 -1.125	9.750 7.500	66 61	500	4.1
USAir 427 Delta 1083	2302:06.95 2302:07.17	-4.313 -0.813	9.500 7.438	65 61	400	4.1
USAir 427 Delta 1083	2302:11.95 2302:11.77	-4.125 -0.500	9.313 7.375	64 61	300	4.1
USAir 427 Delta 1083	2302:16.14 2302:16.46	-4.000 -0.188	9.125 7.375	63 61	200	4.2
USAir 427 Delta 1083	2302:20.71 2302:21.14	-3.813 0.000	8.875 7.375	62 61	100	4.1
USAir 427 Delta 1083	2302:25.45 2302:25.76	-3.625 0.313	8.625 7.313	61 61	0	4.2
USAir 427 Delta 1083	2302:30.08 2302:30.45	-3.438 0.563	8.438 7.313	60 61	0	4.2
USAir 427 Delta 1083	2302:34.70 2302:35.02	-3.250 0.813	8.250 7.250	60 60	0	4.2
USAir 427 Delta 1083	2302:39.29 2302:39.64	-2.938 1.125	8.063 7.250	60 60	0	4.1
USAir 427 Delta 1083	2302:43.95 2302:44.20	-2.750 1.375	7.938 7.188	60 60	0	4.2
USAir 427 Delta 1083	2302:48.53 2302:48.96	-2.500 1.688	7.813 7.188	60 60	0	4.2
USAir 427 Delta 1083	2302:53.15 2302:53.61	-2.188 1.938	7.750 7.125	60 60	0	4.2
USAir 427 Delta 1083	2302:57.76 2302:58.16	-1.938 2.250	7.625 7.063	60 60	0	4.5
USAir 427 Delta 1083	2303:02.45 2303:02.81	-1.625 2.500	7.625 7.063	60 60	0	4.2
USAir 427 Delta 1083	2303:07.13 2303:07.46	-1.313 2.813	7.625 7.000	58 60	-200	4.2
USAir 427 Delta 1083	2303:11.77 2303:12.14	-1.188 3.063	7.813 6.938	53 60	-700	4.3

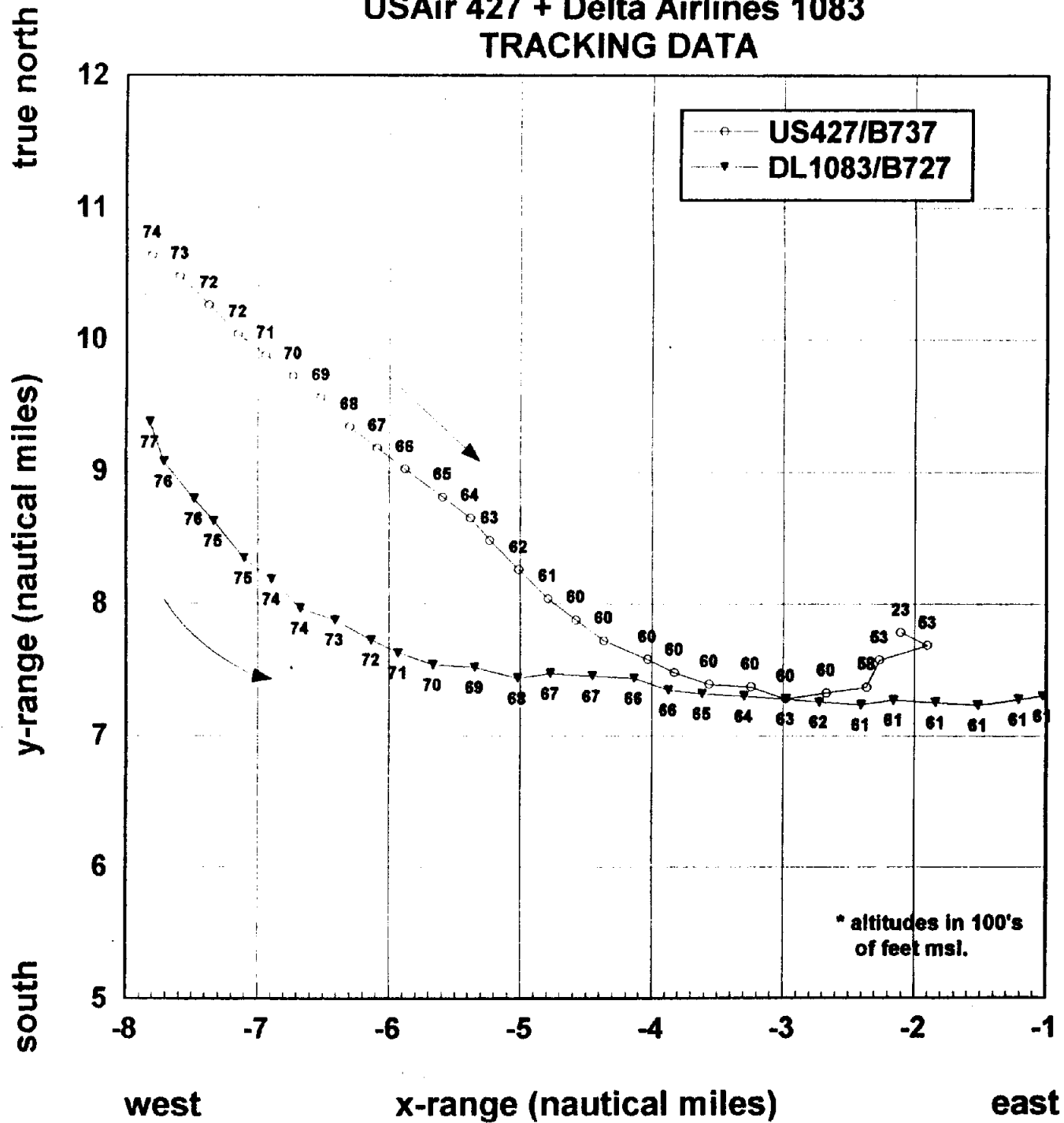
2.2
11

USAir 427 & Blue Ridge 425 Separation Table

Aircraft	Radar Return UCT	X - Position (n.m.)	Y - Position (n.m.)	Mode C Alt (100s of Ft)	Vertical Separation (Feet)	Lateral Separation (n.m.)
USAir 427 BLR 425	2302:48.53 2302:48.00	-2.500 0.120	7.810 4.050	60 41	1900	4.2
USAir 427 BLR 425	2302:53.15 2302:53.47	-2.188 0.188	7.75 4.250	60 42	1800	4.2
USAir 427 BLR 425	2302:57.76 2302:58.05	-1.938 0.250	7.625 4.500	60 43	1700	3.8
USAir 427 BLR 425	2303:02.45 2303:02.70	-1.625 0.313	7.625 4.688	60 45	1500	3.5
USAir 427 BLR 425	2303:07.14 2303:07.33	-1.313 0.375	7.625 4.938	58 46	1200	3.2
USAir 427 BLR 425	2303:11.76 2303:11.97	-1.188 0.375	7.813 5.188	53 47	600	3.1
USAir 427 BLR 425	2303:20.96 2303:21.97	-1.000 0.438	8.000 5.625	23 49	-2600	2.8

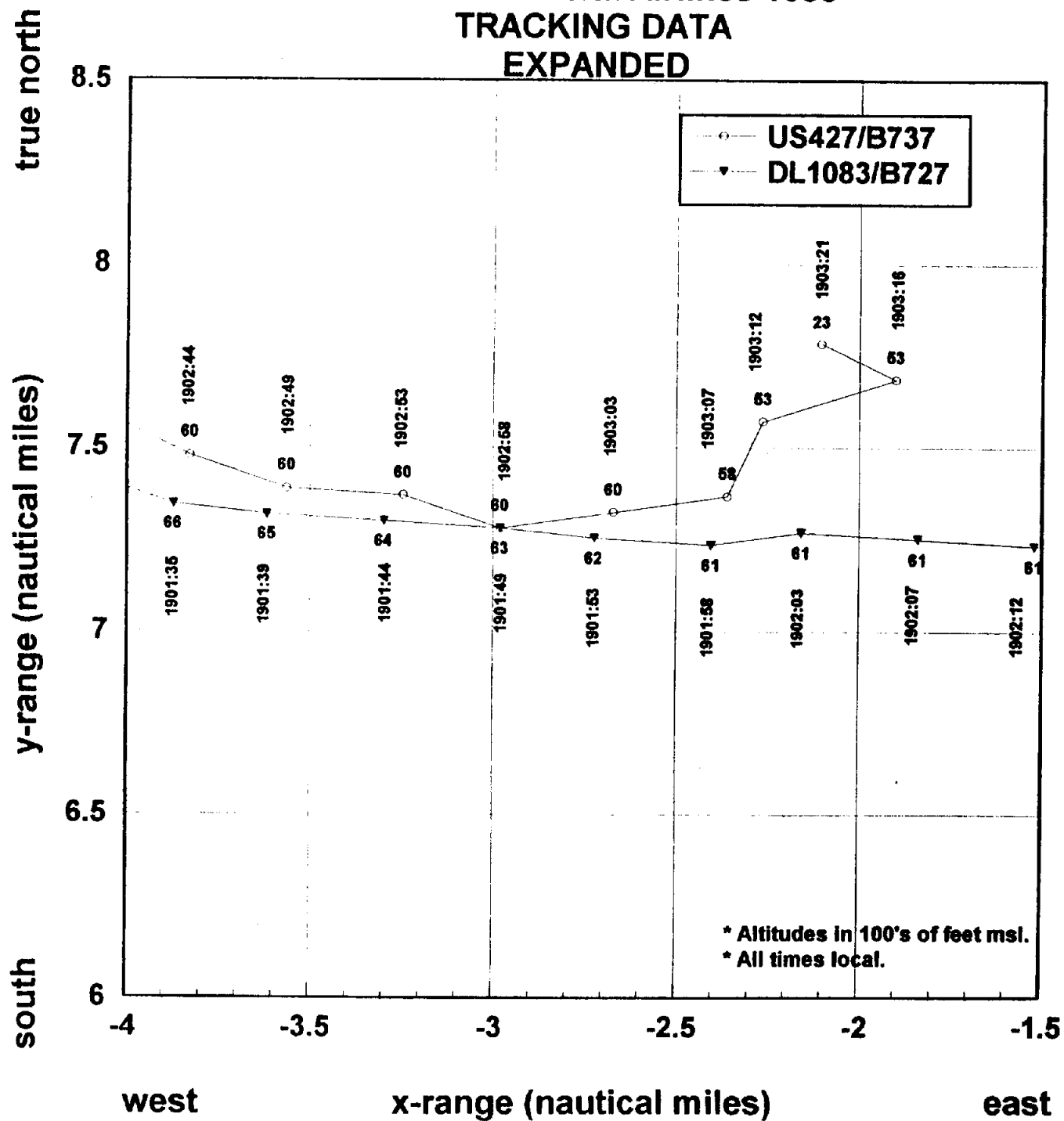
4-0

USAir 427 + Delta Airlines 1083 TRACKING DATA



42

USAir 427 + Delta Airlines 1083 TRACKING DATA EXPANDED



13

ATTACHMENT 2

First Simulator Session

List of Simulator Failures or Malfunction Scenarios Attempted

- 1) 1 engine cut at climb power by using fuel lever - to use as baseline for the type of upset
- 2) Rudder hardover rates:
 - a) 0.5°/second
 - b) 2.5°/second
 - c) 5°/second
 - d) 10°/second
 - e) Maximum rate (52°/second)
 - f) Maximum Yaw Damper Input
- 3) Input rudder hardover, let aircraft roll to 80°, then pull column back into stickshaker
- 4) Leading Edge Assymetry, with or without auto-slats (number 2 slat)
- 5) Auto-slat misfire at stickshaker
- 6) Initial rudder input, hands off wheel (i.e. no aileron input) then pull column back
- 7) Backdrive the simulator with FDR data control inputs to replicate the FDR data
- 8) Put in maximum rudder position and maximum wheel position and then hold in - adverse wheel and rudder
- 9) Limited lateral control - eliminate roll control spoilers
- 10) Check of aircraft roll rates
 - a) δ_{WH} - wheel input rate
 - b) δ_R - rudder input rate
 - c) $\delta_{WH} + \delta_R$ - additive rate
 - d) $\delta_{WH} + \delta_R$ - adverse rate

**SUMMARY OF BOEING ENGINEERING FLIGHT SIMULATOR RUNS FOR
USAIR FLIGHT 427 INVESTIGATION - AIRCRAFT PERFORMANCE GROUP
September 22, 1994**

<u>RUN #</u>	<u>SCENARIO SUMMARY</u>
1	Maximum wheel roll rate, no rudder input
2	Maximum wheel roll rate, rudder input - wheel added after rudder
3	Maximum wheel roll rate to left using wheel only, roll LWD & return to 0° bank using max right rate
4	Maximum wheel roll rate using wheel and rudder input
5	Maximum adverse right wheel & left rudder - stick shaker and auto-slat fired
6	Failure using left engine cut @ 5700', free controls - IAS too high ~200 KIAS
7	Repeat scenario no. 6, IAS closer to 190 KIAS - speedbrake handle up
8	Repeat scenario no. 6, without speedbrake input
9	Repeat scenario no. 6, with pilot recovery input @ roll = 45°, used full wheel and pedal input
10	Repeat scenario no. 6, with pilot recovery input @ roll = 45°, used wheel input only
11	0.5°/sec. rudder input, no auto-pilot (A/P), pilot recover @ roll = 90°
12	Repeat scenario no. 11, A/P on, missed onset of the full wheel and rudder
13	2.5°/sec rudder input, A/P off, recovery initiated at roll = 90°
14	Repeat scenario no. 13, but A/P on
15	Repeat scenario no. 13 - No Data
16	2.5°/sec rudder input, A/P on, no recovery attempted
17	Repeat scenario 16 - CANCEL
18	Repeat scenario 16 - rudder input at 8° bank; pull at -70° pitch
19	5°/sec rudder input, no A/P; no recovery attempted
20	Repeat scenario 19, A/P on
21	10°/sec rudder input - Abort
22	Repeat scenario 21, A/P off
23	Repeat scenario 21, A/P on
24	Maximum rudder input, A/P off
25	Repeat scenario 24, A/P off, Y/D off
26	Repeat scenario 24, A/P on, Y/D on
27	2.5°/sec rudder input, A/P on, at roll = 70°, pull to stickshaker; A/P on throughout maneuver
28	2.5°/sec rudder input, A/P off, roll = 70° pull back
29	2.5°/sec rudder input, A/P on, disconnect A/P at roll = 55° and pull column back to stickshaker

RUN**SCENARIO SUMMARY**

30 Roll checks - A/P on and off
31 2.5 °/sec rudder input, A/P off - Practice - data not plotted
32 Cancel
33 Cancel
34 Cancel - data plotted
35 2.5°/sec rudder input, at roll = 20° pull column to stickshaker,
auto-pilot disconnect at 8° roll
36 Auto-slat fail to fire, flaps = 5°
37 Repeat scenario 36
38 Repeat scenario 36, pull column back into stall
39 Slat Assymetry
40 2.5°/sec rudder input, disconnect A/P at 60° - 70° roll
41 Yaw damper hardover
42 Repeat scenario 41
43 Abort
44 Dual Flight Spoilers Hardover
45 Repeat scenario 44

ATTACHMENT 3**Second Simulator Session**

**SUMMARY OF BOEING ENGINEERING FLIGHT SIMULATOR RUNS FOR
USAIR FLIGHT 427 INVESTIGATION AIRCRAFT PERFORMANCE GROUP
October 12, 1994**

<u>RUN #</u>	<u>SCENARIO SUMMARY</u>
1	Check of airplane model, distributed lift model off
2	Repeat scenario 1, distributed lift model off, on, and off
3	Distributed lift model on, $\Gamma = 2125 \text{ ft}^2/\text{sec}$, intercept vortex
4	Repeat of scenario no. 3
5	Repeat scenario no. 3, intercept angle of airplane to vortex = 5° , auto-pilot (A/P) on
6	Hand-fly airplane, check of distributed lift model
7	Descend through vortex, with A/P on
8	Repeat scenario 7
9	Below vortex
10	Below vortex
11	Airplane placed in center of the vortex
12	Repeat scenario no. 11
13	Repeat scenario no. 11, airplane altitude +8'
14	Abort
15	Wake $\Gamma = 1200 \text{ ft}^2/\text{sec}$, a/c left of vortex, A/P on
16	Repeat scenario no. 15, MCAB motion on
17	Wake $\Gamma = 1700 \text{ ft}^2/\text{sec}$, a/c left of vortex, A/P on
18	A/C below wake, A/P on, climb through wake
19	Repeat scenario 18, climb at 350 FPM
20	Wake $\Gamma = 2125 \text{ ft}^2/\text{sec}$
21	A/C cg in middle of wake, free response
22	A/C in center of wake
23	Wake $\Gamma = 1200 \text{ ft}^2/\text{sec}$, fly through middle of wake
24	Repeat scenario 23
25	Wake $\Gamma = 1500 \text{ ft}^2/\text{sec}$, wake descend on airplane
26	Repeat scenario 25
27	Repeat scenario 25
28	Repeat scenario 25
29	ABORT
30	ABORT
31	Wake speed -10, A/C placed 200' left of vortex
32	Repeat scenario 31
33	Repeat scenario 31
51	Wake $\Gamma = 1500 \text{ ft}^2/\text{sec}$, a/c left of wake intercept angle = 10°
52	Repeat scenario 51, a/c position -10'
53	Repeat scenario 51, a/c position -20'

RUN #**SCENARIO SUMMARY**

53a Repeat scenario 51, a/c position -30'
 54 Increase intercept angle to 20°
 55 Repeat scenario 54, a/c position change to 5980 (-20)
 56 Repeat scenario 54, a/c position change to 5990 (-10)
 57 Increase intercept angle to 30°
 59 Wake $\Gamma = 1200 \text{ ft}^2/\text{sec}$, a/c intercept angle = 5°
 60 Wake $\Gamma = 1000 \text{ ft}^2/\text{sec}$
 61 Wake $\Gamma = 800 \text{ ft}^2/\text{sec}$
 62 Repeat scenario 61
 63 Repeat scenario 61
 64 Wake $\Gamma = 1500 \text{ ft}^2/\text{sec}$, core radius = 2', position = -10
 65 Repeat scenario 64
 66 Repeat scenario 64
 67 Change a/c position to 5990'
 68 Repeat scenario 67
 69 Wake $\Gamma = 2125 \text{ ft}^2/\text{sec}$, a/c position 5980'
 70 Repeat scenario 69, a/c position -10'
 71 Repeat scenario 70
 72 Repeat scenario 70, a/c position below wake, 300 FPM
 73 Repeat scenario 72, climb at 800 FPM
 74 Repeat scenario 73
 75 A/C top of wake, descend to right of wake
 76 Start in core of vortex, A/P off
 77 CG in center of wake, free response of a/c
 78 Repeat scenario 77
 79 Pilot attempt to stay in vortex core
 80 Wake $\Gamma = 1500 \text{ ft}^2/\text{sec}$, pilot attempt to stay in vortex core
 81 Repeat 80

START P.M. SESSION

100 Wake $\Gamma = 1500 \text{ ft}^2/\text{sec}$, core $r = 8.5'$, A/P on, a/c below wake,
 wake $\phi = -3.5^\circ$, wake $V_{\text{spd}} = 0$
 101 repeat scenario 100, wake $v_{\text{spd}} = 300 \text{ FPM}$
 102 Repeat 101
 103 Airplane offset to left of wake
 104 Repeat 103
 105 Offset
 106 Cancel
 107 Repeat 105 - problem of run 106 corrected
 108 Simulator motion on - repeat 105
 109 Wake $\Gamma = 2125 \text{ ft}^2/\text{sec}$

RUN #**SUMMARY SCENARIO**

110 Repeat 109, A/C offset 29' below wake
 111 Repeat 109, A/C offset 39' below wake
 112 Repeat 109, A/C offset 50' below wake
 113 Repeat 109, A/C offset 60', middle of vortex
 114 Change core radius to $r = 2'$
 115 Repeat 114
 116 Repeat 114
 117 Wake $\Gamma = 1500 \text{ ft}^2/\text{sec}$
 118 Change offset to 50' below wake
 119 Wake $v_{\text{spd}} = 300 \text{ FPM}$
 120 Wake $\Gamma = 2125 \text{ ft}^2/\text{sec}$
 121 Airplane intercept = 30°
 122 Airplane intercept = 20°
 123 Airplane intercept = 10°
 124 Core size $r = 8.5'$
 125 A/P turn - missed wake
 126 Repeat 125
 127 Repeat 125
 128 Wake $\Gamma = 1500 \text{ ft}^2/\text{sec}$, repeat A/P turn
 129 Core radius $r = 2'$, A/P turn
 130 Left core $\Gamma = 1500 \text{ ft}^2/\text{sec}$, right core $\Gamma = 2125 \text{ ft}^2/\text{sec}$
 131 Left core $\Gamma = 2125 \text{ ft}^2/\text{sec}$, right core $\Gamma = 1500 \text{ ft}^2/\text{sec}$
 132 Left core $\Gamma = 2100 \text{ ft}^2/\text{sec}$, right core $\Gamma = 500 \text{ ft}^2/\text{sec}$
 133 Repeat scenario 132
 134 A/P off - end below wake
 135 Wake = 0, A/P off
 136 Repeat 135
 137 Left wake $\Gamma = 0$, right wake $\Gamma = 2125 \text{ ft}^2/\text{sec}$, core = $2'$, $\phi = 10^\circ$,
 A/P on
 138 Reverse intercept
 139 A/P turn from 140° to 100° heading
 140 +15 FFA

ATTACHMENT 4

Third Simulator Session

**SUMMARY OF BOEING ENGINEERING FLIGHT SIMULATOR RUNS FOR
USAIR FLIGHT 427 INVESTIGATION AIRCRAFT PERFORMANCE GROUP
NOVEMBER 2, 1994**

<u>RUN #</u>	<u>SCENARIO SUMMARY</u>
1	Heading change from 140° to 100°, Auto-Throttles on, Yaw Damper (Y/D) on, a/c @ 190 KIAS
2	Same scenario as no. 1, except Yaw Damper off
3	Control Wheel Steering (CWS) turn from 140° to 100°, Y/D on
4	Repeat of scenario no. 3
5	Basic airplane, pull column back to stickshaker
6	Repeat of scenario no. 5
7	Distributed lift model off, Horizontal tail model on, repeat no. 5
8	Distributed lift model off, Horizontal tail model off, check free response of airplane from column pitch-ups - pitch doublets
9	Repeat scenario 8, with distributed lift model on, horizontal tail model on - pitch doublets
10	Distributed lift model off, horizontal tail model off, Y/D off, rudder doublets - check of dutch roll
11	Repeat scenario no. 10
12	Repeat scenario no. 10, distributed lift model on, horizontal tail model off, vertical tail model on
13	Distributed lift model on, vertical tail model off, auto-pilot off, auto-throttle off, Y/D off; center of RH wake vortex ($r = 2$ ft., $\Gamma = 1500$ ft ² /sec.)
14	Repeat scenario no. 13, but Y/D on
15	Repeat scenario no. 13, Y/D off, vertical tail model on
16	Repeat scenario no. 13, Y/D on, vertical tail model on
101	Check of auto-throttle rates - ABORT
102	Repeat scenario 101, increase IAS
103	Repeat scenario 101, increase IAS
104	Repeat scenario 101, decrease IAS
105	Check of auto-throttle rates, increase IAS then decrease IAS
106	Repeat scenario 105 - ABORT
107	Check of auto-throttle - dial speed up and then dial speed down
108	Distributed lift model on, horizontal tail model off, vertical tail model on, attempted wake vortex intercept - missed intercept attempt
109	Repeat scenario 108
110	Left wake $\Gamma = 0$, right wake $\Gamma = 1500$ ft ² /sec., auto-pilot on; attempted intercept from left of wake
111	ABORT

RUN #**SCENARIO SUMMARY**

112	Enter rudder into scenario
113	ABORT
114	ABORT
115	ABORT
116	Retry entry of rudder input
117	Repeat scenario 116, attempt pilot recovery @ roll = 40°
118	ABORT
119	Repeat scenario 116, attempt pilot recovery @ roll = 60°
120	Repeat scenario 119
121	Repeat scenario 120, input 3°/sec rudder pedal rate
122	Repeat scenario 121, pull column back then roll airplane
123	Repeat scenario 122, input rudder little sooner
124	Repeat scenario 122, let auto-pilot recover
125	Repeat scenario 124, roll into then rudder @ 90° roll
126	Attempt wake intercept w/ only tail entrance into wake
127	Start with aircraft underneath right wake vortex
128	Repeat scenario 127

ATTACHMENT 5**CVR Correlation**

USAIR 427