NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, D.C. 20594

September 26, 2000

Radar Data Study

Radar Data Study
by Daniel R. Bower, Ph.D.

A. ACCIDENT

Location:	Aberdeen, SD
Date:	October 25, 1999
Time:	1226 local time (CDT)
Aircraft:	Learjet Model 35
	N47BA
NTSB#:	DCA00MA005

B. GROUP

Not Applicable

C. SUMMARY

A Learjet crashed near Aberdeen (and Mina), South Dakota, on October 25, 1999. The aircraft, a Learjet model 35, registration number N47BA, was operated by Sun Jet Aviation of Sanford, Florida. It was built in 1976, and is serial number 60.

The aircraft was flown from Sanford to Orlando, Florida, on the morning of the accident, where it picked up its passengers. The flight departed Orlando with two pilots and four passengers, including professional golfer Payne Stewart, about 0919 eastern daylight time (EDT), destined for Love Field in Dallas, Texas. The planned flight time was 2 hours. The airplane had about 4 hours 45 minutes of fuel aboard.

Air traffic control lost radio contact with the flight at 9:44 a.m. eastern daylight time, when the airplane was climbing through 37,000 feet and located northwest of Gainesville, Florida. The flight was cleared to 39,000 feet. The aircraft proceeded on a northwest heading. The aircraft was intercepted at about 45,000 feet by military aircraft, which followed the plane until it crashed near Aberdeen, South Dakota.

This study examines the radar data for N47BA and correlates when various events occurred. Federal Aviation Administration (FAA) radar data, Air Traffic Control (ATC) communication data, and Cockpit voice recorder (CVR) data were used to develop the time history described in this report.

D. DETAILS OF THE INVESTIGATION

Section I - Radar Data

Radar data was obtained for the initial part of the flight as the airplane departed from Orlando and headed north-westerly. Air Route Surveillance Radar (ARSR) data was obtained from the FAA's Jacksonville Traffic Control Center (ARTCC) output using the National Track Analysis Program (NTAP). Airport Surveillance Radar (ASR) data was acquired from Orlando International Airport (MCO), Gainesville Florida (GNV), and Daytona Beach Florida (DAB). Radar data was also obtained for the final portion of the flight from the FAA's Minneapolis ARTCC and from the US Air Force 84th Radar Evaluation Squadron (RADES).

ASR radar normally records data approximately every 4½ seconds, but NTAP data is only recorded every 12 seconds. Both transponder radar returns and primary radar data (i.e. "skin paint") were recorded in the various ASR data sets. N47BA was using a beacon code of 3245 during its entire flight.

The ASR range/azimuth transponder beacon radar data and primary radar data for the accident flight was provided by the FAA. The format supplied by the FAA contains time in hours, minutes, seconds, range from the radar site in nautical miles (NM), azimuth in ACP's (4096 ACP's = 360°), flight level in 100's of feet-msl, and beacon code (3245). The range-azimuth-altitude format for each data set was converted to x-y-altitude format relative to the respective radar antenna using the appropriate magnetic variation for each radar site. In this converted x-y coordinate system, x represents true east and y is true north in nautical miles from the radar antenna. NTAP data and USAF RADES data was obtained in latitude-longitude-altitude format, and are similarly converted to the same x-y-altitude coordinates as the ASR data sets for the early radar data, and were converted relative to the accident site for the data near the end of the flight.

Figure 1 shows a ground track of N47BA as it climbed from Orlando. Radar data from several sites have been overlaid on this plot, and selected radar returns are labeled with Universal Time Code (UTC) time and mean sea level (MSL) altitude. Figure 2 shows a similar plot, with conversations with ATC during the climb out overlaid onto the ground track. The final transmission from N47BA was at 1327:18 UTC (0927:18 EDT) when the aircraft was at an altitude of 23,200 ft-msl. ATC received no response from N47BA at 1333:38 UTC. Figure 3 shows the altitude time history during the ascent Figure 4 shows a portion of the groundtrack after the final transmission from N47BA, and prior to the first ATC attempt to contact N47BA. The grountrack shows a slight change in heading of approximately six degrees to the north at approximately 1330:45 UTC. Figure 5 shows additional air traffic in the vicinity of N47BA during its ascent.

During the final portion of the flight, only ARTCC data and USAF RADES radar data was available. The ground track of the accident aircraft, and other aircraft in the

area for the final 12 minutes of flight of N47BA are shown in Figures 6 and 7, with UTC time and altitude noted. Figures 8 and 9 show the groundtrack of N47BA only in the final minutes of flight. The slight difference in groundtracks between the ZMP radar data and the USAF RADES data is due to the error in sensed position for each radar system, which increases with increasing distance from each radar antenna.

Data from the CVR was correlated with the radar data by correlating the time of the altitude alert heard on the CVR. Prior to the final descent, the aircraft was flying at 48,800 ft-msl. The autopilot altitude selector was located in the aircraft wreckage, set at a flight level of 390 (39,000 feet). Hence the sound of the altitude alert on the CVR was used to correlate to a USAF RADES radar sensed altitude of 40,000 feet. An overlay of the CVR data onto plots of altitude versus time, and of X and Y distance versus time are shown in Figure 10.

Files are available electronically on the public docket that contains all of the radar data for N47BA in ASCII tabular format. All files contain UTC time, latitude, longitude, transponder altitude, and converted x-y-altitude coordinates as shown on the plots. The ASR radar data files also contain the raw range-azimuth from the respective radar site. The files are detailed below.

File	**Description**
3245bcn_zjx.txt	Radar data from Jacksonville ARTCC
3245bcn_mco.txt	ASR Radar data from Orlando
3245bcn_gnv.txt	ASR Radar data from Gainesville
3245bcn_dtb.txt	ASR Radar data from Daytona Beach
3245bcn_zmp.txt	Radar data from Minneapolis ARTCC
Rades_3245.txt	USAF RADES Radar data

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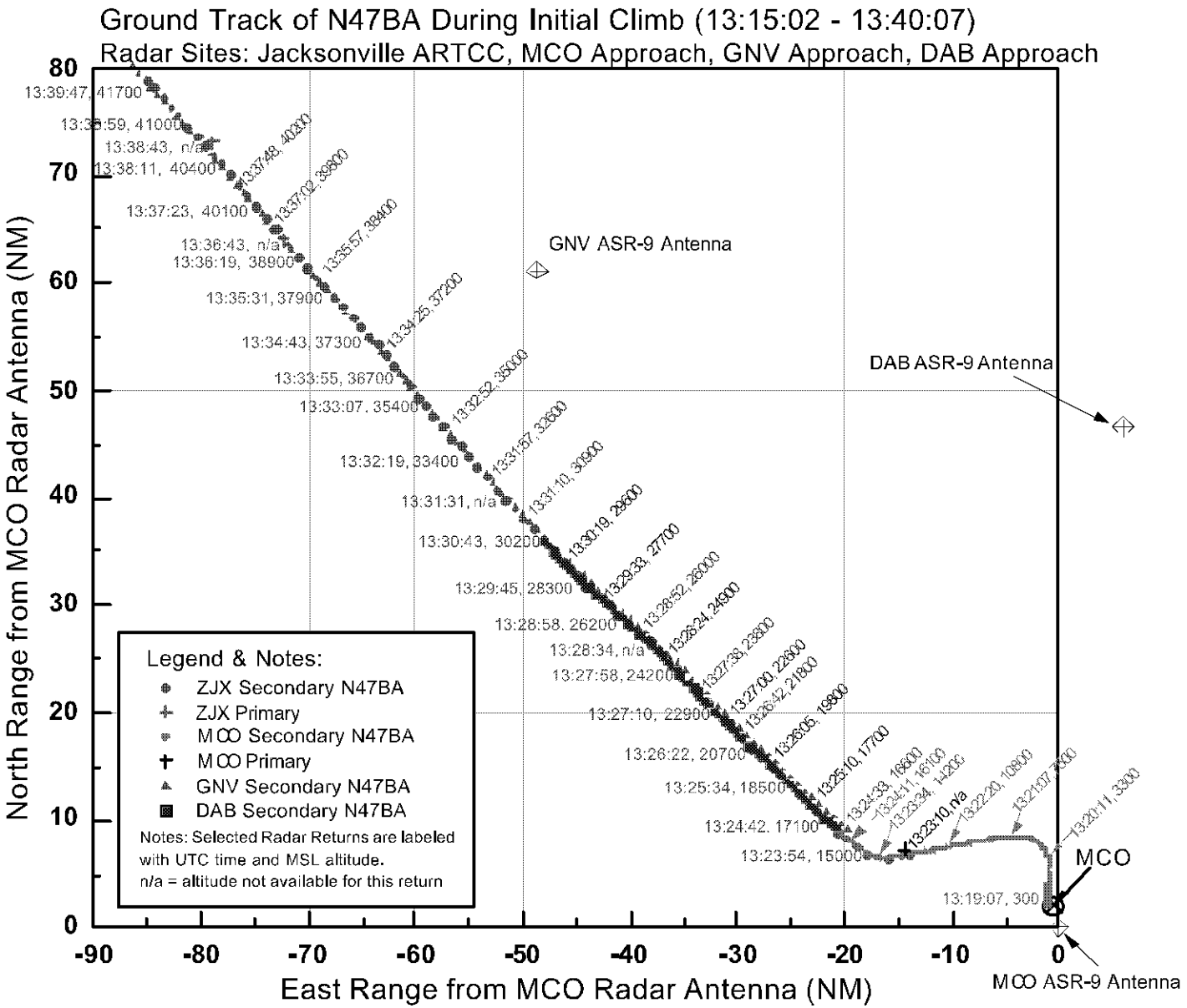
Ground Track of N47BA During Initial Climb (13:15:02 - 13:40:07)
Radar Sites: Jacksonville ARTCC, MCO Approach, GNV Approach, DAB Approach
North Range from MCO Radar Antenna (NM)
East Range from MCO Radar Antenna (NM)
GNV ASR-9 Antenna
DAB ASR-9 Antenna
MCO
MCO ASR-9 Antenna
Legend & Notes:
ZJX Secondary N47BA
ZJX Primary
MCO Secondary N47BA
MCO Primary
GNV Secondary N47BA
DAB Secondary N47BA
Notes: Selected Radar Returns are labeled with UTC time and MSL altitude.
n/a = altitude not available for this return
13:39:47, 41700
13:38:43, n/a
13:38:11, 40400
13:37:48, 40200
13:37:23, 40100
13:37:02, 39800
13:36:43, n/a
13:36:19, 38900
13:35:57, 38400
13:35:31, 37900
13:34:43, 37300
13:34:25, 37200
13:33:55, 36700
13:33:07, 35400
13:32:52, 35000
13:32:19, 33400
13:31:57, 32600
13:31:31, n/a
13:31:10, 30900
13:30:43, 30200
13:30:19, 29600
13:29:45, 28300
13:29:33, 27700
13:28:58, 26200
13:28:52, 26000
13:28:34, n/a
13:28:24, 24900
13:27:58, 24200
13:27:39, 23600
13:27:10, 22900
13:27:00, 22600
13:26:42, 21900
13:26:22, 20700
13:26:05, 19900
13:25:34, 18500
13:25:10, 17700
13:24:42, 17100
13:24:33, 16900
13:24:11, 16100
13:23:54, 15000
13:23:34, 14200
13:23:10, n/a
13:22:20, 10900
13:21:07, 7000
13:20:11, 3300
13:19:07, 300

Figure1

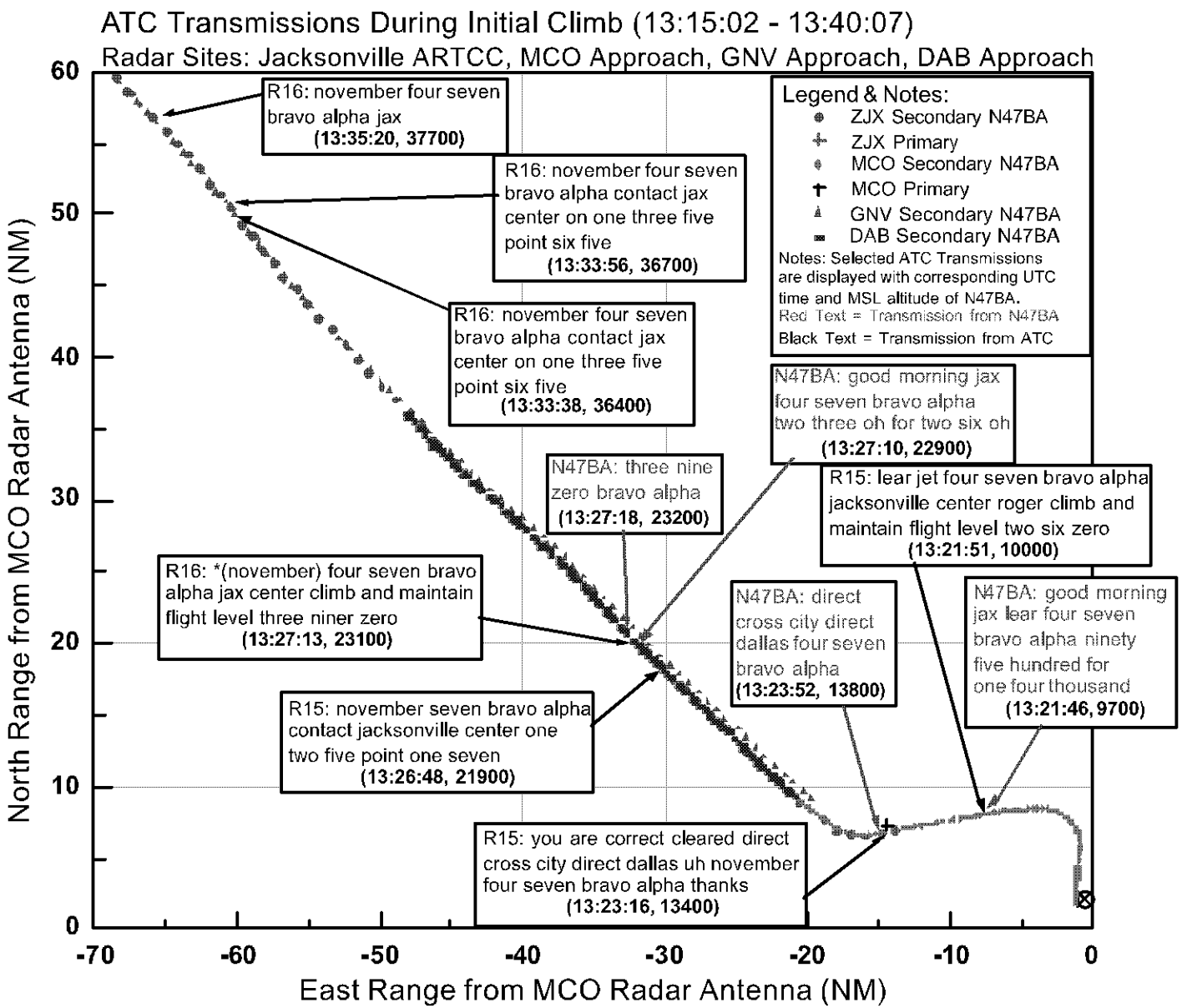
ATC Transmissions During Initial Climb (13:15:02 - 13:40:07)
Radar Sites: Jacksonville ARTCC, MCO Approach, GNV Approach, DAB Approach
North Range from MCO Radar Antenna (NM)
East Range from MCO Radar Antenna (NM)
60
50
40
30
20
10
0
-70
-60
-50
-40
-30
-20
-10
0
R16: november four seven bravo alpha jax (13:35:20, 37700)
R16: november four seven bravo alpha contact jax center on one three five point six five (13:33:56, 36700)
R16: november four seven bravo alpha contact jax center on one three five point six five (13:33:38, 36400)
N47BA: three nine zero bravo alpha (13:27:18, 23200)
R16: *(november) four seven bravo alpha jax center climb and maintain flight level three niner zero (13:27:13, 23100)
R15: november seven bravo alpha contact jacksonville center one two five point one seven (13:26:48, 21900)
R15: you are correct cleared direct cross city direct dallas uh november four seven bravo alpha thanks (13:23:16, 13400)
N47BA: direct cross city direct dallas four seven bravo alpha (13:23:52, 13800)
N47BA: good morning jax four seven bravo alpha two three oh for two six oh (13:27:10, 22900)
R15: lear jet four seven bravo alpha jacksonville center roger climb and maintain flight level two six zero (13:21:51, 10000)
N47BA: good morning jax lear four seven bravo alpha ninety five hundred for one four thousand (13:21:46, 9700)
Legend & Notes:
ZJX Secondary N47BA
ZJX Primary
MCO Secondary N47BA
MCO Primary
GNV Secondary N47BA
DAB Secondary N47BA
Notes: Selected ATC Transmissions are displayed with corresponding UTC time and MSL altitude of N47BA.
Red Text = Transmission from N47BA
Black Text = Transmission from ATC

Figure 2

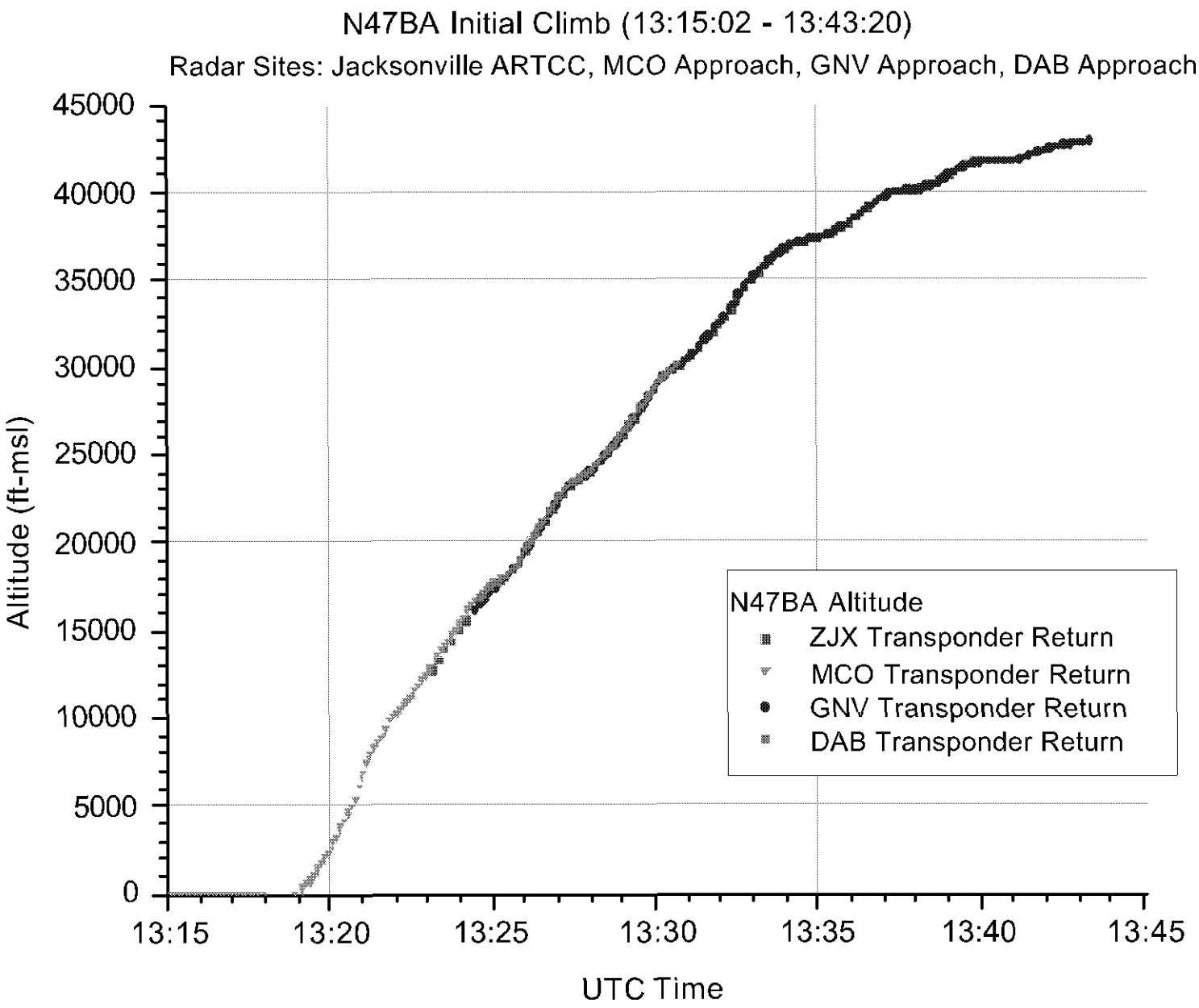
N47BA Initial Climb (13:15:02 - 13:43:20)
Radar Sites: Jacksonville ARTCC, MCO Approach, GNV Approach, DAB Approach
Altitude (ft-msl)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
13:15
13:20
13:25
13:30
13:35
13:40
13:45
UTC Time
N47BA Altitude
ZJX Transponder Return
MCO Transponder Return
GNV Transponder Return
DAB Transponder Return

Figure 3

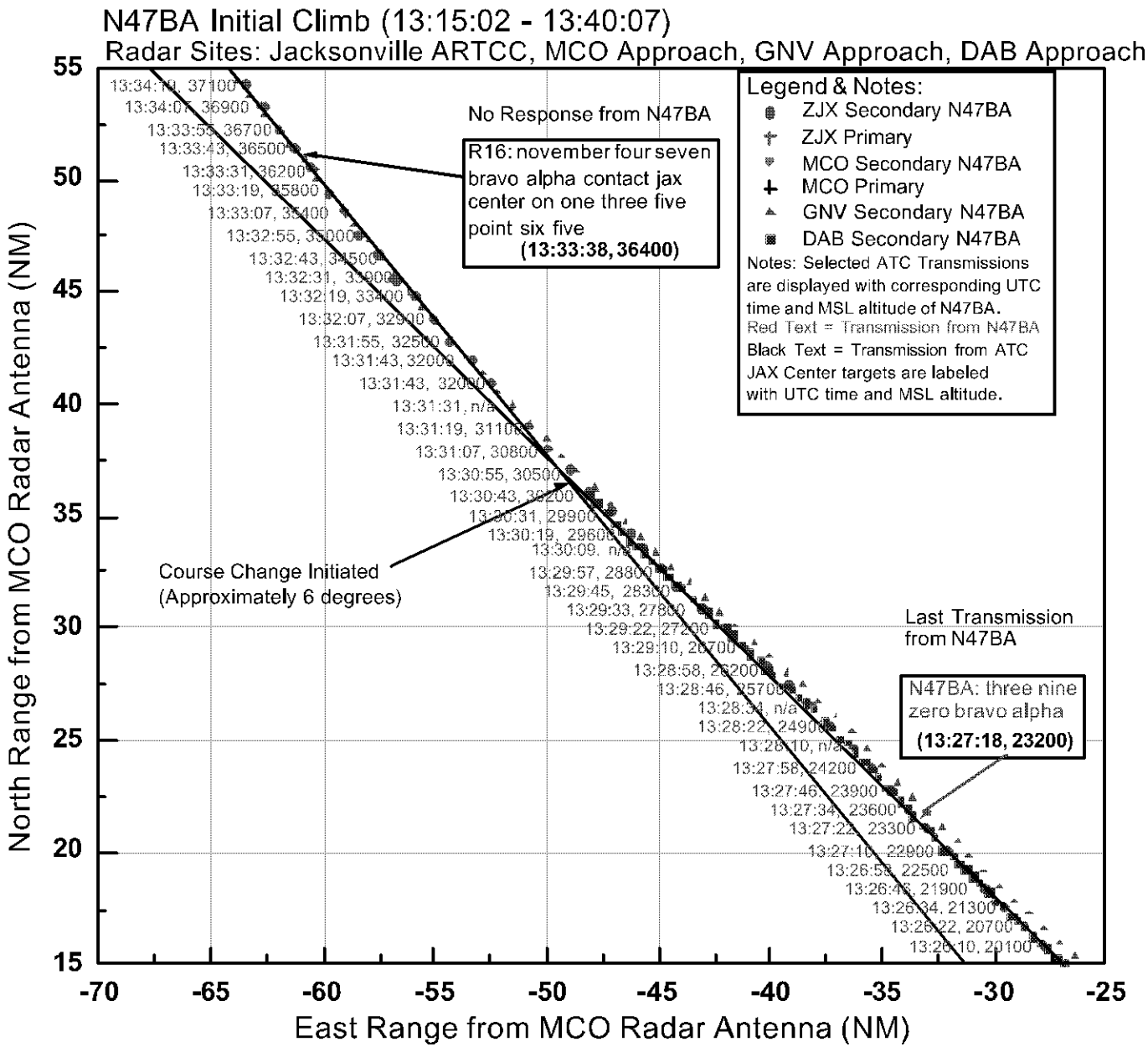
N47BA Initial Climb (13:15:02 - 13:40:07)
Radar Sites: Jacksonville ARTCC, MCO Approach, GNV Approach, DAB Approach
North Range from MCO Radar Antenna (NM)
East Range from MCO Radar Antenna (NM)
55
50
45
40
35
30
25
20
15
-70
-65
-60
-55
-50
-45
-40
-35
-30
-25
Legend & Notes:
ZJX Secondary N47BA
ZJX Primary
MCO Secondary N47BA
MCO Primary
GNV Secondary N47BA
DAB Secondary N47BA
Notes: Selected ATC Transmissions are displayed with corresponding UTC time and MSL altitude of N47BA.
Red Text = Transmission from N47BA
Black Text = Transmission from ATC
JAX Center targets are labeled with UTC time and MSL altitude.
No Response from N47BA
R16: november four seven bravo alpha contact jax center on one three five point six five
(13:33:38, 36400)
Course Change Initiated
(Approximately 6 degrees)
Last Transmission from N47BA
N47BA: three nine zero bravo alpha
(13:27:18, 23200)

Figure 4

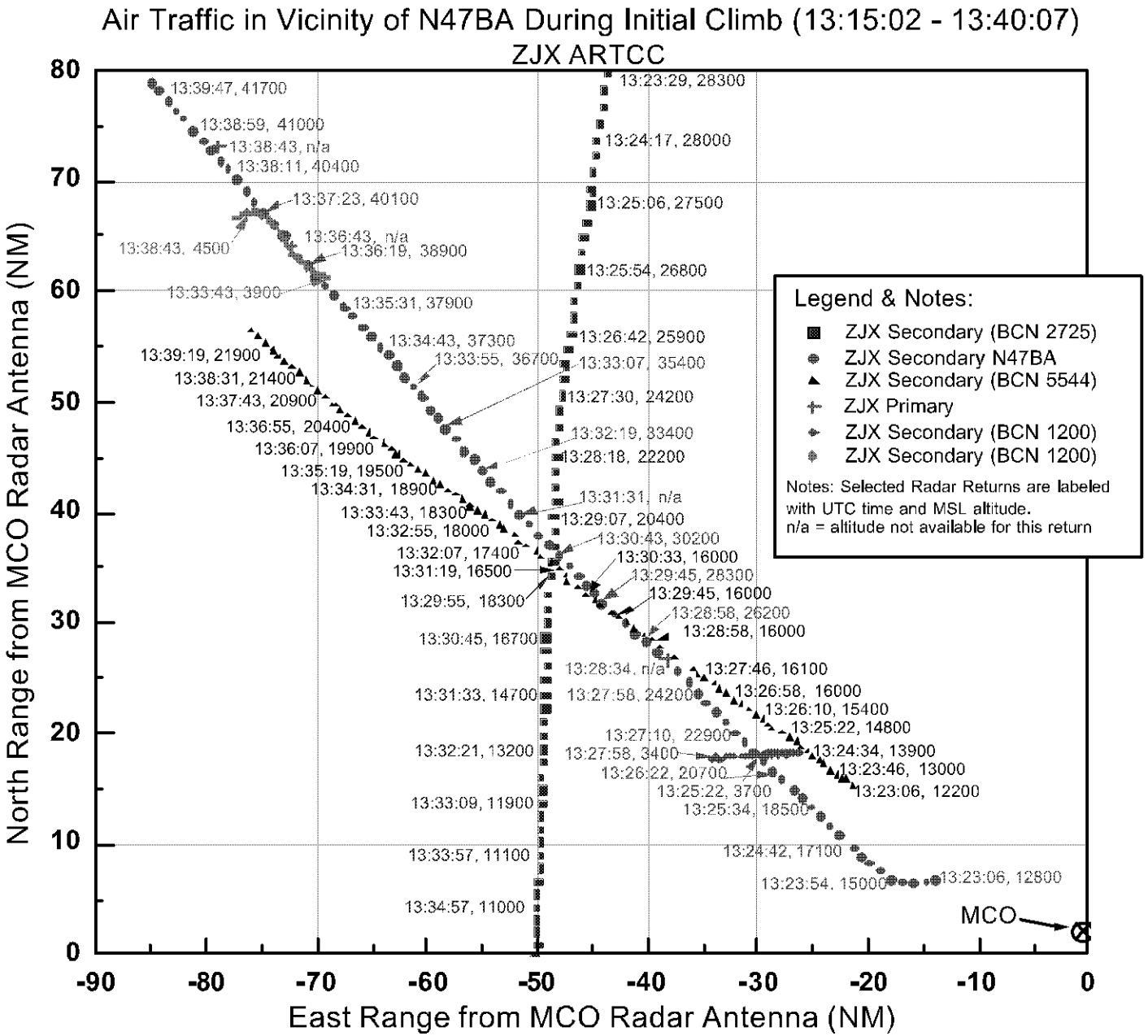
Air Traffic in Vicinity of N47BA During Initial Climb (13:15:02 - 13:40:07)
ZJX ARTCC
North Range from MCO Radar Antenna (NM)
East Range from MCO Radar Antenna (NM)
80
70
60
50
40
30
20
10
0
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
13:39:47, 41700
13:38:59, 41000
13:38:43, n/a
13:38:11, 40400
13:37:23, 40100
13:38:43, 4500
13:36:43, n/a
13:36:19, 38900
13:33:43, 3900
13:35:31, 37900
13:34:43, 37300
13:39:19, 21900
13:33:55, 36700
13:38:31, 21400
13:37:43, 20900
13:36:55, 20400
13:36:07, 19900
13:35:19, 19500
13:34:31, 18900
13:33:43, 18300
13:32:55, 18000
13:32:07, 17400
13:31:19, 16500
13:29:55, 18300
13:30:45, 16700
13:31:33, 14700
13:32:21, 13200
13:33:09, 11900
13:33:57, 11100
13:34:57, 11000
13:23:29, 28300
13:24:17, 28000
13:25:06, 27500
13:25:54, 26800
13:26:42, 25900
13:33:07, 35400
13:27:30, 24200
13:32:19, 83400
13:28:18, 22200
13:31:31, n/a
13:29:07, 20400
13:30:43, 30200
13:30:33, 16000
13:29:45, 28300
13:29:45, 16000
13:28:58, 26200
13:28:58, 16000
13:28:34, n/a
13:27:46, 16100
13:27:58, 24200
13:26:58, 16000
13:26:10, 15400
13:25:22, 14800
13:27:10, 22900
13:27:58, 3400
13:24:34, 13900
13:26:22, 20700
13:23:46, 13000
13:25:22, 3700
13:23:06, 12200
13:25:34, 18500
13:24:42, 17100
13:23:54, 15000
13:23:06, 12800
MCO
Legend & Notes:
ZJX Secondary (BCN 2725)
ZJX Secondary N47BA
ZJX Secondary (BCN 5544)
ZJX Primary
ZJX Secondary (BCN 1200)
ZJX Secondary (BCN 1200)
Notes: Selected Radar Returns are labeled with UTC time and MSL altitude.
n/a = altitude not available for this return

Figure 5

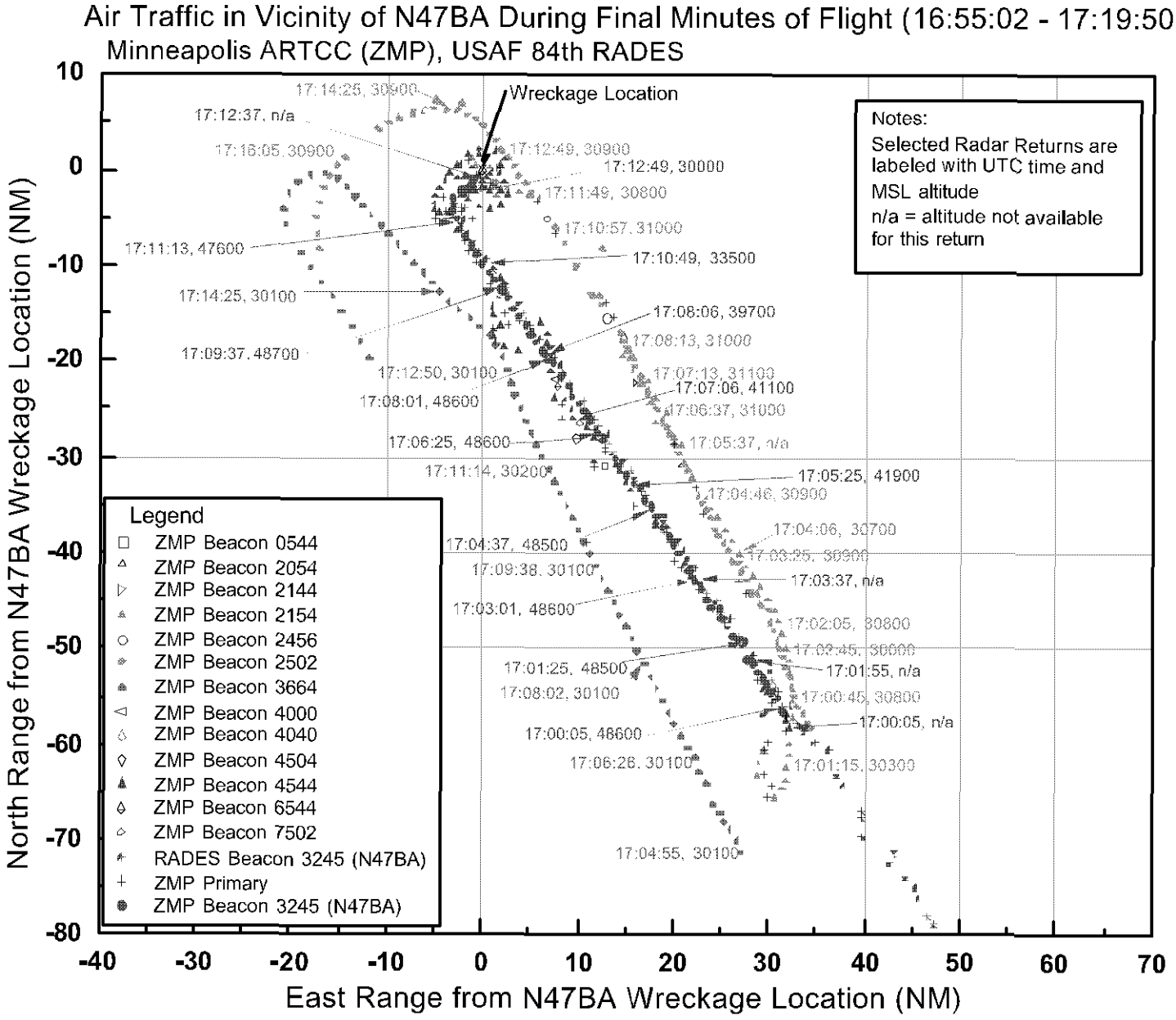
Air Traffic in Vicinity of N47BA During Final Minutes of Flight (16:55:02 - 17:19:50)
Minneapolis ARTCC (ZMP), USAF 84th RADES
Wreckage Location
Notes:
Selected Radar Returns are labeled with UTC time and MSL altitude
n/a = altitude not available for this return
Legend
ZMP Beacon 0544
ZMP Beacon 2054
ZMP Beacon 2144
ZMP Beacon 2154
ZMP Beacon 2456
ZMP Beacon 2502
ZMP Beacon 3664
ZMP Beacon 4000
ZMP Beacon 4040
ZMP Beacon 4504
ZMP Beacon 4544
ZMP Beacon 6544
ZMP Beacon 7502
RADES Beacon 3245 (N47BA)
ZMP Primary
ZMP Beacon 3245 (N47BA)
17:14:25, 30900
17:12:37, n/a
17:16:05, 30900
17:12:49, 30900
17:12:49, 30000
17:11:49, 30800
17:10:57, 31000
17:11:13, 47600
17:10:49, 33500
17:14:25, 30100
17:08:06, 39700
17:08:13, 31000
17:09:37, 48700
17:12:50, 30100
17:07:13, 31100
17:07:06, 41100
17:08:01, 48600
17:06:37, 31000
17:06:25, 48600
17:05:37, n/a
17:11:14, 30200
17:05:25, 41900
17:04:46, 30900
17:04:06, 30700
17:04:37, 48500
17:03:25, 30900
17:09:38, 30100
17:03:37, n/a
17:03:01, 48600
17:02:05, 30800
17:02:45, 30600
17:01:25, 48500
17:01:55, n/a
17:08:02, 30100
17:00:45, 30800
17:00:05, n/a
17:00:05, 48600
17:06:26, 30100
17:01:15, 30300
17:04:55, 30100
North Range from N47BA Wreckage Location (NM)
East Range from N47BA Wreckage Location (NM)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-40
-30
-20
-10
0
10
20
30
40
50
60
70

Figure 6

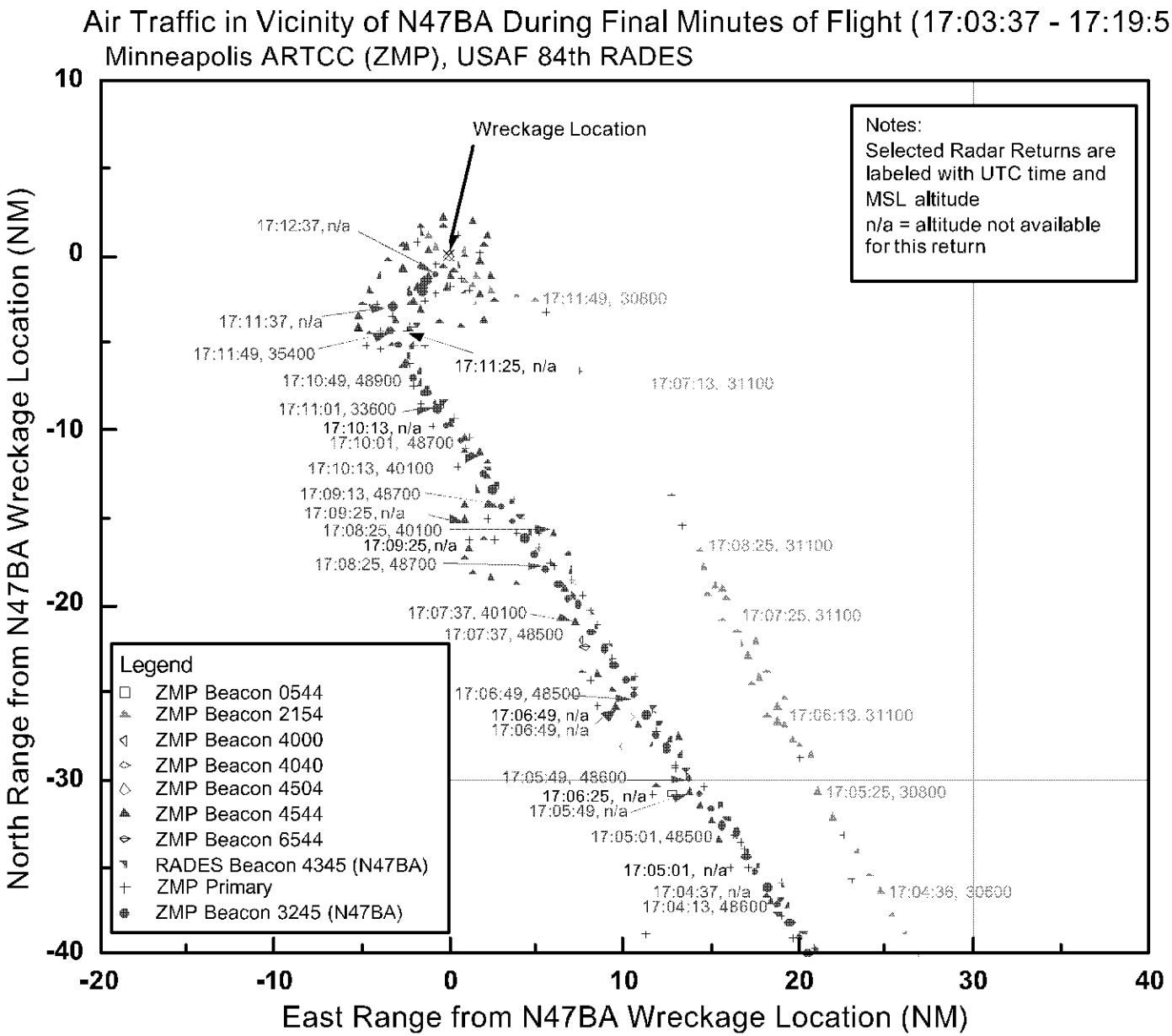
Air Traffic in Vicinity of N47BA During Final Minutes of Flight (17:03:37 - 17:19:50)
Minneapolis ARTCC (ZMP), USAF 84th RADES
Wreckage Location
Notes:
Selected Radar Returns are labeled with UTC time and MSL altitude
n/a = altitude not available for this return
Legend
ZMP Beacon 0544
ZMP Beacon 2154
ZMP Beacon 4000
ZMP Beacon 4040
ZMP Beacon 4504
ZMP Beacon 4544
ZMP Beacon 6544
RADES Beacon 4345 (N47BA)
ZMP Primary
ZMP Beacon 3245 (N47BA)
17:12:37, n/a
17:11:49, 30800
17:11:37, n/a
17:11:49, 35400
17:11:25, n/a
17:10:49, 48900
17:07:13, 31100
17:11:01, 33600
17:10:13, n/a
17:10:01, 48700
17:10:13, 40100
17:09:13, 48700
17:09:25, n/a
17:08:25, 40100
17:09:25, n/a
17:08:25, 48700
17:08:25, 31100
17:07:37, 40100
17:07:25, 31100
17:07:37, 48500
17:06:49, 48500
17:06:49, n/a
17:06:49, n/a
17:06:13, 31100
17:05:49, 48600
17:06:25, n/a
17:05:49, n/a
17:05:25, 30800
17:05:01, 48500
17:05:01, n/a
17:04:37, n/a
17:04:13, 48600
17:04:36, 30800
North Range from N47BA Wreckage Location (NM)
East Range from N47BA Wreckage Location (NM)
10
0
-10
-20
-30
-40
-20
-10
0
10
20
30
40

Figure 7

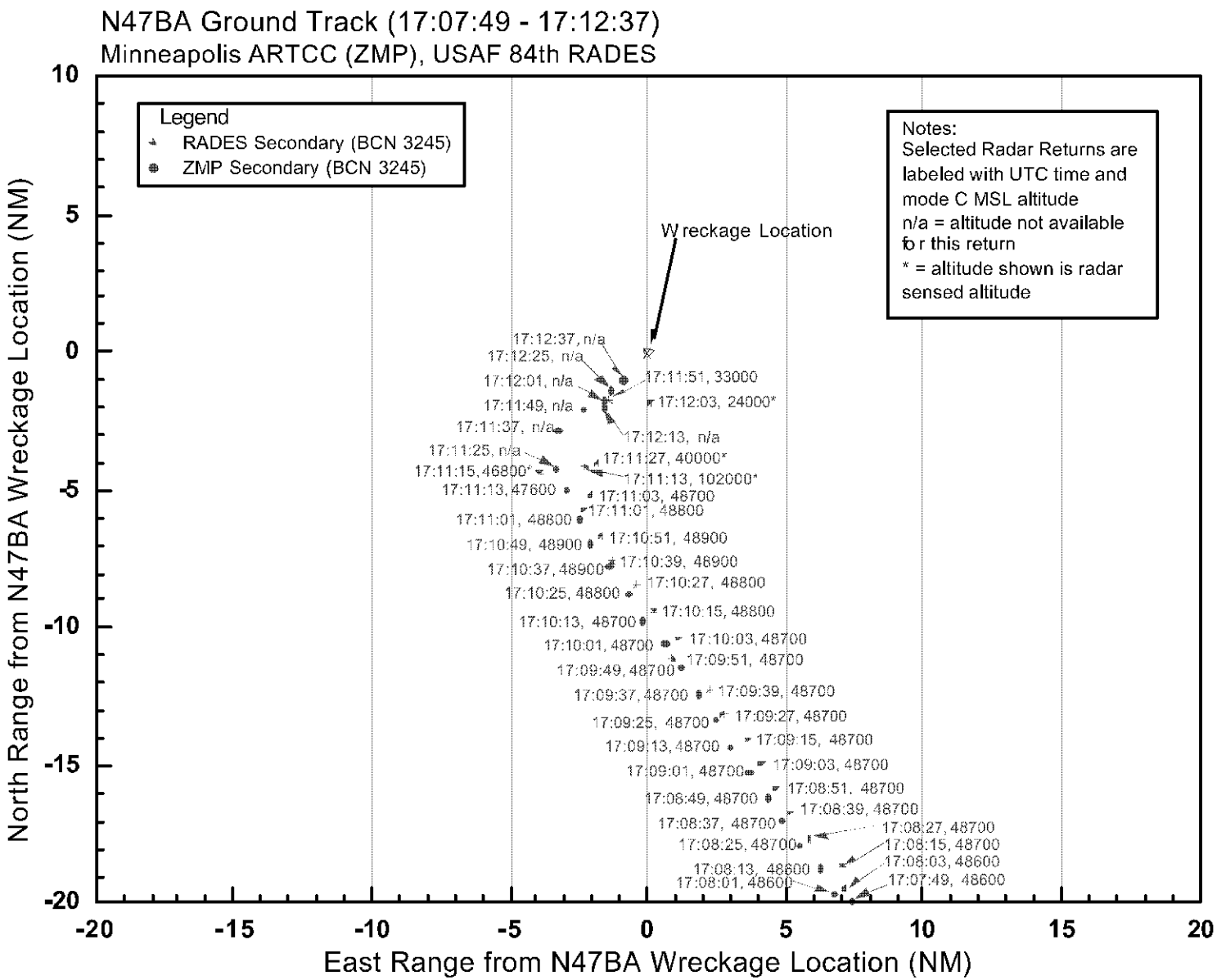
N47BA Ground Track (17:07:49 - 17:12:37)
Minneapolis ARTCC (ZMP), USAF 84th RADES
Legend
RADES Secondary (BCN 3245)
ZMP Secondary (BCN 3245)
Notes:
Selected Radar Returns are labeled with UTC time and mode C MSL altitude
n/a = altitude not available for this return
* = altitude shown is radar sensed altitude
Wreckage Location
North Range from N47BA Wreckage Location (NM)
East Range from N47BA Wreckage Location (NM)
10
5
0
-5
-10
-15
-20
-20
-15
-10
-5
0
5
10
15
20
17:12:37, n/a
17:12:25, n/a
17:12:01, n/a
17:11:49, n/a
17:11:37, n/a
17:11:25, n/a
17:11:15, 46800*
17:11:13, 47600
17:11:01, 48800
17:10:49, 48900
17:10:37, 48900
17:10:25, 48800
17:10:13, 48700
17:10:01, 48700
17:09:49, 48700
17:09:37, 48700
17:09:25, 48700
17:09:13, 48700
17:09:01, 48700
17:08:49, 48700
17:08:37, 48700
17:08:25, 48700
17:08:13, 48600
17:08:01, 48600
17:11:51, 33000
17:12:03, 24000*
17:12:13, n/a
17:11:27, 40000*
17:11:13, 102000*
17:11:03, 48700
17:11:01, 48800
17:10:51, 48900
17:10:39, 48900
17:10:27, 48800
17:10:15, 48800
17:10:03, 48700
17:09:51, 48700
17:09:39, 48700
17:09:27, 48700
17:09:15, 48700
17:09:03, 48700
17:08:51, 48700
17:08:39, 48700
17:08:27, 48700
17:08:15, 48700
17:08:03, 48600
17:07:49, 48600

Figure 8

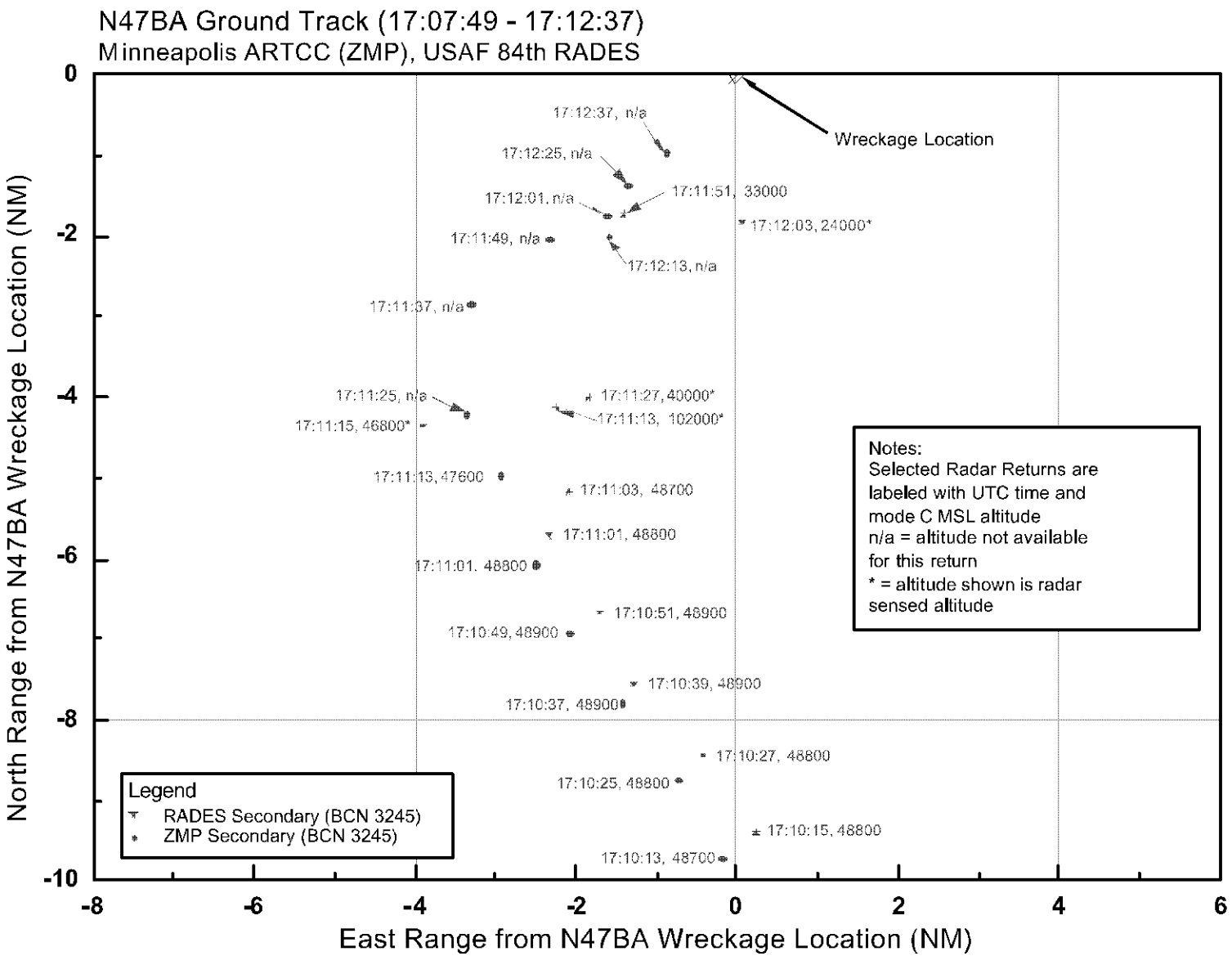
N47BA Ground Track (17:07:49 - 17:12:37)
Minneapolis ARTCC (ZMP), USAF 84th RADES
Wreckage Location
17:12:37, n/a
17:12:25, n/a
17:12:01, n/a
17:11:51, 33000
17:12:03, 24000*
17:11:49, n/a
17:12:13, n/a
17:11:37, n/a
17:11:25, n/a
17:11:27, 40000*
17:11:15, 46800*
17:11:13, 102000*
17:11:13, 47600
17:11:03, 48700
17:11:01, 48800
17:11:01, 48800
17:10:51, 48900
17:10:49, 48900
17:10:39, 48900
17:10:37, 48900
17:10:27, 48800
17:10:25, 48800
17:10:15, 48800
17:10:13, 48700
Notes:
Selected Radar Returns are labeled with UTC time and mode C MSL altitude
n/a = altitude not available for this return
* = altitude shown is radar sensed altitude
Legend
RADES Secondary (BCN 3245)
ZMP Secondary (BCN 3245)
North Range from N47BA Wreckage Location (NM)
East Range from N47BA Wreckage Location (NM)
0
-2
-4
-6
-8
-10
-8
-6
-4
-2
0
2
4
6

Figure 9

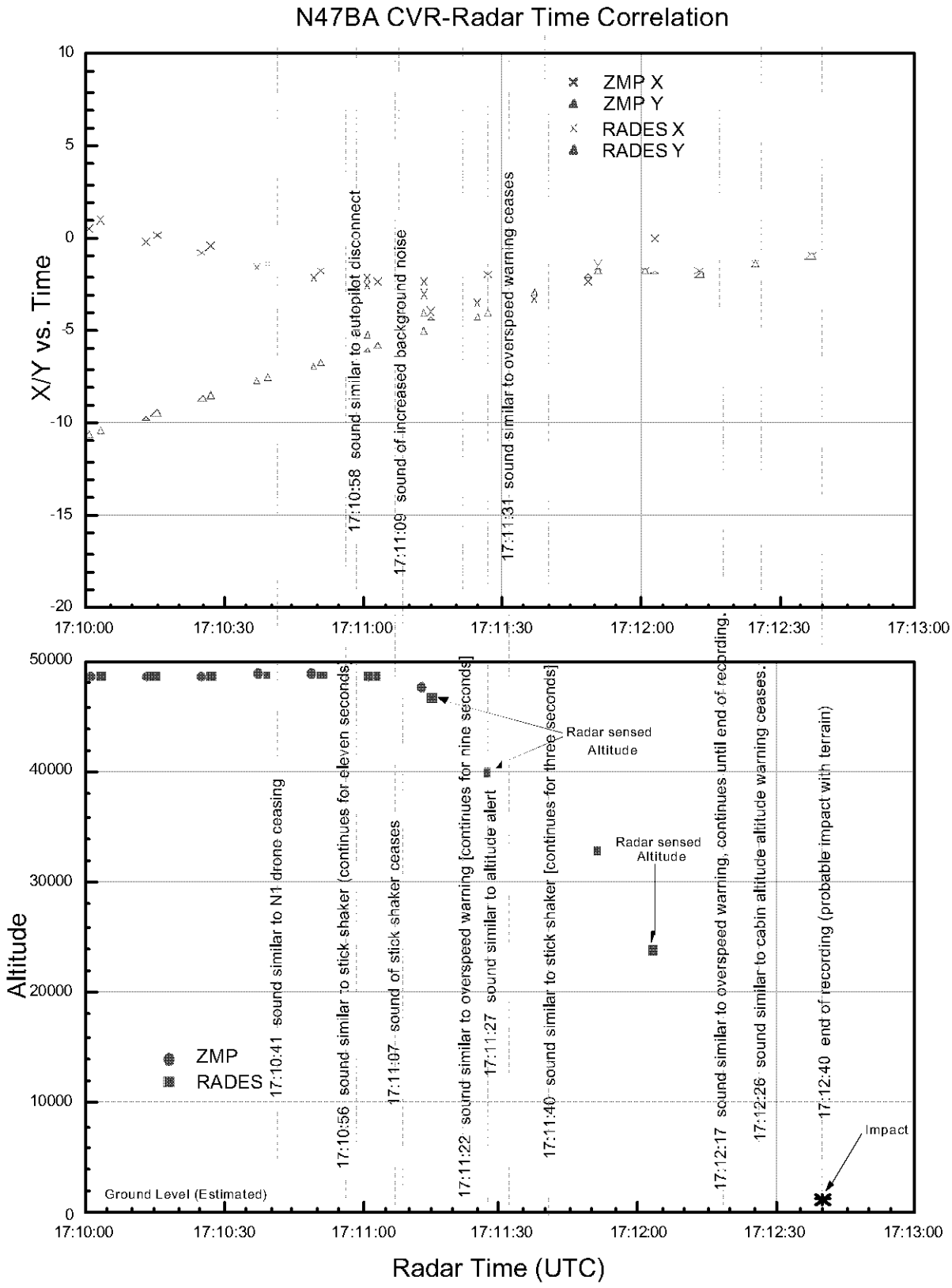
N47BA CVR-Radar Time Correlation
X/Y vs. Time
ZMP X
ZMP Y
RADES X
RADES Y
17:10:58 sound similar to autopilot disconnect
17:11:09 sound of increased background noise
17:11:31 sound similar to overspeed warning ceases
Altitude
ZMP
RADES
Ground Level (Estimated)
17:10:41 sound similar to N1 drone ceasing
17:10:56 sound similar to stick shaker (continues for eleven seconds)
17:11:07 sound of stick shaker ceases
17:11:22 sound similar to overspeed warning [continues for nine seconds]
17:11:27 sound similar to altitude alert
17:11:40 sound similar to stick shaker [continues for three seconds]
Radar sensed Altitude
Radar sensed Altitude
17:12:17 sound similar to overspeed warning, continues until end of recording.
17:12:26 sound similar to cabin altitude altitude warning ceases.
17:12:40 end of recording (probable impact with terrain)
Impact
Radar Time (UTC)

Figure 10