TAP / ASTA Flight Demo Data Analysis

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Data Analysis

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1.0 Abstract

Recently the Low Visibility Landing and Surface Operations (LVLASO) project team of the Systems Integration Branch at the NASA Langley Research Center completed a flight demonstration of TAP / ASTA concepts at the Atlantic City airport. This paper is concerned with the analysis of the aircraft data that was recorded by the test vehicle during the duration of the flight demonstrations.

2.0 Introduction

The Airport Surface Traffic Automation (ASTA) program was started by the Federal Aviation Administration to increase the capacity of todays airports while maintaning high levels of safety. The NASA Terminal Area Productivity (TAP) program is concerned with the possibilities of clear weather capacities in Instrument Flight Rule (IFR) conditions. The test demonstration at the Atlantic City airport illustrated many aspects of the TAP and ASTA programs.

During a test, data was recorded by the test aircraft itself, and by NORDEN on the ground. This data consisted of positions, velocity, time, altitude, and a host of other variables.

3.0 Objective

This analysis is concerned with two main questions.

1. What was the accuracy of the various GPS and radar data that was recorded ?

In all cases the "true" position of the aircraft is the post processed GPS which is accurate to within three centimeters of the actual position. ASDE-3 radar, Raw GPS, and Differential GPS are all compared to the post processed GPS to determine their accuracy.

2. What was the availability of the data link that was used to transmit data to the test aircraft from the ground station ?

When looking at the ARINC message data, one finds that there are 'gaps' in the data stream where there is no data. These 'gaps' represent the time when the aircraft did not receive ASDE-3 radar data. By looking at these gaps, one can find the percentage of time that the radar data was not available.

4.0 Procedure

To analyze the GPS data, the collected data is first extracted from a file that contains all of the variables that were recorded by the test aircraft during the test. Then the latitude and longitude position data for the DGPS, and the Raw GPS are converted into an x,y position in a local plane coordinate system with the NGS Monument used as the reference position. Once the data is in the local plane coordinate system, plots are made. Next the error in the DGPS and Raw GPS position are calculated using the post processed GPS as a reference. The error is just the linear distance away from the post processed GPS at a given time.

Analysis of the radar data is a bit more complicated, as there is a time delay from when the radar echo was seen on the ground, to when the radar echo was received in the plane. The reason is that the radar uses a rho, theta coordinate system which must be converted to a local plane x,y coordinate system, which is then converted to a lat, lon. Then the data is transmitted to the plane on a wireless RF link. Once the data is received by the plane, it is converted back into a local plane coordinate system. So we have to make sure one knows what question they are asking when doing the analysis. If an error analysis is done using the positions based on a matching timestamp, then all of this delay is going into the error measurement. To do a strictly positional error analysis the time must be disregarded.

To do this, a Matlab(tm) routine was written to take a radar point, and the nearest 20 points in time, and compute the distance between them. The smallest distance must be the error that one desires to find. In the simple drawing below, the line represents the post processed track, and the small circles are the radar returns. D1 would represent the error, when comparing positions using timestamps. The strictly positional error would be D2. This kind of measurement is what is recorded in the table *Position Sensor Accuracy*.
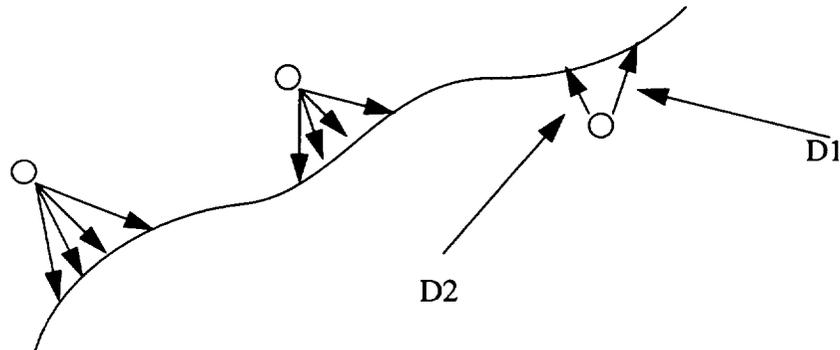
To analyze the 'gaps' in the data, the file that contains the saved ARINC messages is manipulated into an ASCII format. Then the test aircraft's timestamps are extracted from the file for examination. 'Double' entries are removed, and analysis of the timestamps can occur.

Gaps in the timestamps were counted using a simple C program that lets the user specify the gap width to ignore, and the file to parse. If a user specified a gap width of two, gaps such as 15:08:25 - 15:08:27, and of course 15:05:12 - 15:05:13 are ignored. The program then parsed the time stamp file counting the time that elapsed in the gaps.

5.0 Data

The data used in this analysis was collected from the June 27th, 28th, and 29th demo flights of the test aircraft at the Atlantic City airport. The data is sampled at 20 times per second. For the purpose of this analysis, one took one sample of the 20 Hz data per second to match the post processed data which is one sample per second. Most of the test flight intervals were between 20 and 30 minutes long. The run number and the start and stop times are listed in the next table.

TABLE 1. Start and Stop Times

Demo Label	Start Time	Stop Time
June 27#1	14:40:42	15:07:20
June 27#2	15:15:11	15:32:19
June 27#3	15:35:50	15:49:27
June 27#4	18:20:17	18:33:44
June 27#5	19:05:52	19:14:43
June 27#6	19:33:19	19:46:30
June 27#7	19:52:17	20:05:21
June 28#1	14:28:36	14:44:44
June 28#2	18:41:44	18:55:00
June 28#3	19:52:31	20:06:33
June 28#4	20:07:28	20:18:30
June 29#1	15:08:26	15:18:40
June 29#2	16:08:30	16:19:30
June 29#3	16:43:00	16:51:00

The radar data came from two sources. The ARINC messages file contains the radar data that was received by the plane over the RF data link from the ground station. The ground station (NORDEN) also kept a file of the radar data that was uplinked from the ground station. By looking at was sent, versus what was received gives one another view on the radar data availability.

The Norden radar data was in a hexadecimal format that must be manipulated to extract the data that one wants to look at, particularily the target positions. Once the target positions are extracted, they are sorted based on the identification number of the target.

Also, the June 27th radar data was off by a constant rho,theta factor which turned out to be approximately negative forty feet, and one one hundreth of a radian.

6.0 Results

The table entitled *Position Sensor Accuracy*, on the next page, shows the error in the DGPS, Raw GPS, and the ASDE data as received by the test aircraft, compared to the post processed GPS. The position plots are shown after this table, as is a plot showing the Atlantic City airport itself.

The *Norden Ground Tracks* plot and *TSRV Ground Tracks* plot show the radar data in a three dimensional perspective. The *Norden Ground Tracks* plot is a plot of the targets that were seen by the radar ground station. The *TSRV Ground Tracks* plot is a plot of the same radar data after it was uplinked to the plane on the RF data link. The z axis is time, and the x, and y axis are x and y position of the target. Also the targets are projected down onto the x, y plane. These plots show the gaps in the radar data vividly. Look at the long red target on the Norden Ground Tracks plot, and compare it to the same target on the TSRV Ground Tracks plot. Notice the breaks in the TSRV plot's target. These are gaps in the radar data.

The three dimensional availability charts that follow represent the percentage of time that radar data was NOT available.

   Example: For an ignored gap of two on the June 27-1 test - gaps in the data of 1 (i.e. 15:08:25 - 15:08:26), and 2 (i.e. 15:08:25 - 15:08:27) are ignored - the radar data was unavailable for approximately 45% of the time.

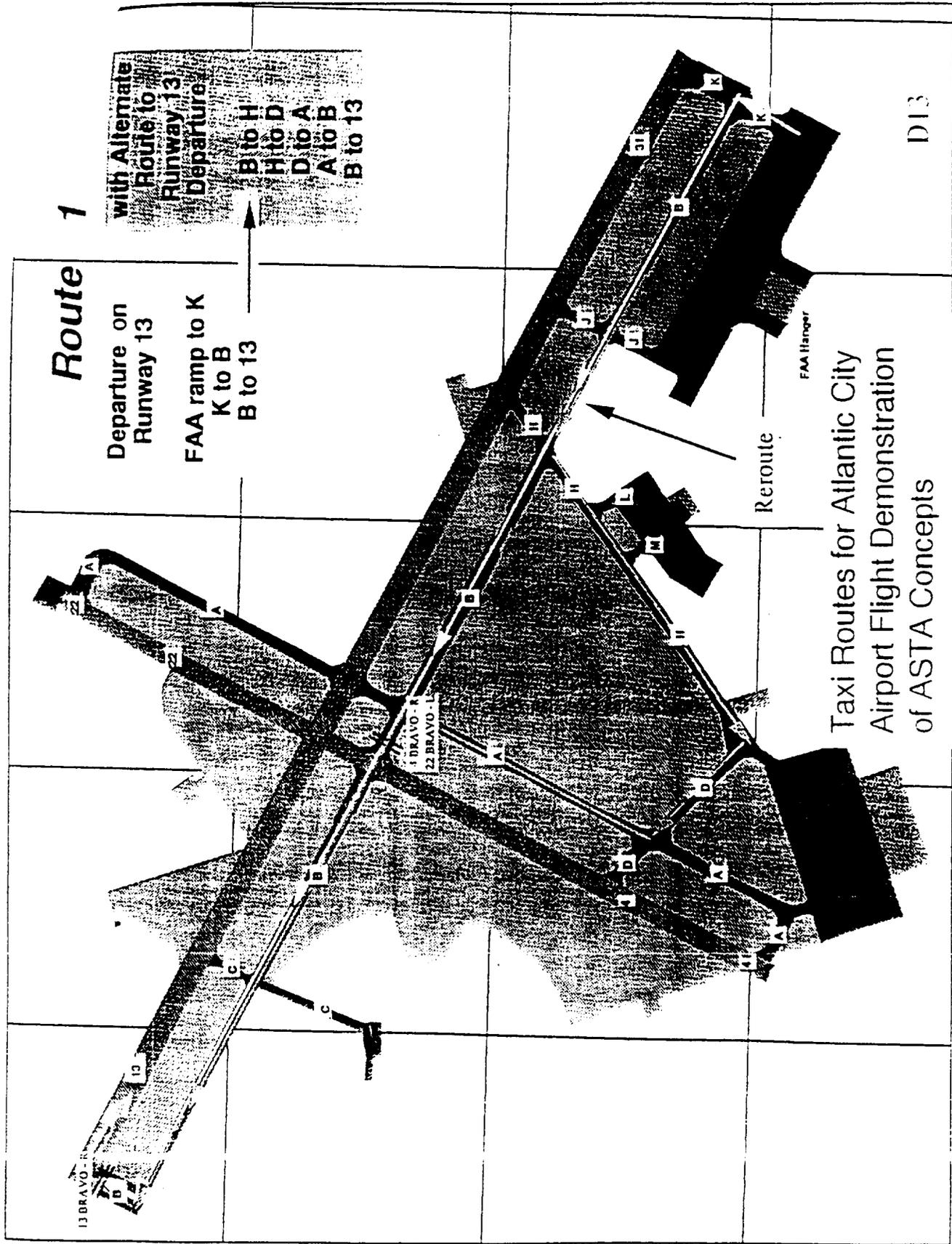There are three separate charts for *June 27th, 28th*, and *29th* respectively.

The *Maximum and Minimum Nonavailability* chart shows the maximum and minimum percentage for each gap count in the data.

The *Nonavailability* chart shows for ignored gaps of one, two, and three, the percent of time that radar data was NOT available.
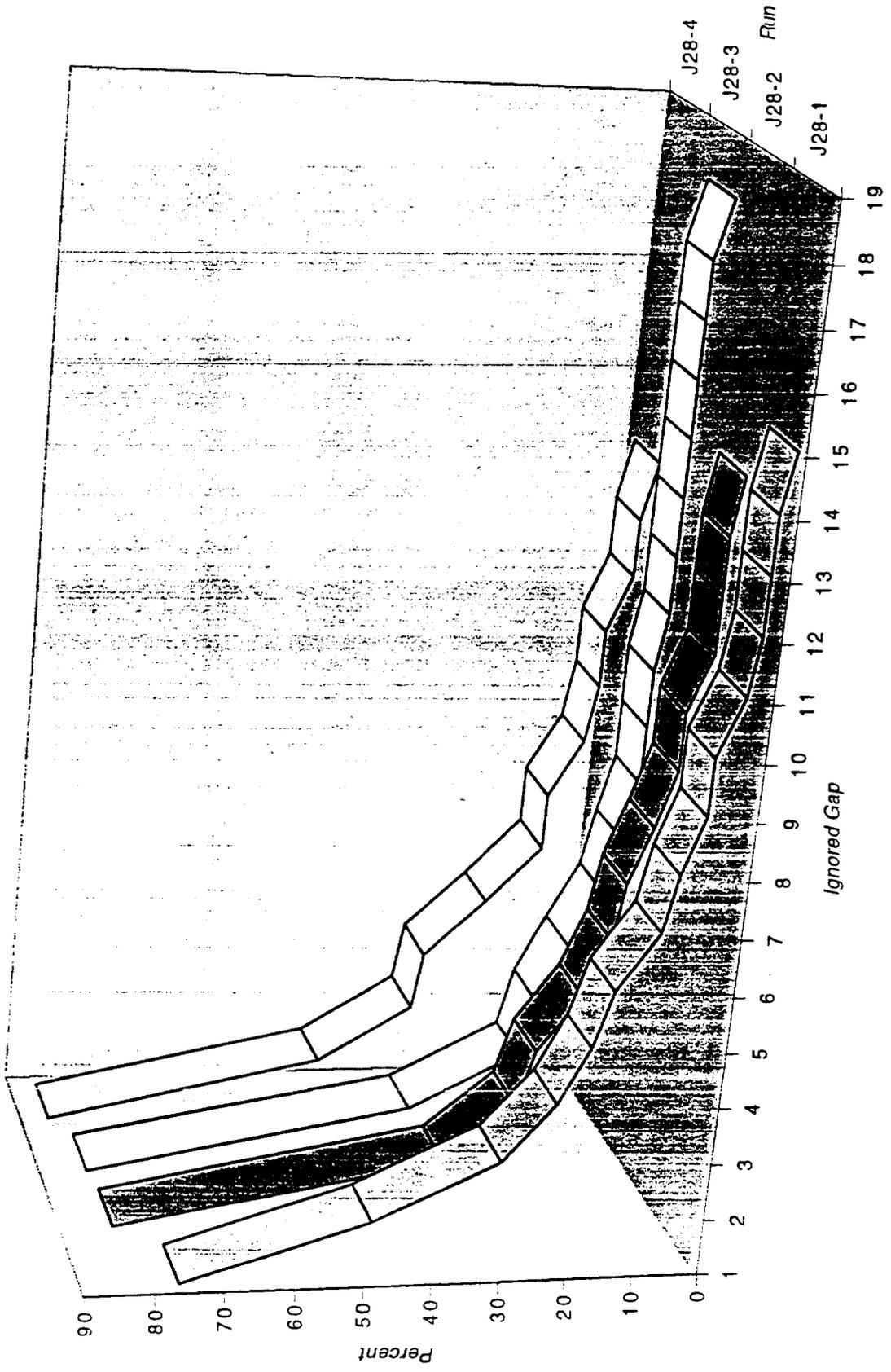
   Example: For the June 27-1 test with an ignored gap of three, the radar data is available approximately 77% of the time.
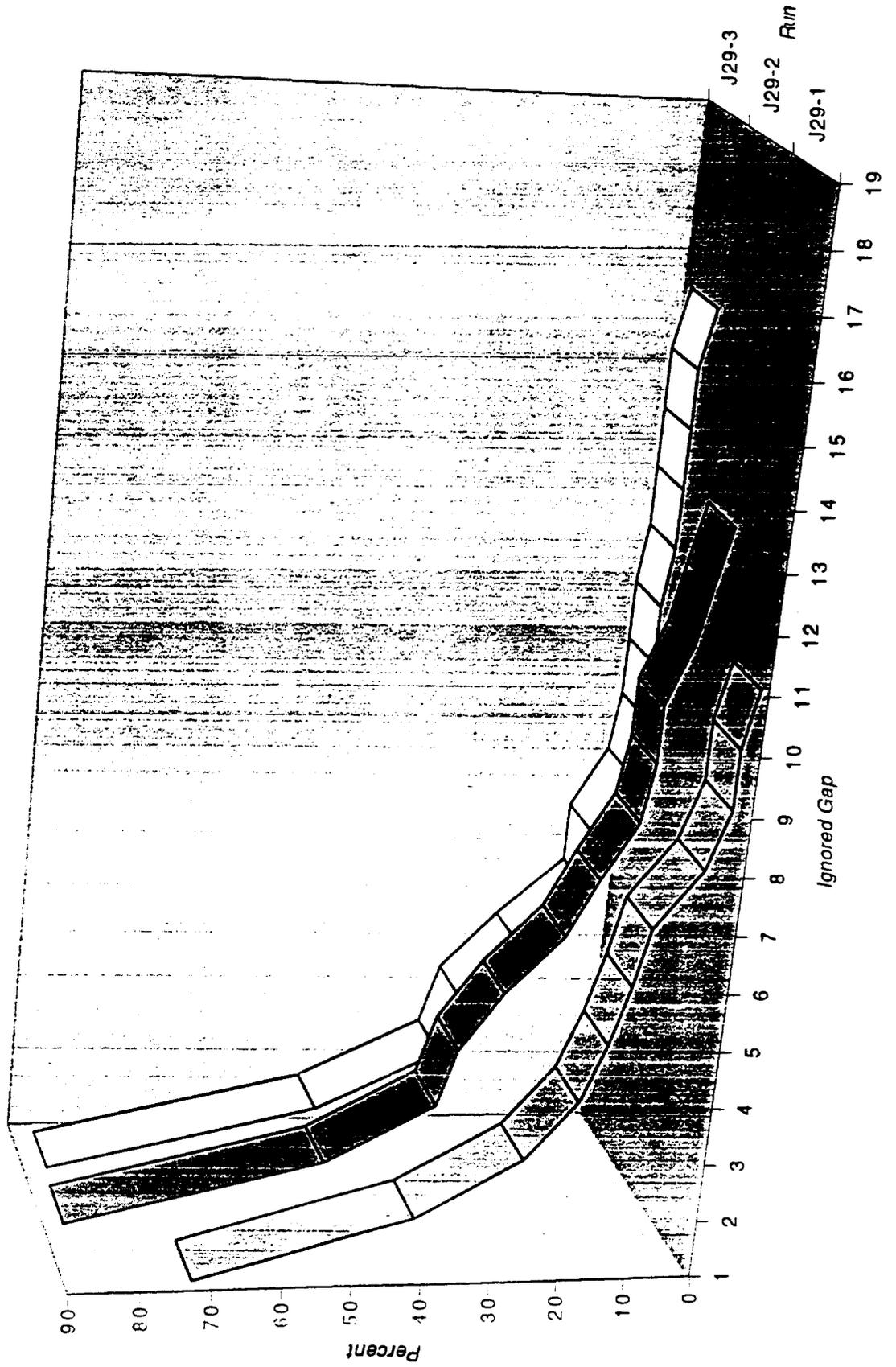
Table 1: Position Sensor Accuracy

Run	DGPS		Raw GPS		ASDE			
	Ave	St Dev	Ave	St Dev	Max	Min	Ave	St Dev
June 27 #1	1.428	.872	2.2488	1.1891	131.1947	.3466	26.2402	12.7354
June 27 #2	.981	.758	1.5082	.900	78.3067	.1291	21.1918	13.1129
June 27 #3	1.071	.710	1.5469	.0854	101.1187	1.0096	21.2796	18.0285
June 27 #4	2.124	1.06	2.5198	1.0918	80.0446	2.6318	25.2072	15.6991
June 27 #5	1.853	.680	3.3280	1.434	143.1957	.7720	49.7544	33.033
June 27 #6	2.468	1.018	4.0093	1.6173	129.419	1.8322	32.0267	24.4280
June 27 #7	2.175	.860	4.2102	38.58	170.966	2.2097	25.9786	19.5341
June 28 #1	2.32	3.175	3.5347	3.7858	201.4672	3.7559	55.0196	57.4167
June 28 #2	2.122	1.175	2.44	1.0605	120.02	3.6650	36.6327	22.7458
June 28 #3	2.40	1.03	3.1066	.9930	82.7639	.6285	21.7515	15.0172
June 28 #4	1.88	1.07	2.482	1.11	521.0634	2.3769	42.4445	87.9175
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Average	1.8929		2.7934		159.9608	1.7552	32.5024	
St Dev	.517		.8919		125.8380	1.2860	11.9384	

Route 1

Departure on Runway 13

FAA ramp to K
K to B
B to 13

Reroute

Taxi Routes for Atlantic City
Airport Flight Demonstration
of ASTA Concepts

FAA Hanger

D13

June 27

June 28

June 29

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Sheet1 Chart 7

Maximum and Minimum Nonavailability

Maximun

Minimum

Ignored Gap

Percent

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
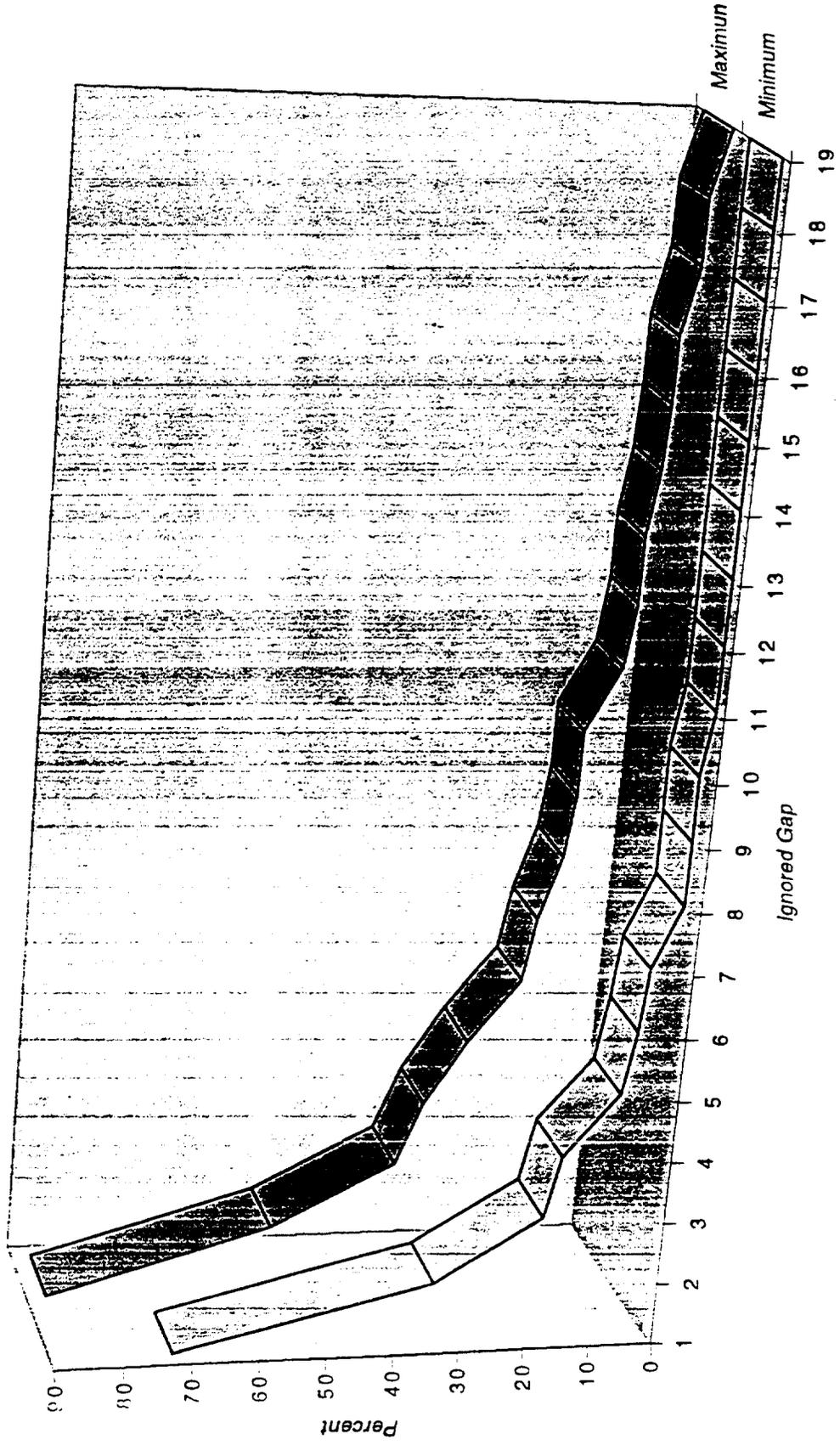
Sheet1 Chart 7

Nonavailability
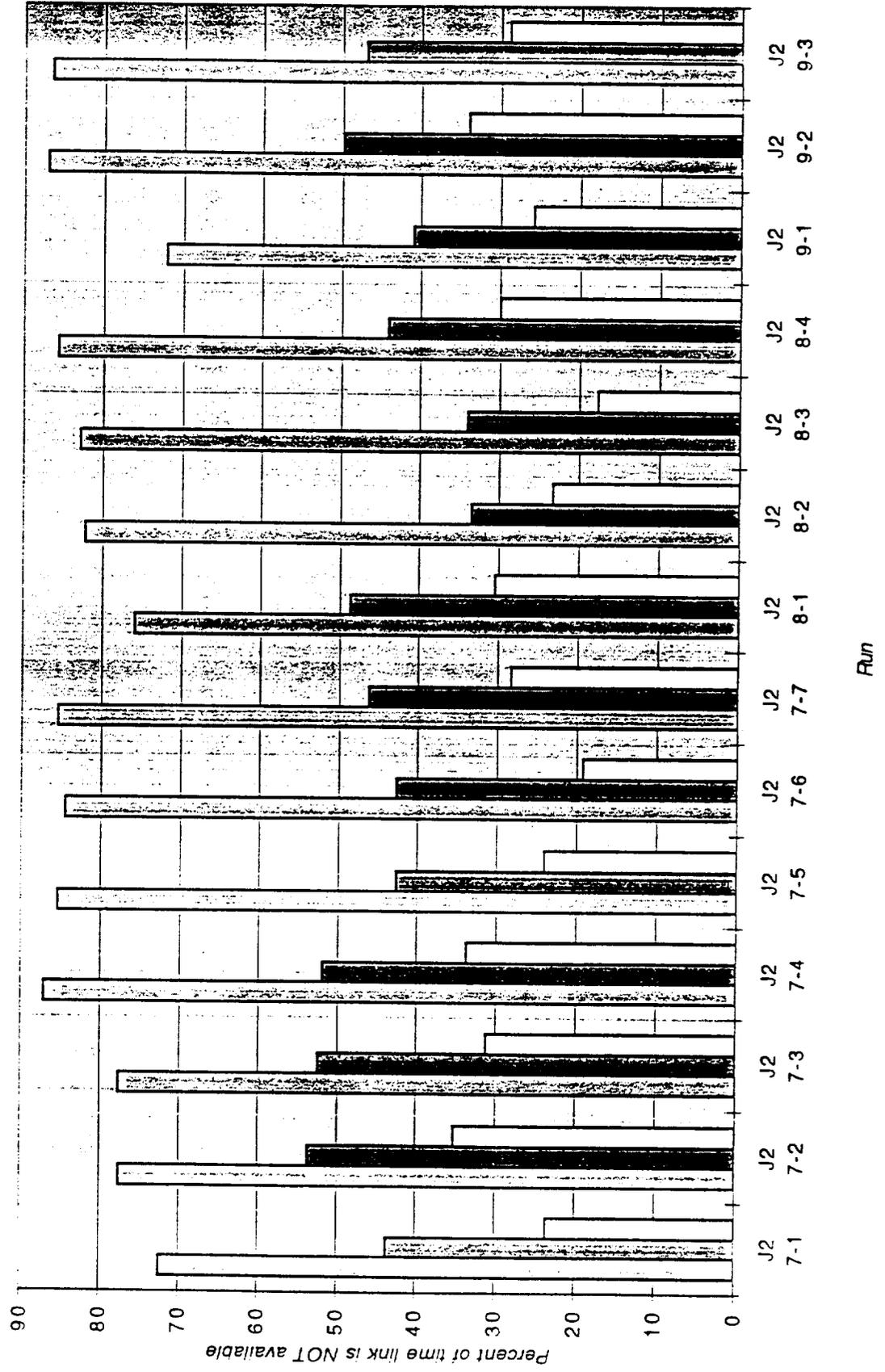
Run

Percent of time link is NOT available
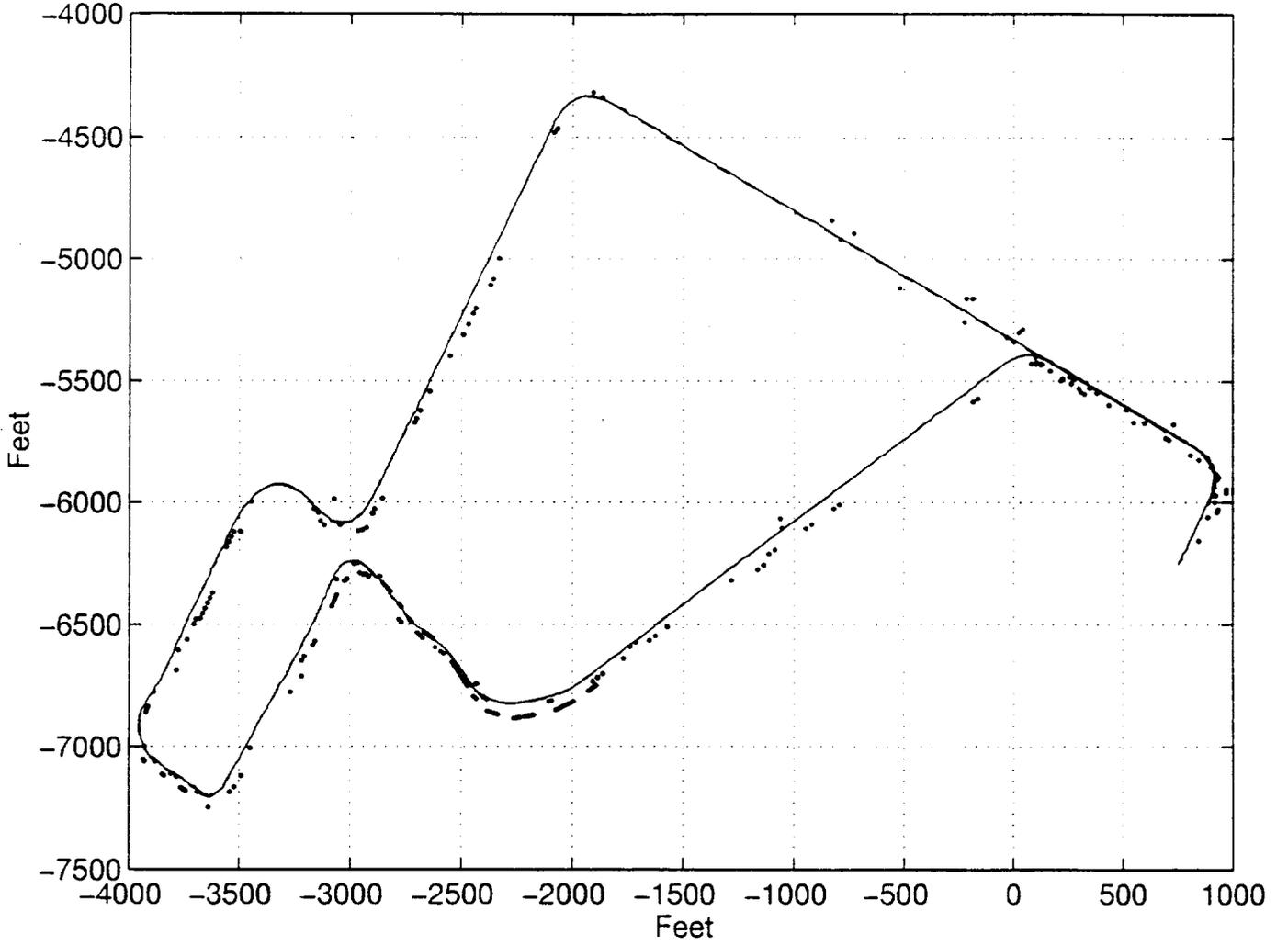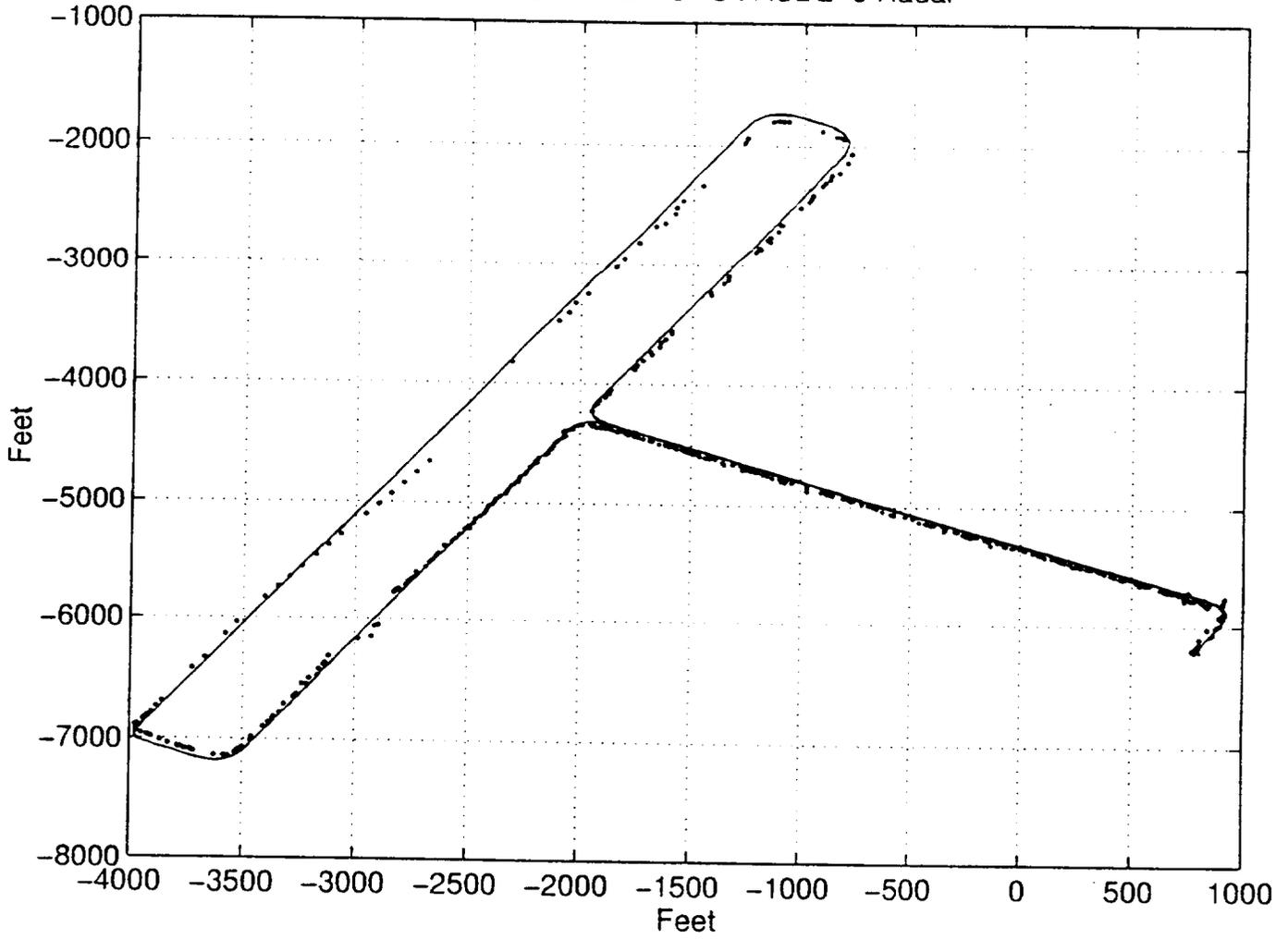
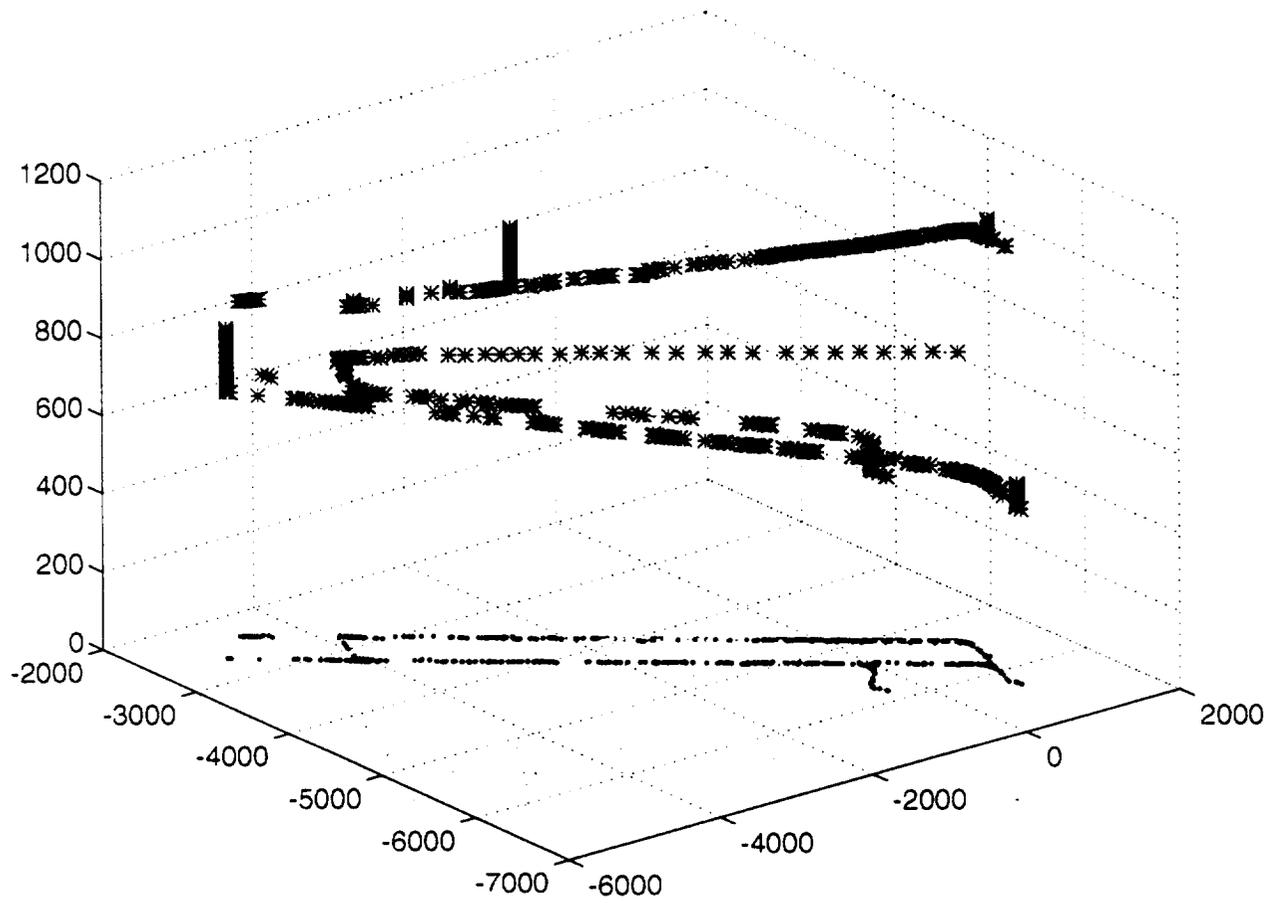494

– DGPS –– Raw GPS . ASDE–3 Radar

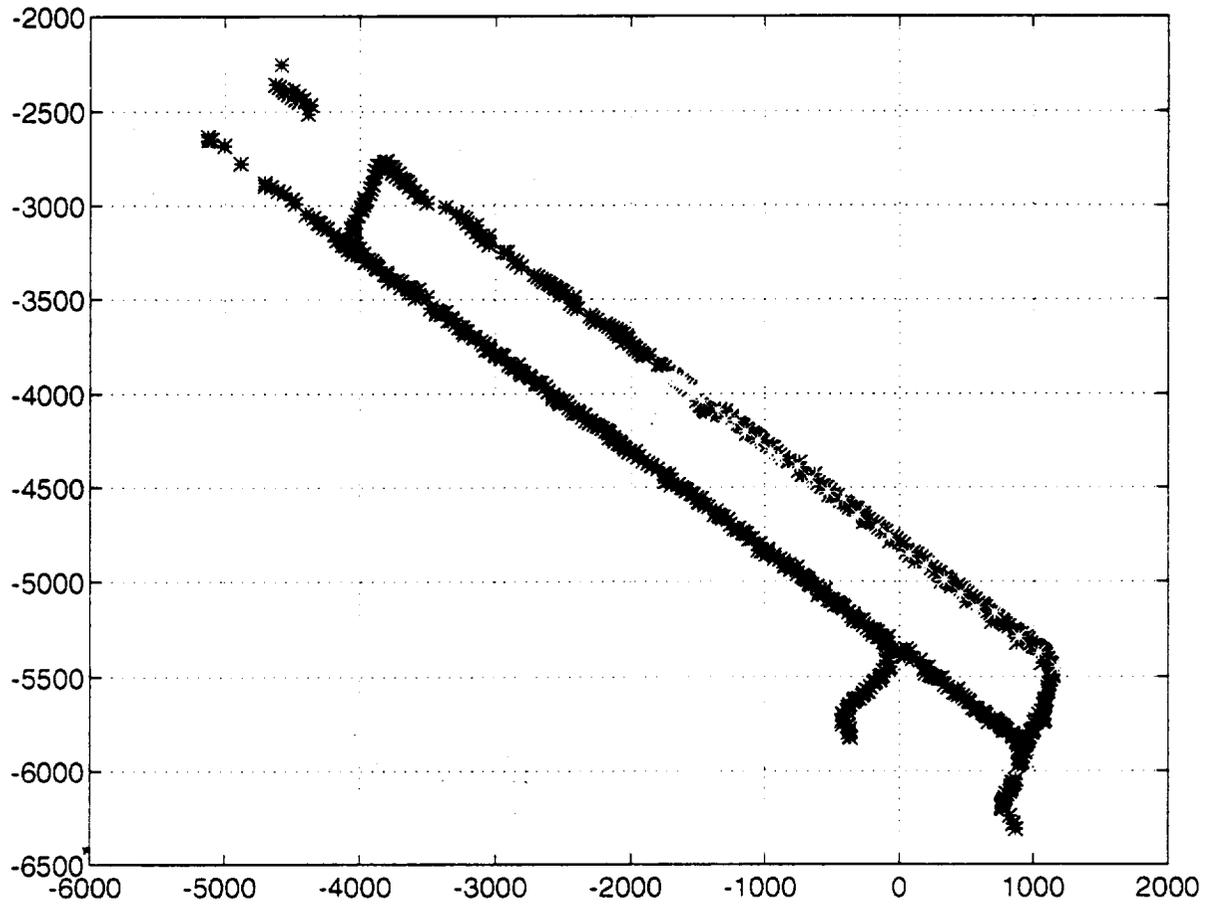- DGPS -- Raw GPS . ASDE-3 Radar
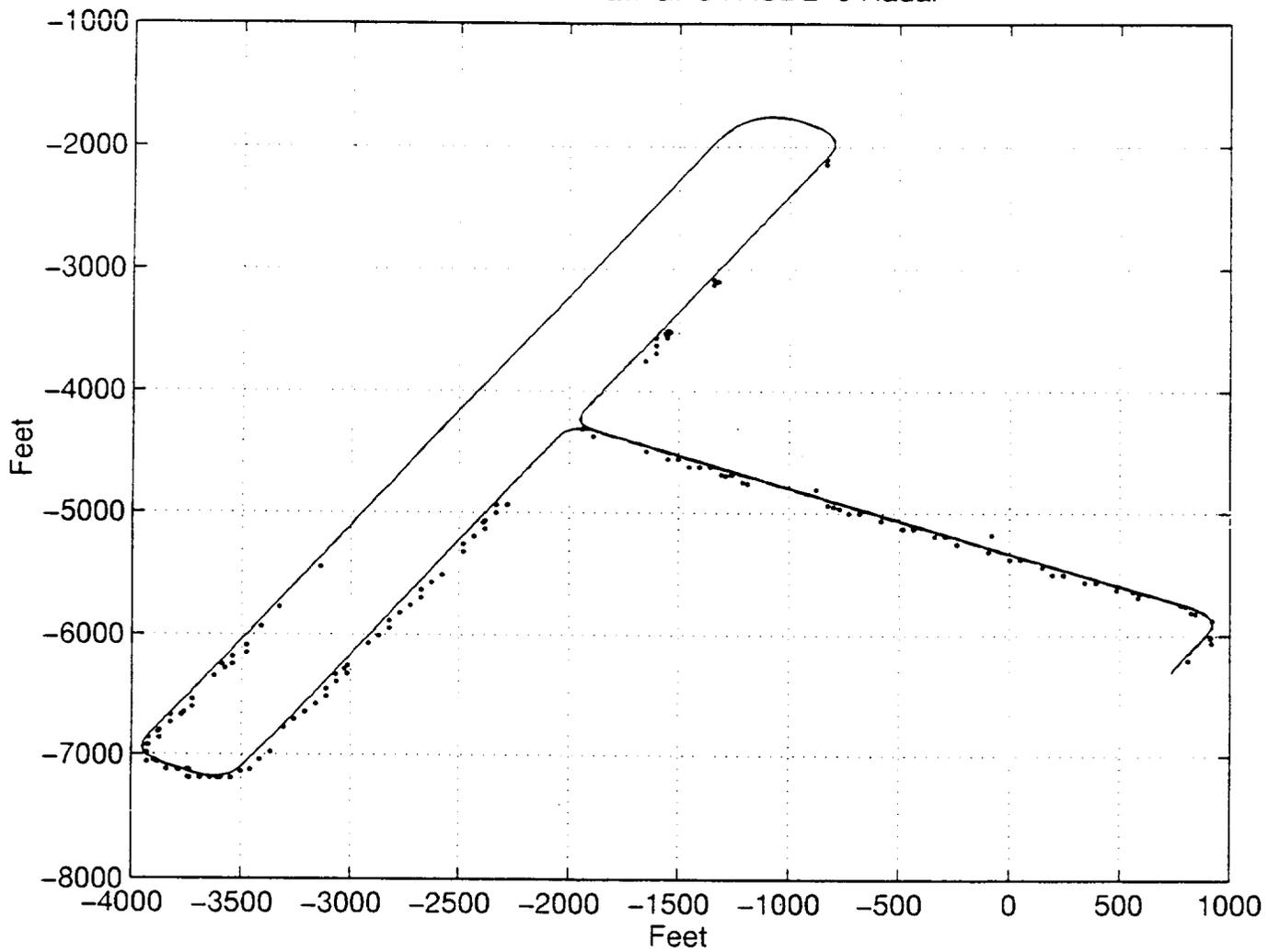
- DGPS — Raw GPS . ASDE-3 Radar

Norden Ground Tracks June 28 20:07z

TSRV Ground Tracks June 28 20:07z

Norden Ground Tracks June 28 20:07z

TSRV Ground Tracks June 28 20:07z
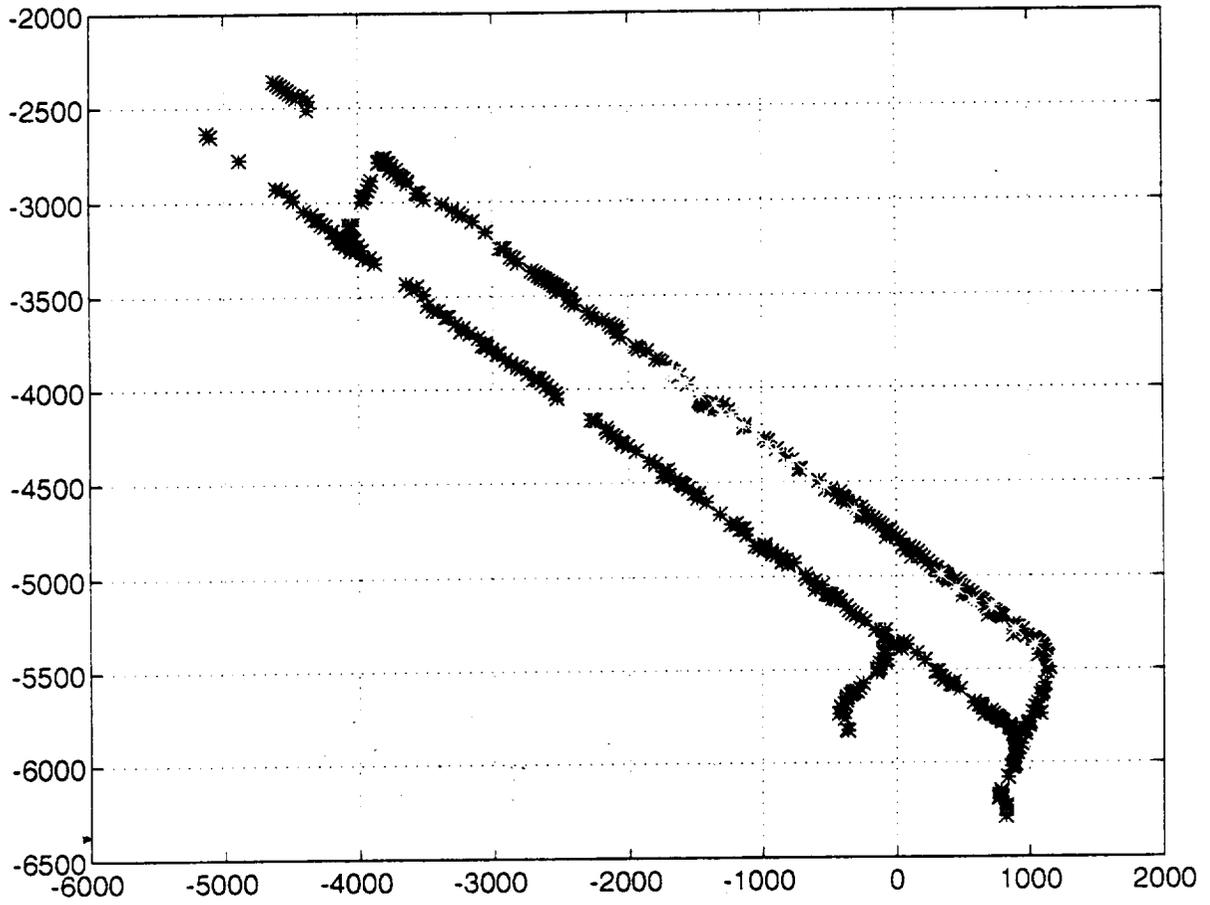
4260043	16:34:13	39.46279507	-74.590999056
Ownship	16:34:13	39.45155829	-74.568328941
4260043	16:34:14	39.46287159	-74.591031997
Ownship	16:34:14	39.45155829	-74.568328941
4260043	16:34:16	39.46290572	-74.591044905
Ownship	16:34:16	39.45155829	-74.568328941
4260043	16:34:16	39.46297855	-74.591035433
Ownship	16:34:16	39.45155829	-74.568328941
4260043	16:34:18	39.46303571	-74.591043228
Ownship	16:34:18	39.45155829	-74.568328941
4260043	16:34:19	39.46308340	-74.591009282
Ownship	16:34:19	39.45155829	-74.568328941
4260043	16:34:19	39.46310344	-74.590947172
Ownship	16:34:19	39.45155829	-74.568328941
4260043	16:34:21	39.46314359	-74.590939628
Ownship	16:34:21	39.45155829	-74.568328941
4260043	16:34:22	39.46317561	-74.590930240
Ownship	16:34:22	39.45155829	-74.568328941
4260043	16:34:22	39.46320762	-74.590916578
Ownship	16:34:22	39.45155829	-74.568328941
4260043	16:34:24	39.46326060	-74.590879949
Ownship	16:34:24	39.45155829	-74.568328941
4260043	16:34:24	39.46327803	-74.590868717
Ownship	16:34:24	39.45155829	-74.568328941
4260043	16:34:25	39.46332380	-74.590805098
Ownship	16:34:25	39.45155829	-74.568328941
4260043	16:34:27	39.46336445	-74.590754556
Ownship	16:34:27	39.45155829	-74.568328941
4260043	16:34:27	39.46338163	-74.590739552
Ownship	16:34:27	39.45155829	-74.568328941
4260043	16:34:29	39.46344676	-74.590741480
Ownship	16:34:29	39.45155829	-74.568328941
4260043	16:34:30	39.46349596	-74.590707282
Ownship	16:34:30	39.45155829	-74.568328941
4260043	16:34:30	39.46354944	-74.590674089
Ownship	16:34:30	39.45155829	-74.568328941
4260043	16:34:32	39.46359847	-74.590611560
Ownship	16:34:32	39.45155829	-74.568328941
Ownship	16:34:33	39.45155829	-74.568328941
Ownship	16:34:33	39.45155829	-74.568328941
Ownship	16:34:35	39.45155829	-74.568328941
4260043	16:34:35	39.46374801	-74.590443503
Ownship	16:34:35	39.45155829	-74.568328941
4260043	16:34:36	39.46377407	-74.590412406
Ownship	16:34:36	39.45155829	-74.568328941
4260043	16:34:38	39.46382311	-74.590345351
Ownship	16:34:38	39.45155829	-74.568328941
4260043	16:34:38	39.46382730	-74.590264214
Ownship	16:34:38	39.45155829	-74.568328941
4260043	16:34:40	39.46378966	-74.590179138

7.0 Conclusion

As one can see from the error table, the radar data was the least accurate of the three positions compared with the post processed GPS. However, if the few points that are skewing the mean value in the radar data are ignored, the ASDE Ave becomes closer to the Min. The raw GPS falls in with an overall average of approximately 2.79 feet, which is only a little more than the DGPS. The DGPS has the least overall error with an average of approximately 1.8 feet. This is excellent when one considers that the test aircraft was perhaps 75 feet across. When differential corrections fail, the position of the test aircraft will only be as accurate as the Raw GPS.

Concerning the radar data availability data, at first all the gaps in the data were counted, and the percentage of the total time that the radar data was unavailable was between 75 and 85%. This seemed like a large amount, and it was decided that a closer look at the data was in order.

A large percentage of the gaps in the radar data were two second gaps (i.e. 15:08:25 - 15:08:27). In the target data for the test aircraft, sometimes two positions were sent in the same second - two different packets are stamped with the same time, but contain different ownship (test aircraft) positions. An example of this is shown after the plots. It is possible that the two packets with the same timestamp cause the majority of the two second gaps in the data.

Example: 15:08:09

          15:08:10

          15:08:10 --> Should be counted as 15:08:11 and two second gap ignored.

          15:08:12, etc.

When the two second gaps that are paired with a double timestamp are ignored, the availability of the radar data jumps to between 55 and 60%.

So basically this comes down to how one wants to define availability. If one ignores all gaps in the data that are 19 seconds or less, the radar data was available 100 percent of the time. On the other hand if one does not ignore any gaps in the data (even the two second gaps), the the radar data was available only 18% of the time.

It was later discovered, that while the GPS receiver is operating in DGPS mode, there is no Raw GPS data. The DGPS is mirrored to the Raw GPS, and this is why DGPS, and Raw GPS are so close in the error table. In this case the Raw GPS numbers really have no meaning.