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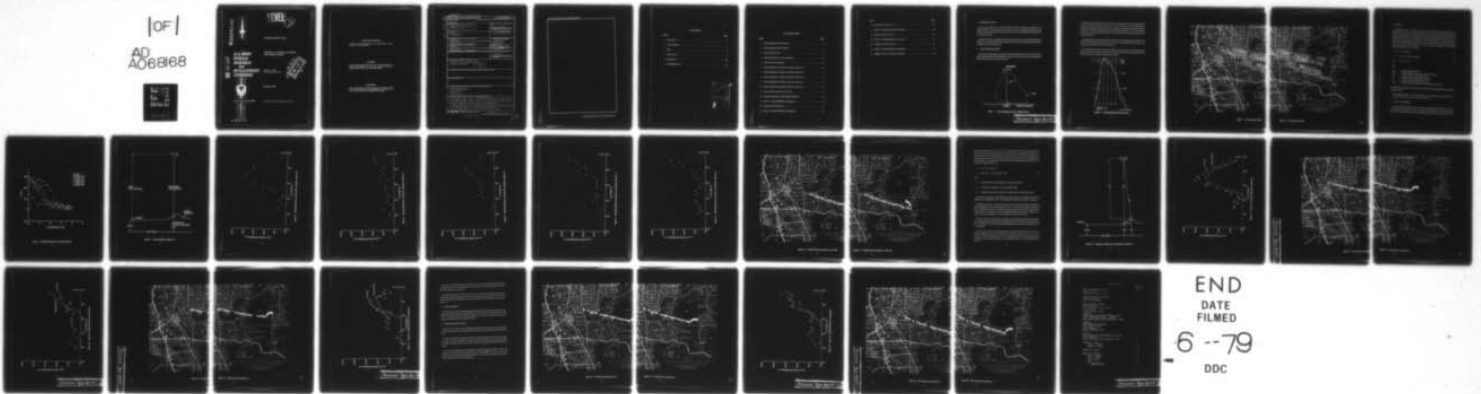
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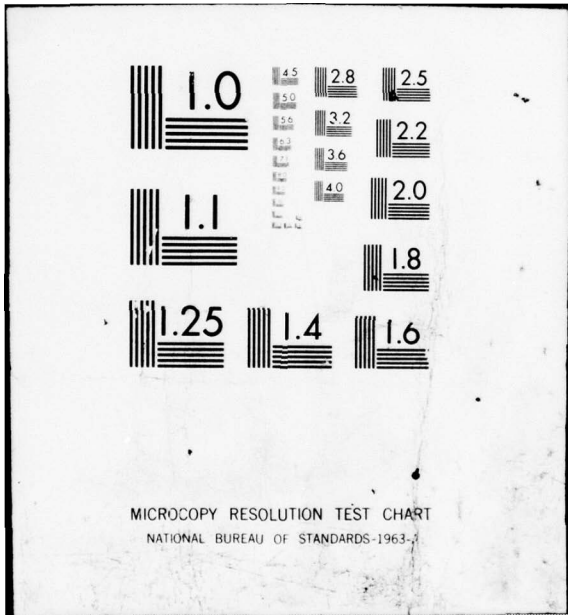
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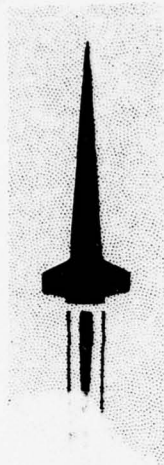
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PERSHING II ALTERNATE ALTIMETER
REPLACEMENT SCHEME

Robert F. Russell
Technology Laboratory

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Redstone Arsenal, Alabama 35809

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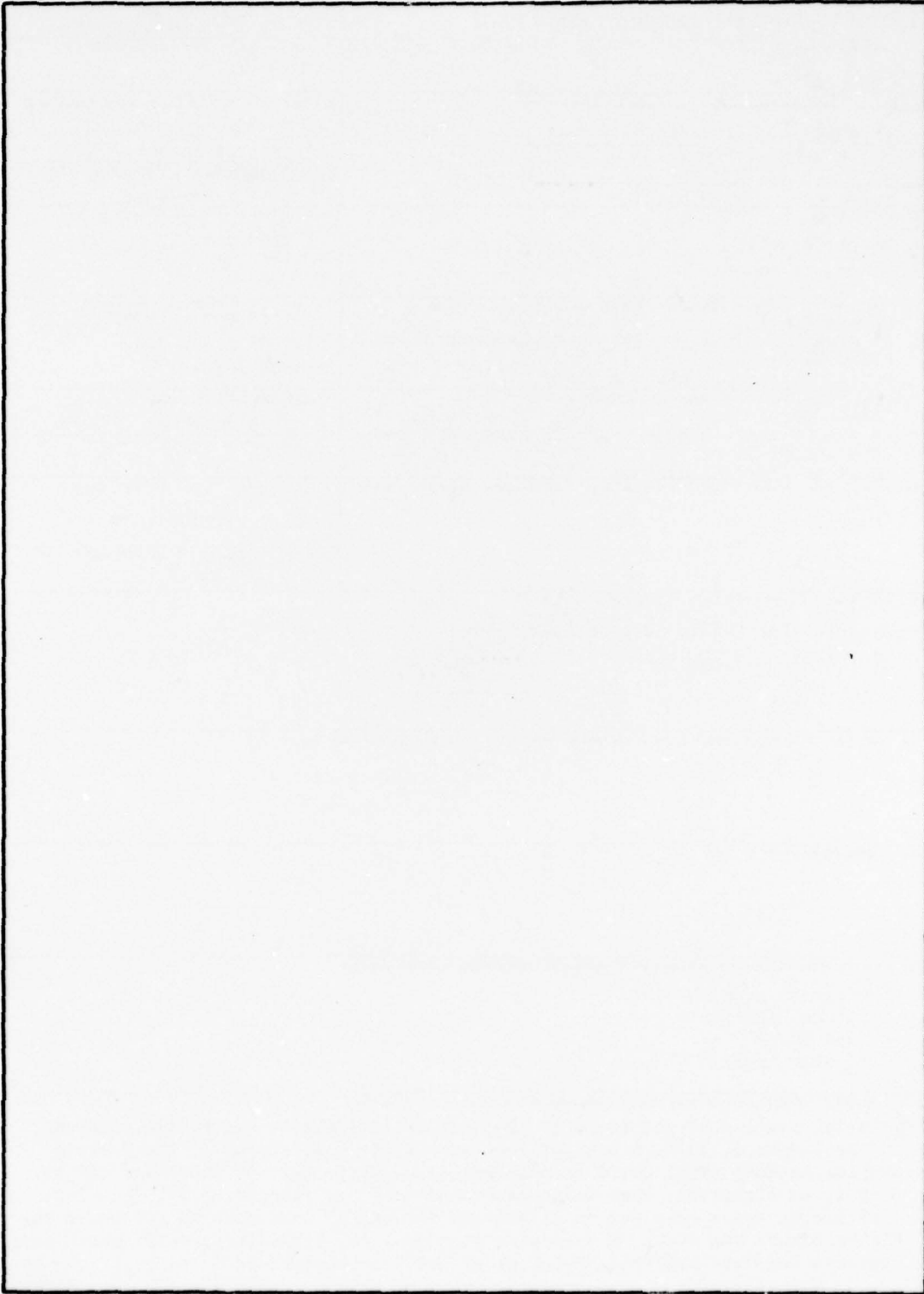
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1. INTRODUCTION

During captive flight tests of the PERSHING II (PII) at Huntsville, Alabama, in the summer of 1978, a special test was flown to determine if the Terrain Mapping Antenna (TMA) could be utilized as an altimeter. If the TMA could be used as an altimeter, then weight and cost could be reduced.

Altimeter tests were run on flights AH 140 and AH 141, with AH 140 being the high-altitude TMA tests. This report discusses the high-altitude TMA tests and presents the data analysis, conclusions and recommendations.

2. TEST DESCRIPTION

The TMA was programmed to point the toe of the TMA beam 20° aft, 10° aft, and then 0° aft of the aircraft nadir, with the normally rotating TMA locked, or pinned, in the longitudinal (flight) direction of the test aircraft (*Figure 1*).

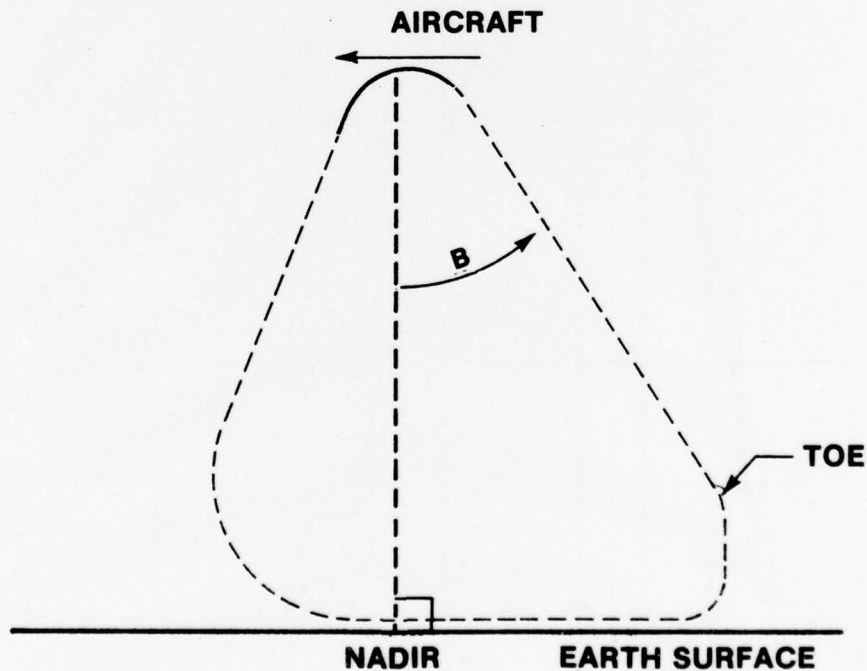


Figure 1. Terrain Mapping Antenna (TMA) position.

With the TMA locked, the aircraft descended on the target from 10 km to 6 km altitude. The threshold for altitude detection was set at a low level, 5 dB above noise, thereby allowing returns from outside the defined TMA beam to trigger the altitude gate. The effect of this low threshold is to negate the beam direction, for the system will accept, as the true altitude, the first return from any position 30° in front to 10° behind the aircraft when the toe is pointed vertically (*Figure 2*).

A distance-measuring system referred to as the Distance Measuring Equipment (DME) was utilized to determine the true altitude of the test aircraft. The DME was referenced to the target with an elevation of 624 ft above sea level.

Five data-collection passes were flown on flight AH 140 as shown in the ground track in *Figure 3*. Note that each pass starts somewhere over Monte Sano Mountain and ends over the relatively flat land of downtown Huntsville, Alabama.

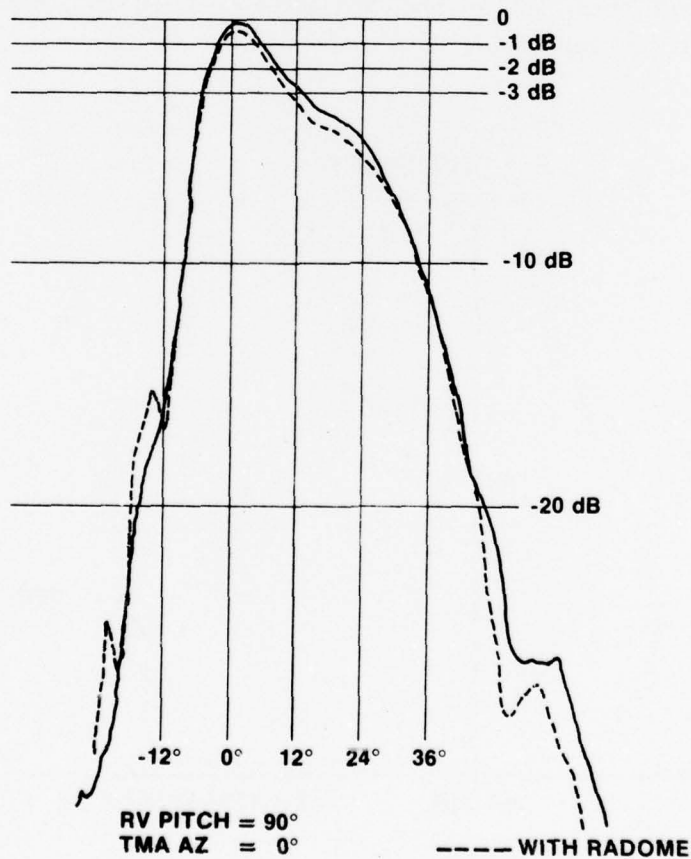


Figure 2. Terrain Mapping Antenna pattern.

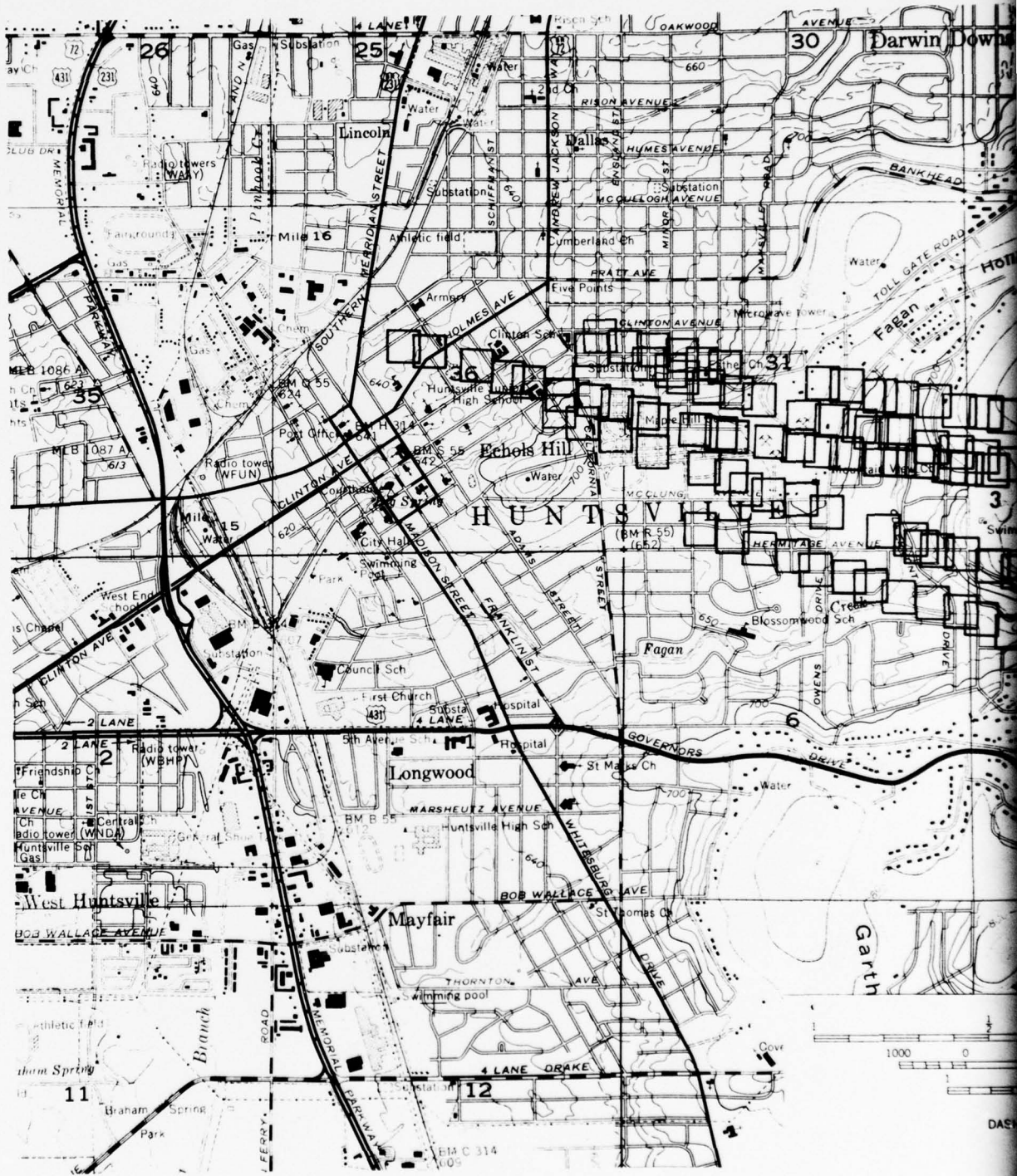


Figure 3. AH 140 ground track.

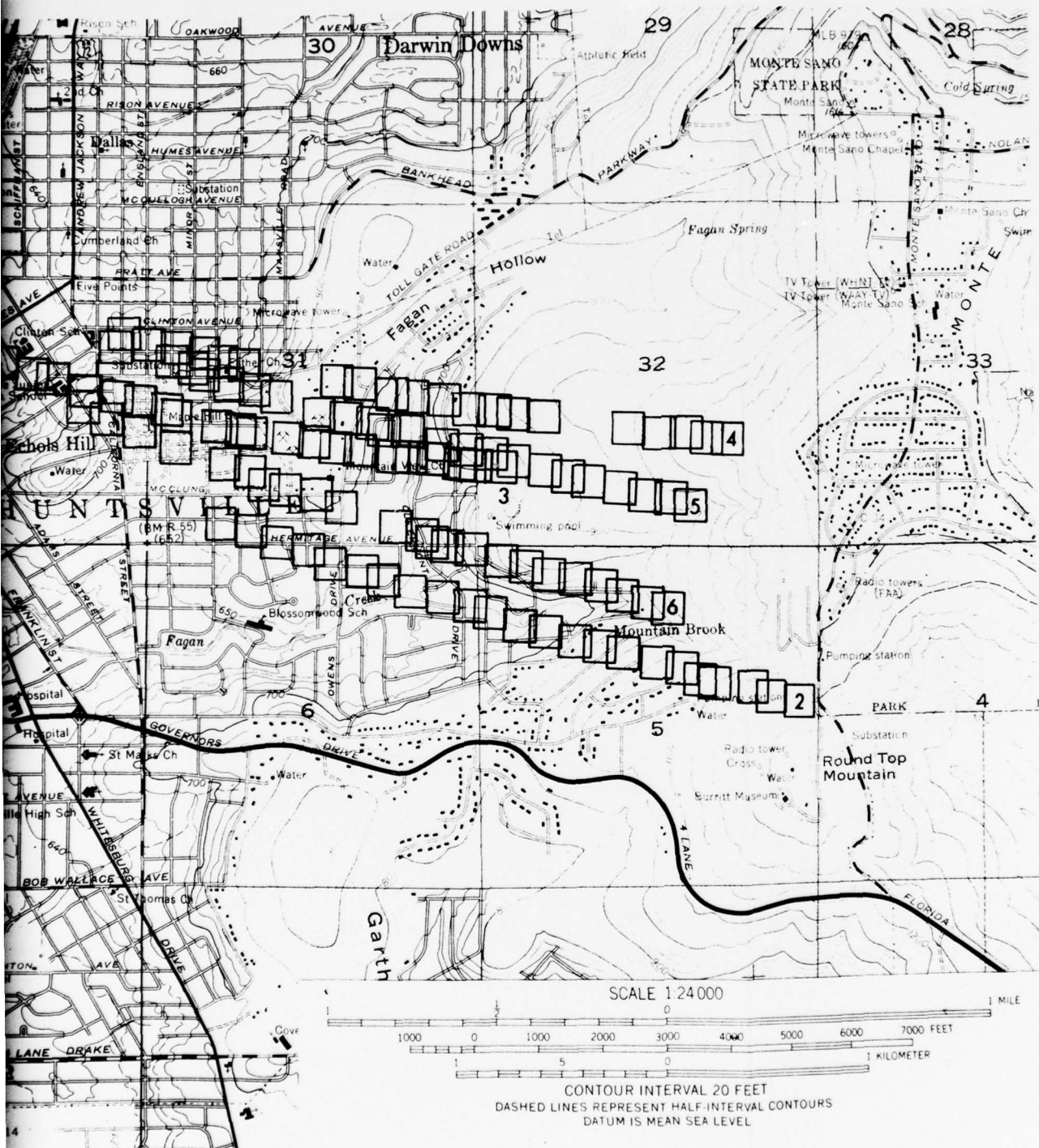


Figure 3. AH 140 ground track.

3. DATA

The difference between the altitude measured with the DME and the altitude measured onboard the test aircraft will be defined as the altitude difference (ΔZ). *Figure 4* is a plot of the five passes of flight AH 140, showing altitude (ΔZ) for various altitudes (H) referenced to the target elevation. These data were tabulated knowing that the aircraft was flying over elevated terrain while the DME was indicating a lower elevation; therefore, an effort was made to remove this elevation difference. *Figure 5* shows the various geometries which are required to correct the altitude measurements for terrain elevation differences. The following relationships are derived from *Figure 5*:

$$\Delta Z = H_D - H \text{ meters} \quad (1)$$

$$A = H - (EL2 - 624)/3.28 \text{ meters} \quad (2)$$

$$\Delta Z_C = H_D - A \text{ meters} \quad (3)$$

where

- ΔZ = Altitude difference, meters
- ΔZ_C = Altitude difference corrected for elevation, meters
- H_D = Altitude measured with DME, meters
- H = Altitude measured with altimeter, meters
- A = H corrected for terrain elevation, meters
- $EL2$ = Elevation (above sea level) of terrain under aircraft, feet.

Note that $EL2$ is in English units because it is obtained from topographical maps which give elevation in feet.

The altitude differences, corrected for the difference in terrain elevation for passes Nos. 2, 3, 4, 5 and 6 of flight AH 140, are presented in *Figures 6-10*.

4. DATA ANALYSIS

A general trend of the data in *Figure 6* shows an increasing altitude difference (ΔZ_C) with decreasing altitude and then a return to a smaller altitude difference. This apparently large difference is not explainable with the simple elevation correction previously applied. *Figure 11*

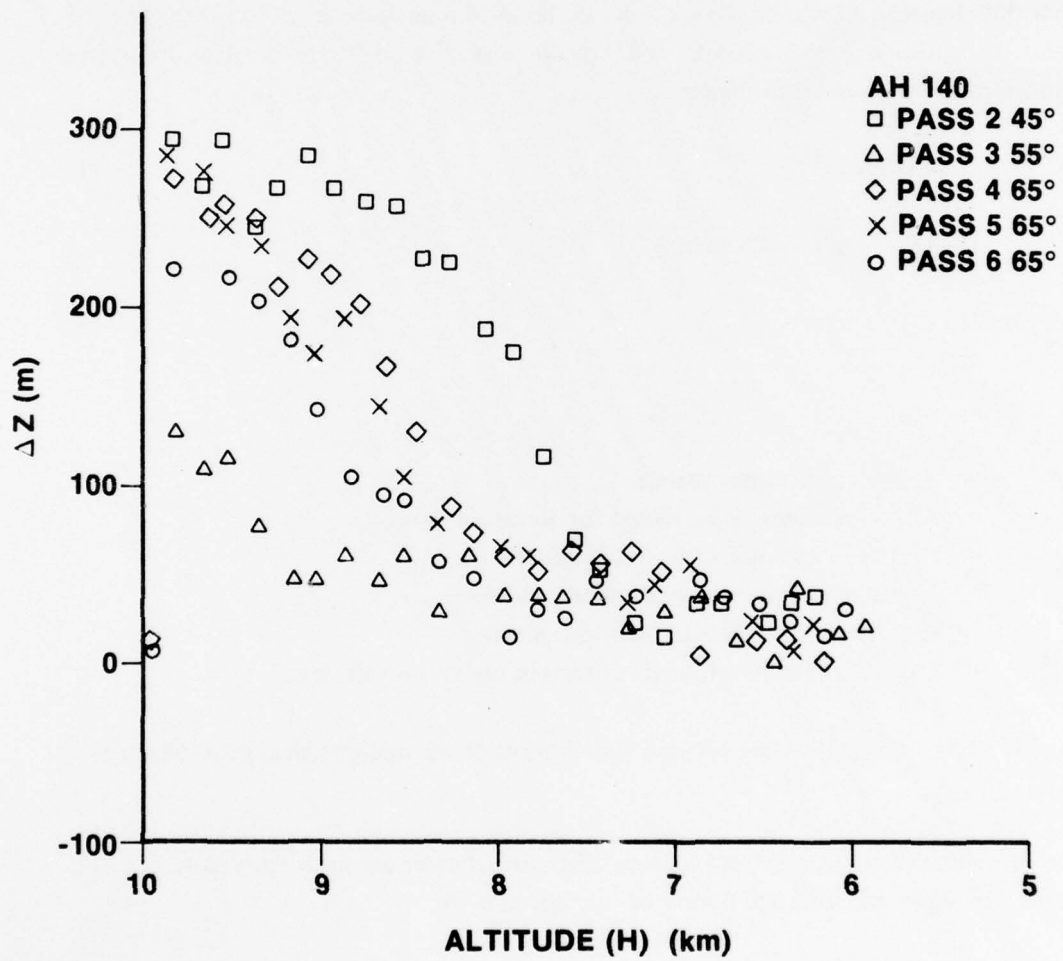


Figure 4. Altitude difference for various altitudes.

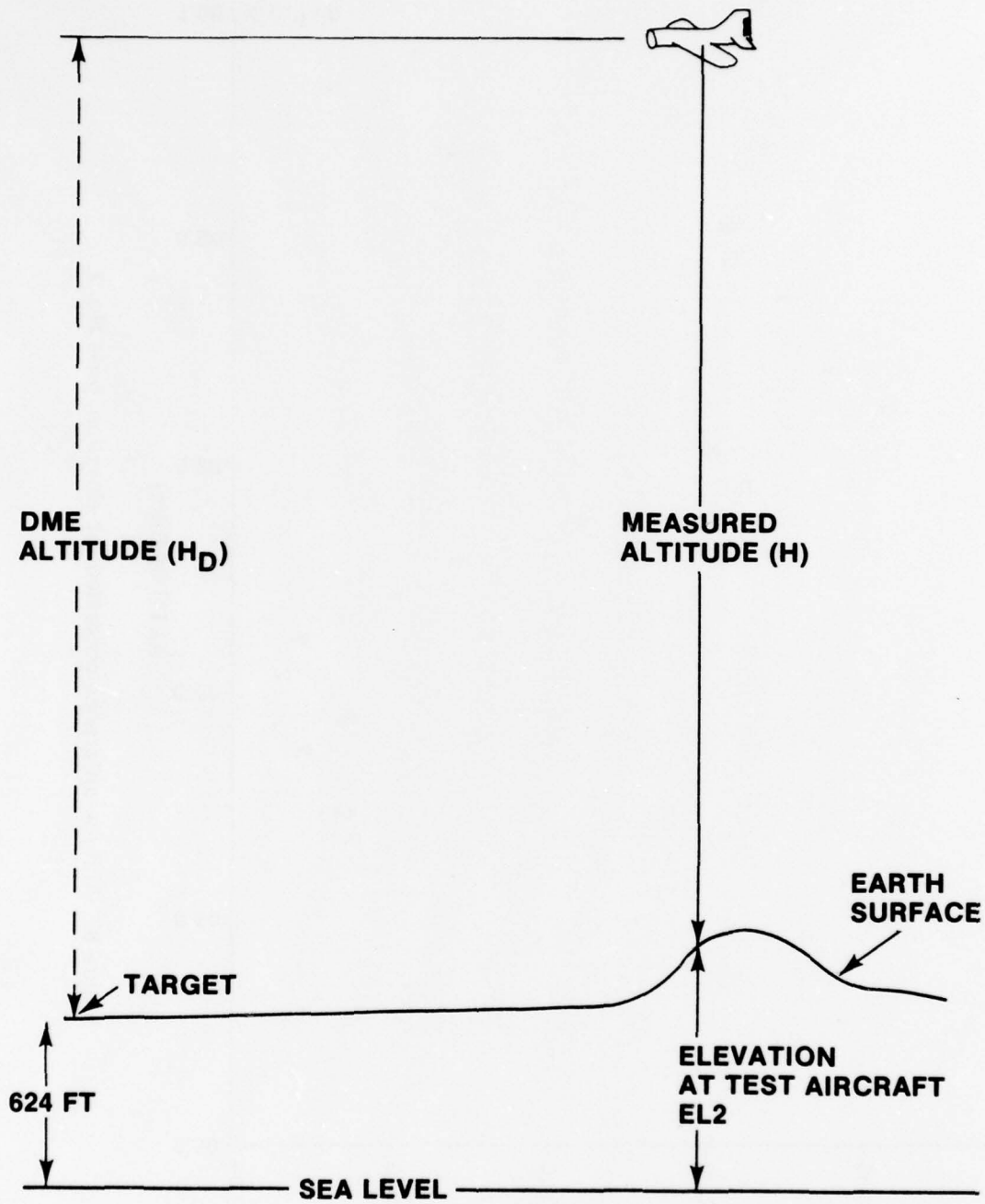


Figure 5. Terrain elevation difference.

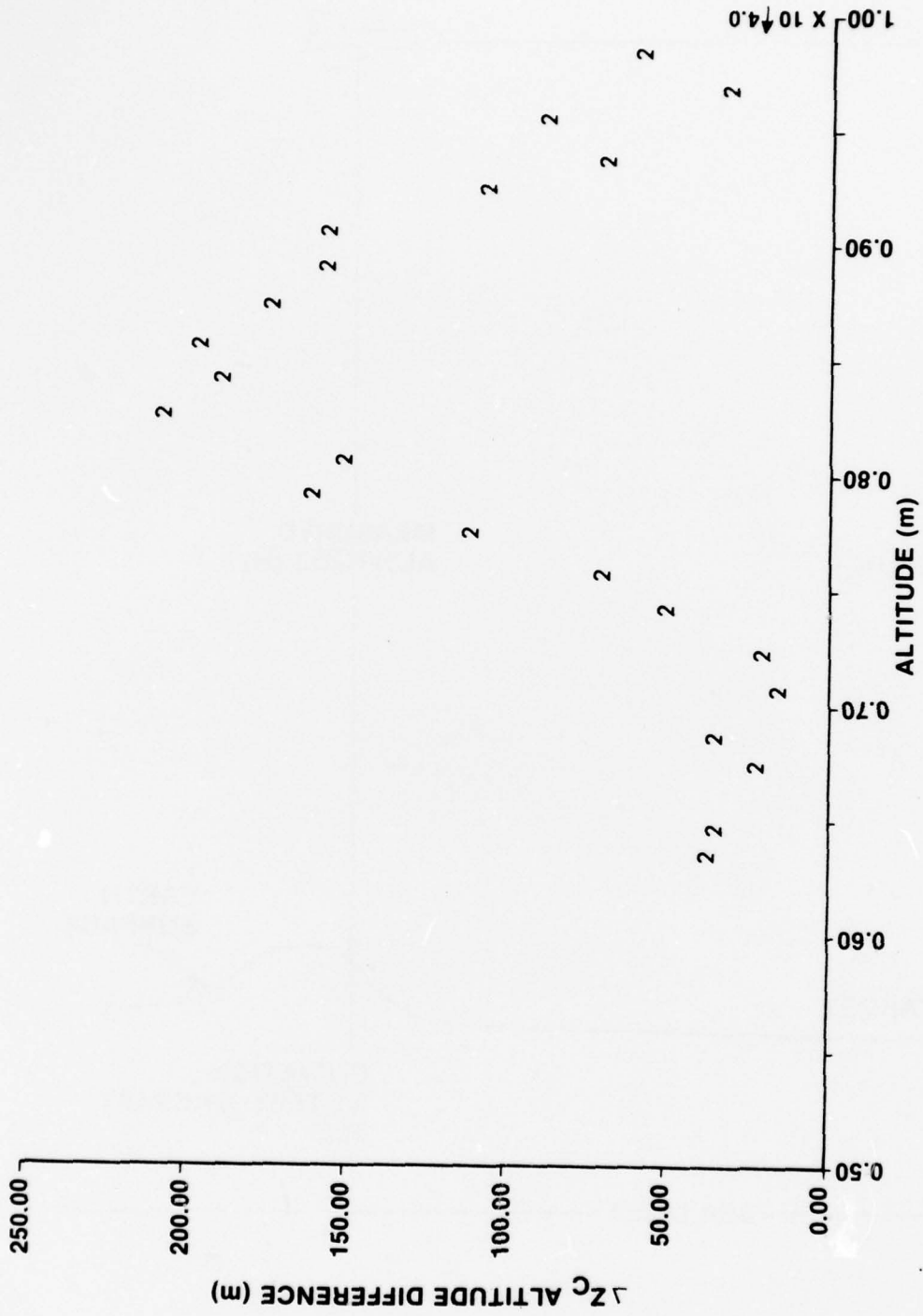


Figure 6. Altitude difference corrected for elevation, pass No. 2.

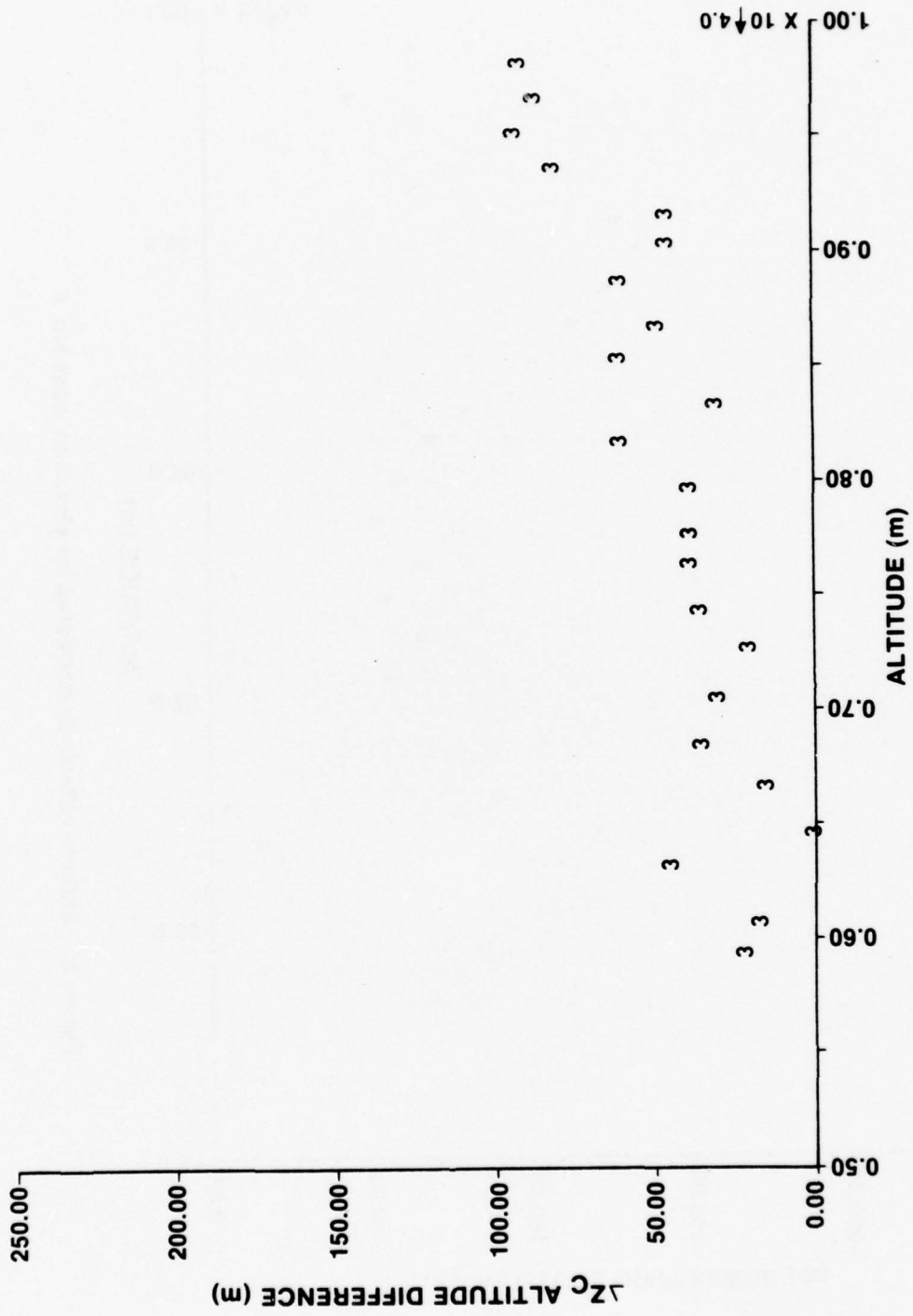


Figure 7. Altitude difference corrected for elevation, pass No. 3.

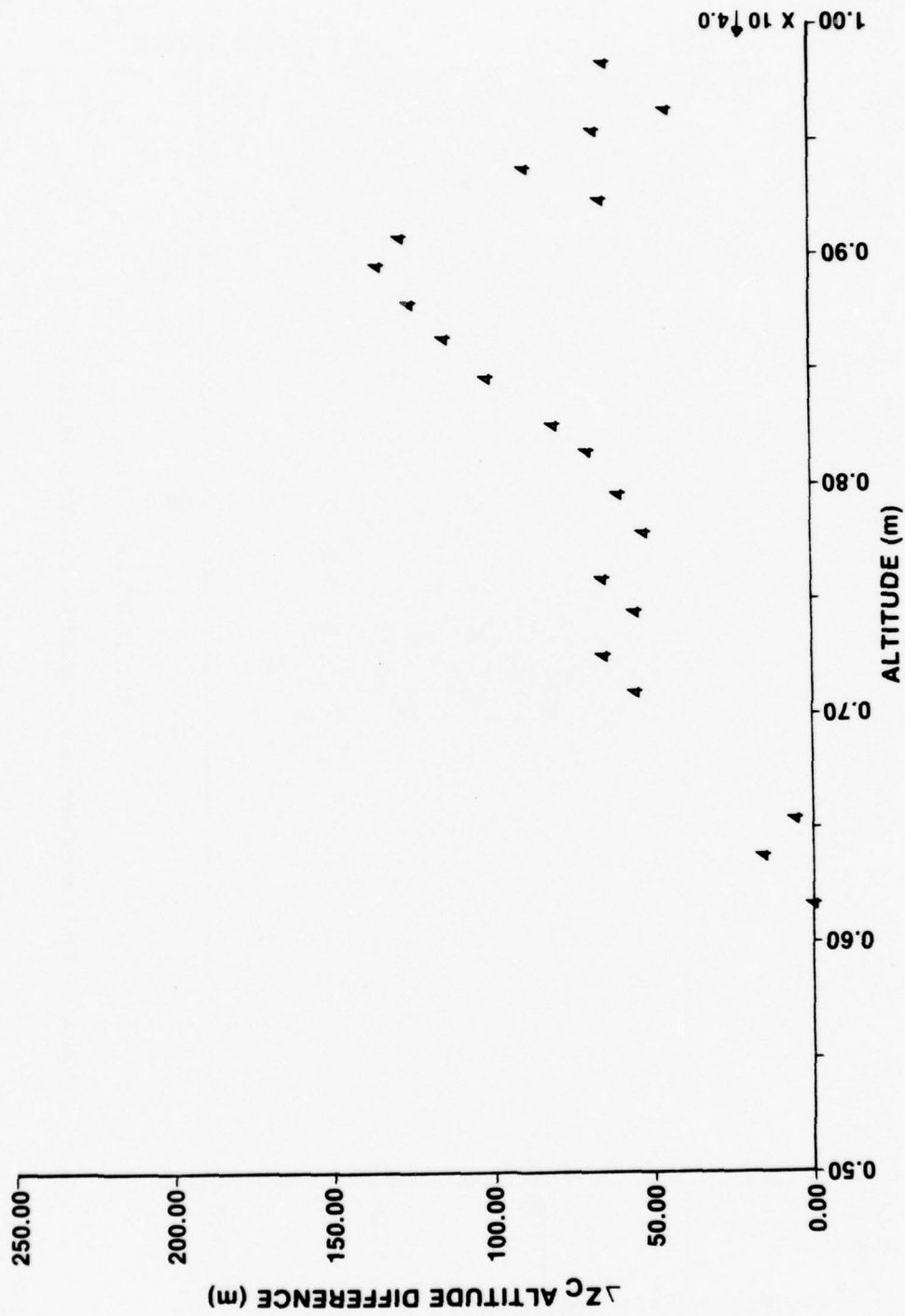


Figure 8. Altitude difference corrected for elevation, pass No. 4.

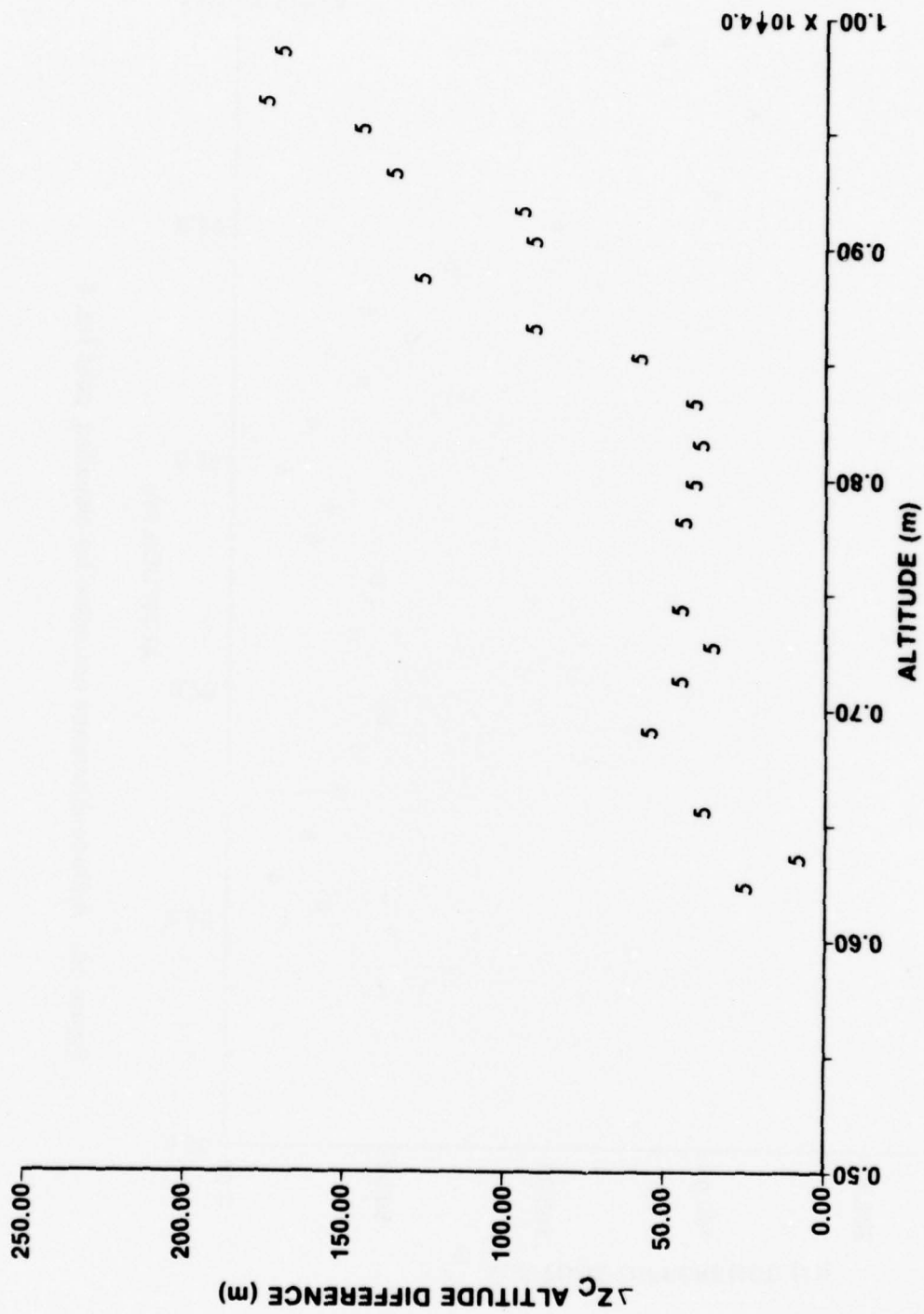


Figure 9. Altitude difference corrected for elevation, pass No. 5.

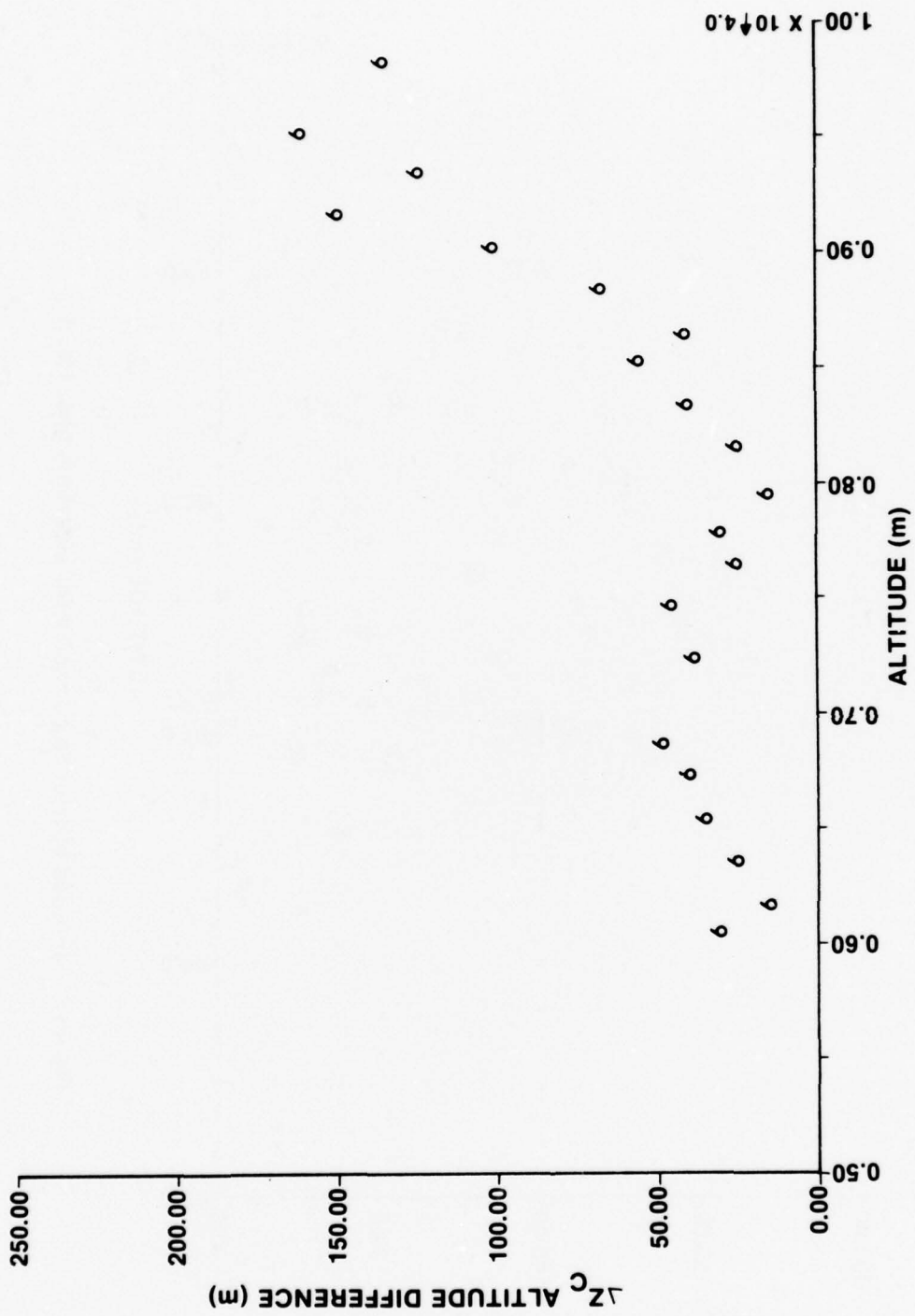


Figure 10. Altitude difference corrected for elevation, pass No. 6.



Figure 11. Ground track for pass No. 2, AH 140.



Figure 11. Ground track for pass No. 2, AH 140.

shows the ground track for pass No. 2; the pass begins at the top of the mountain and terminates over downtown Huntsville, with the largest ΔZ_c occurring along the slope of the mountain. Because the TMA is pointing 20° to the rear of the aircraft, it is obvious that the antenna was receiving signals closer than indicated as the system passed over sloping terrain. This difference was calculated from data obtained knowing the flight profiles, ground track and terrain elevation (*Figure 12*).

$$A = H - (EL2 - 624)/3.28$$

$$S = \left(\{A - [(EL1 - EL2)/3.28]\}^2 + D^2 \right)^{0.5} \quad (4)$$

where

A = Calculated slant range projected to altitude plane, meters

S = Slant range to highest point in beamwidth, meters

D = Range from ground track position to highest point in beamwidth, meters

A program was written to solve Equations (2) and (4). Data were obtained from both the flight test and topographical maps. The computational results are presented in *Figure 13*.

Examination of *Figures 11* and *13* reveals that the first checkpoint (highest altitude) has little altitude difference because the aircraft was over a peak of the mountain. Data indicate that the differences increase as the ground track moves along the slope of the mountain (checkpoints Nos. 2 through 11), and then the difference begins to decrease to a smaller value, which is shown in checkpoints Nos. 12 through 22, being over flat terrain.

Pass No. 3 started near the base of the mountain. After the first ten checkpoints, the system was no longer under the influence of the sloping mountain. The beam's toe was pointing 10° aft of the aircraft. Ground track and altitude difference plots are presented in *Figures 14* and *15*, respectively.

On pass No. 4, the toe of the beam pointed vertically but because of the low receiver threshold setting, the beam was still effectively pointing aft of the aircraft by at least 10° (*Figure 2*). This pass started near a peak of the mountain (*Figure 16*) and by the eleventh checkpoint was on relatively flat terrain. The altitude differences for this pass are presented in *Figure 17*.

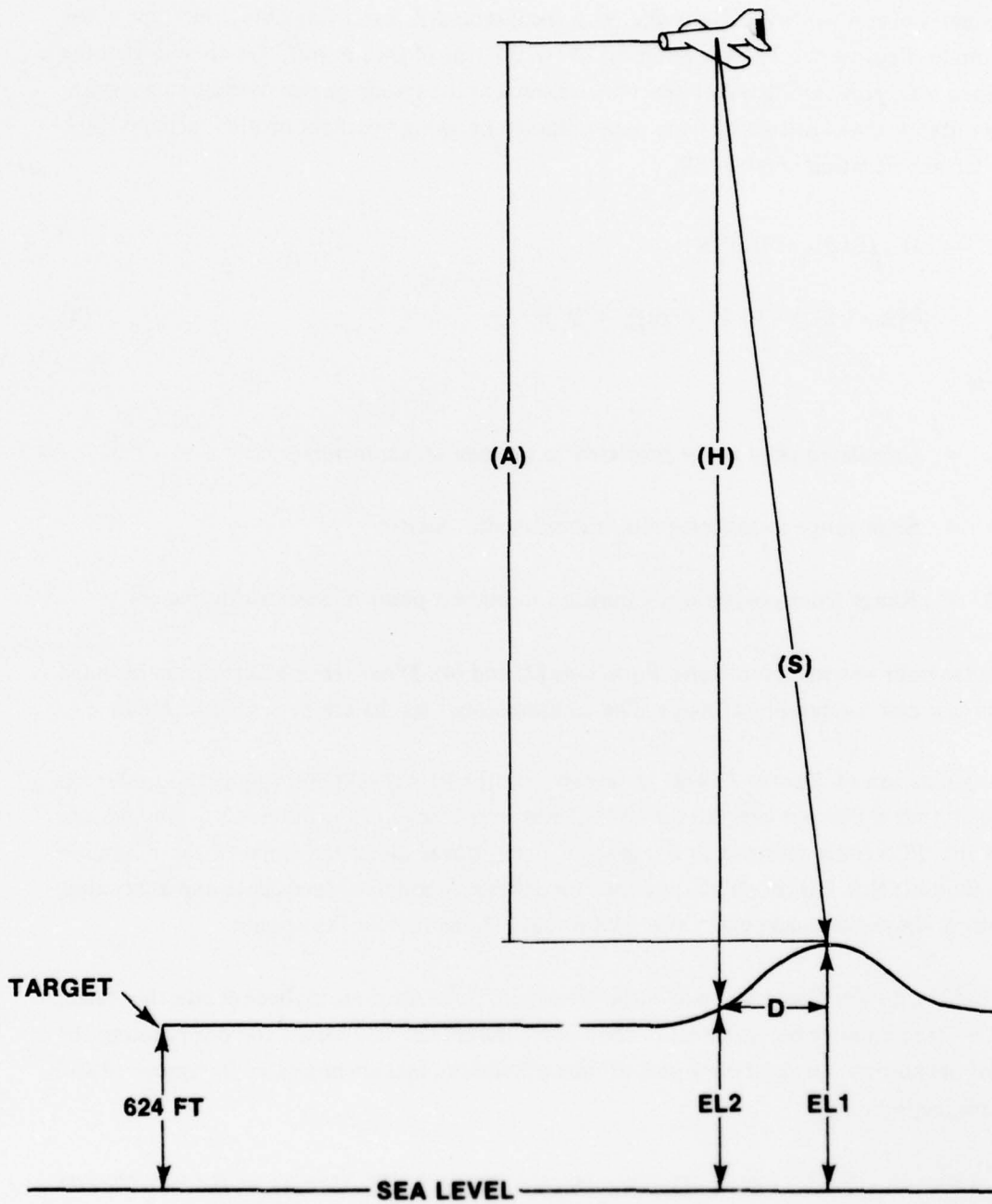


Figure 12. Geometry required for slant range calculations.

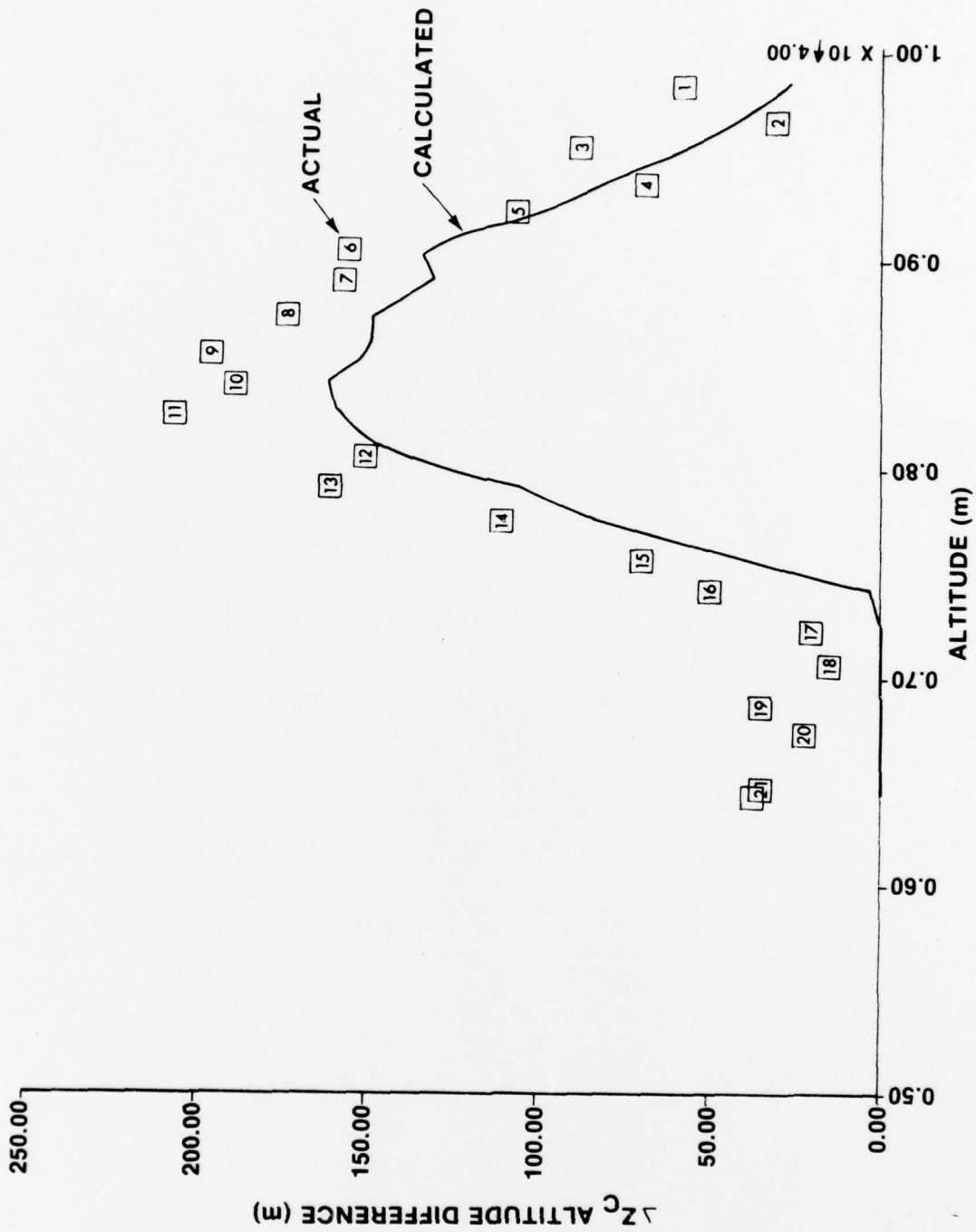


Figure 13. Pass No. 2 altitude difference comparison.



Figure 14. Ground track for pass

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Figure 14. Ground track for pass No. 3.

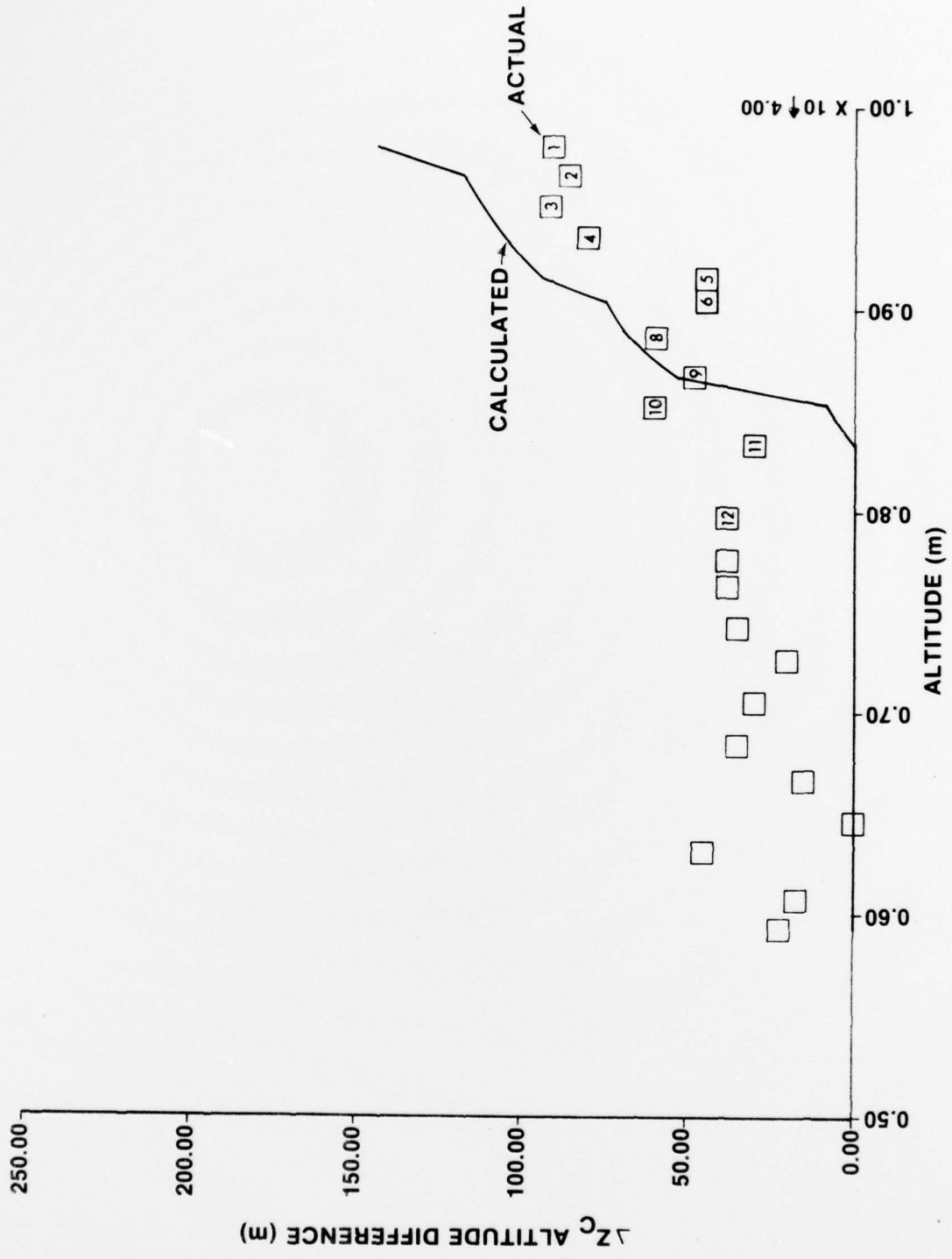


Figure 15. Pass No. 3 altitude difference comparison.

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Figure 16. Ground

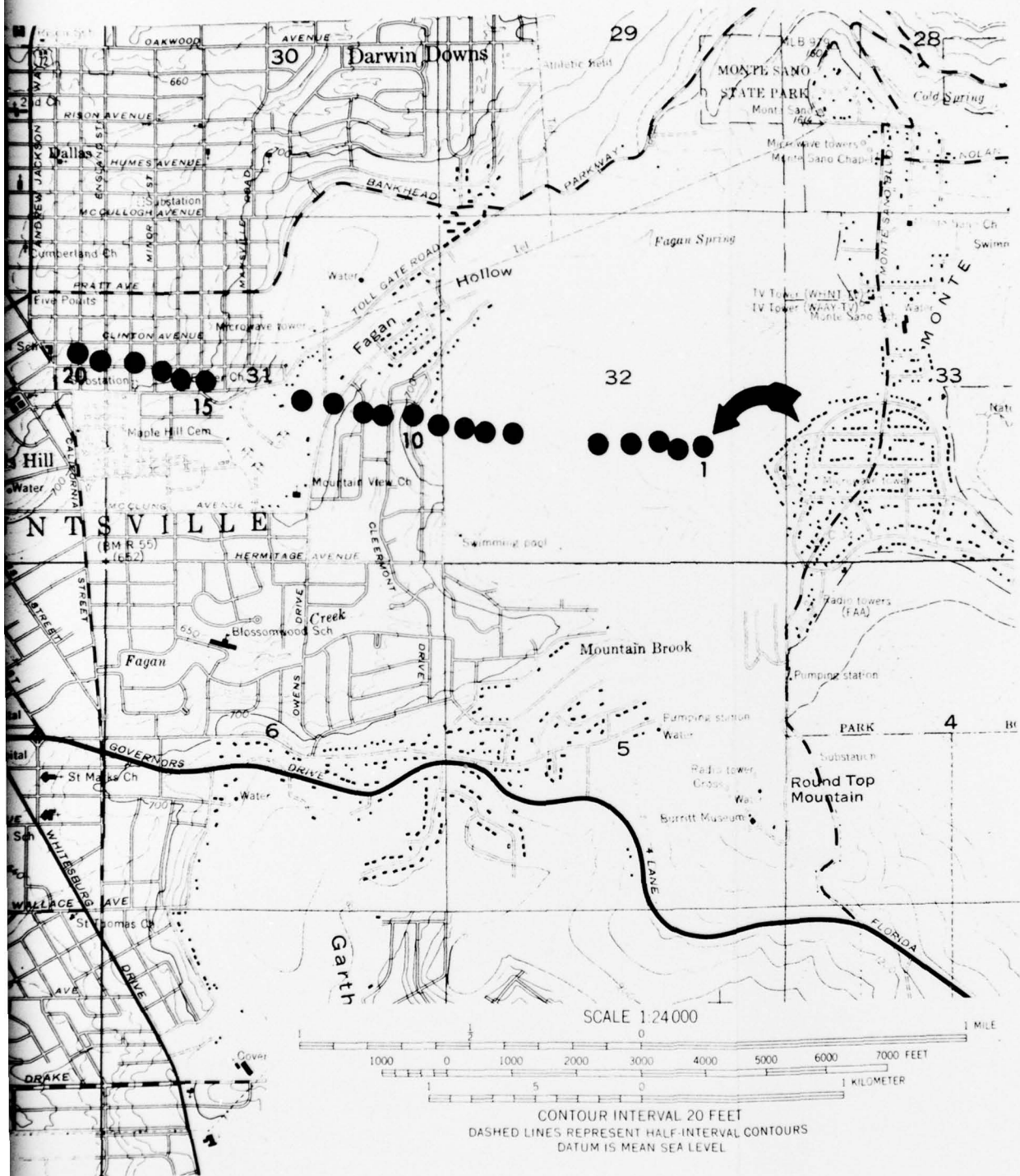


Figure 16. Ground track for pass No. 4.

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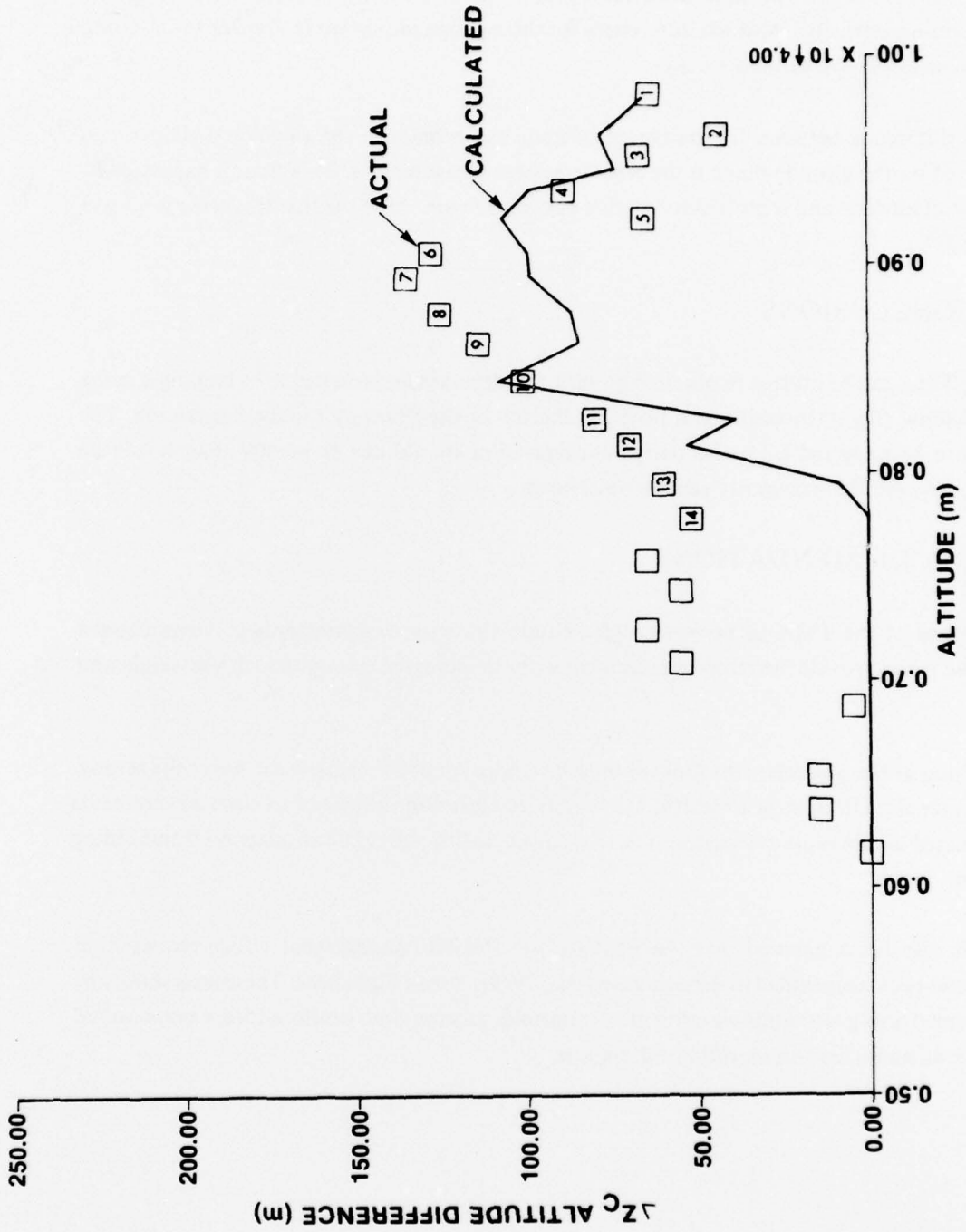


Figure 17. Pass No. 4 altitude difference comparison.

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Passes Nos. 5 and 6 were almost the same ground track, and with both passes the beam toe was pointing vertically. Altitude differences for these passes are shown in *Figures 18-21*, along with their respective ground tracks.

The difference between the measured altitude corrected and the calculated slant range projected on the altitude plane is the error in system measurement. This error is expressed as percent of altitude and is plotted for all five passes in *Figure 22*. Note that this error is always below 1%.

5. CONCLUSIONS

The TMA can be utilized to obtain high-altitude altimeter measurements by locking it in the longitudinal (flight) direction and pointing the toe of the beam in a vertical direction. The errors to be expected from this design configuration should not be greater than would be measured with the previously separate altimeter.

6. RECOMMENDATIONS

The use of the TMA to perform high-altitude altimeter measurements is recommended because it can provide the same measurement *without increased error* and with less weight and cost.

Setting of the altimeter threshold should be studied in detail because the lower the setting, the wider the effective beamwidth, causing more elevation difference in the measurements conducted in mountainous terrain. The first consideration should be an adaptive thresholding circuit.

It is also recommended that the PERSHING Project Management Office request that *altimeter tests* be included in the upcoming (fall 1979) captive flight tests. These tests should be performed using an adaptive altimeter threshold scheme and would address unanswered questions about terrain elevation differences.

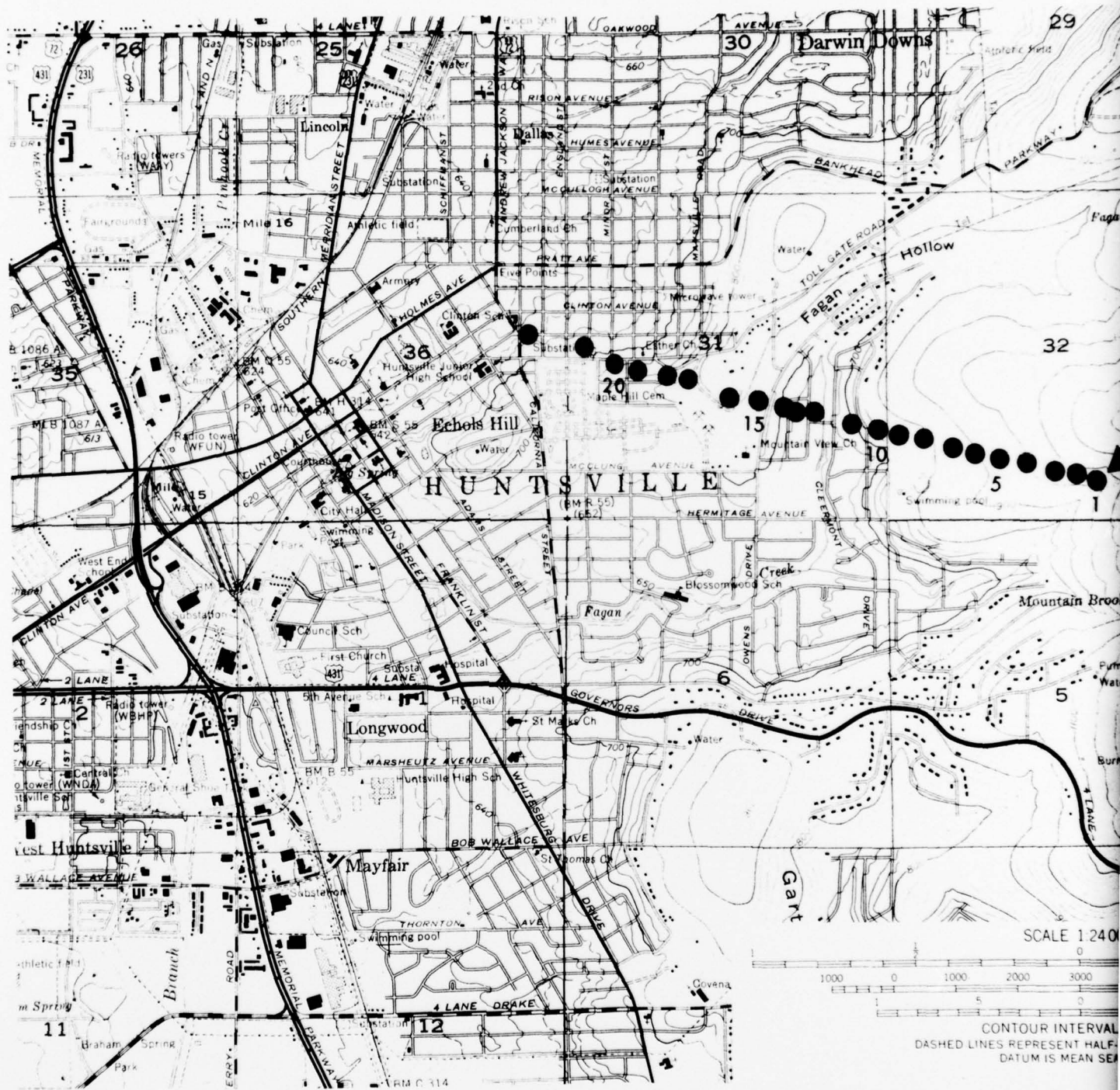


Figure 18. Ground track for pass No. 5.



Figure 18. Ground track for pass No. 5.

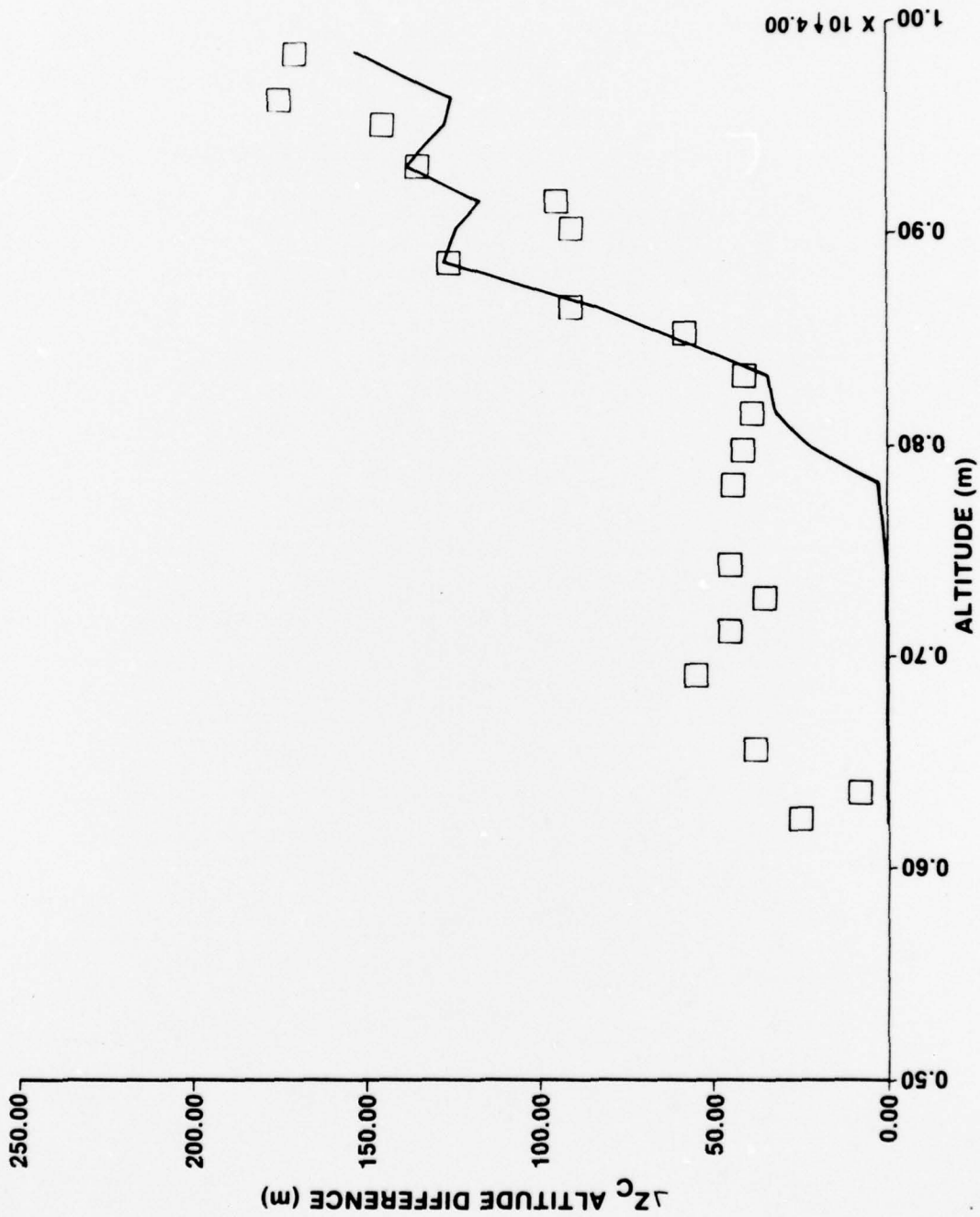


Figure 19. Pass No. 5 altitude difference comparison.

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Figure 20. Ground track for pass No. 6.

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Figure 20. Ground track for pass No. 6.

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