

**ATTACHMENT FOUR
VERIZON MANHATTAN TEST REPORT**

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Laboratories Inc.

**Network Services Technology Department
Wireless Access Technologies**

**Location Accuracy Testing
of TruePosition in Manhattan, New York**

**September 5, 2000
to
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Executive Summary

At the request of Verizon Wireless, Verizon Laboratories tested the accuracy of the TruePosition geo-location system. Testing was conducted in the dense urban environment of Manhattan. Analysis of test results revealed that the TruePosition system meets the FCC accuracy requirements in the challenging environment of Manhattan.

The purpose of the tests was to assess compliance with the FCC requirement for Phase II E911 that a network-based geo-location system shall provide an accuracy of 100 meters 67% of the time, and 300 meters 95% of the time. Testing was focused on assessing the accuracy of locating IS-95 CDMA calls.

The test area covered 1.4 square miles of mid-town Manhattan. Radio coverage in this test area was provided by 30 Verizon Wireless cell sites. Each of the 30 sites was equipped with TruePosition receivers. About 13 of the cell sites were located within the boundaries of the test area while the remainder were located within a third of a mile from the edges of the test area.

Many parts of the test area consisted of streets lined mostly with buildings, which were over 25 stories in height. The remaining parts of the test area consisted mostly of buildings of up to 10 stories in height. Overall, the test area could be characterized as being wholly an urban canyon with multi-lane streets.

The CDMA Development Group (CDG) test plan was used as a basis for the testing. Twelve (12) urban scenarios from the CDG test plan were selected and tested. Test calls were generated outdoors, on the sidewalk, and, in both stationary and walking modes. Test calls were also generated indoors, within tall buildings representing the urban canyon-high rise environment. Other test calls were generated from within a car, both when the car was stationary and when it was in motion.

Verizon Laboratories' analysis also revealed that the TruePosition system yielded compliant results for the majority of individual scenarios tested, but with a few exceptions. TruePosition attributed the high errors in some of the fixes to three reasons. First, some test calls were generated at the edge of the coverage area, which resulted in geometric dilution of precision (GDOP). Second, the multipath mitigation by TruePosition was optimized to deal with strong multipath components at street level whereas for calls from within upper building floors the phones have a direct line of sight to antennas. Third, misconfiguration of a T1 line at a microcell host site which prevented TruePosition from providing coverage at two microcell sites.

The FCC mandate is to achieve overall compliance in a coverage area, as opposed to compliance by environment, or by scenario. However, the FCC does not provide clear guidelines on how to assess overall compliance. Verizon Laboratories analyzed the overall accuracy by evaluating the location errors of each tested scenario and by applying weights to each scenario. Three weighting profiles were considered.

In the first profile it was assumed that in a dense urban environment the majority of 911 calls (95%) originate outdoors, and that most outdoor calls originate from pedestrians (as opposed to from within a vehicle). In the second profile it was assumed that a higher percentage (20% versus 5%) of 911 calls are made indoors, and that the number of calls originating from pedestrians is comparable to those made from within a vehicle. In the third profile it was assumed that all scenarios tested had equal weighting.

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The first weighting profile could be considered more representative of current wireless 911 call behavior. The other two profiles were also considered to assess overall compliance if in the future more calls are made indoor, or from within a moving vehicle. For all three weighting profiles considered, the TruePosition system was compliant in Manhattan with the FCC requirements in locating IS-95 callers.

TruePosition made improvements to their algorithms during the testing conducted by Verizon Laboratories. These improvements involved better handling of GDOP at the edge of the coverage area and modifying their multipath mitigation algorithm to deal with weak multipath signals. TruePosition believes that the new multipath mitigation algorithm significantly improves performance for calls high in the building, while only slightly degrading the performance of the street level calls.

Testing of the TruePosition system in Manhattan was successful, and meets the FCC requirements. It is further recommended that the system be tested in rural and suburban environments.

1. Introduction

This report summarizes the results of the location accuracy tests conducted by Verizon Laboratories of the geo-location system from TruePosition, Inc. The purpose of the tests was to assess compliance with the FCC requirement for Phase II E911 that a network-based system shall provide an accuracy to within 100 meters 67% of the time, and to within 300 meters 95% of the time. Testing was focused on assessing the location determination accuracy of the TruePosition geo-location system in locating IS-95 calls in the cellular band.

The system that was tested employed a time difference of arrival (TDOA) algorithm for estimating fixes. Testing was conducted in mid-town Manhattan from September 5 to September 7, 2000. The test area was between 34th St. and 57th St., and, between 2nd Ave. and 9th Ave. It covered 1.4 square miles of mid-town Manhattan. Radio coverage in this test area was provided by 30 Verizon Wireless cell sites, of which slightly more than half were located outside the boundary of the test area. **Figure 1** illustrates the test area and its boundary.

Figure 1 also illustrates the geo-location field trial network. Each of the 30 cell sites was equipped with a TruePosition Signal Collection System (SCS), i.e., a geolocation receiver.

Many parts of the test area consisted of streets lined mostly with buildings, which were over 25 stories in height. Hence these parts could be characterized as representing the urban canyon-high environment as defined in the CDG Test Plan. The remaining parts of the test area consisted mostly of buildings of up to 10 stories in height, with a few very tall buildings in between these medium sized buildings. These parts could be characterized as representing the urban canyon-medium environment as defined in the CDG Test Plan. Overall, then, the test area could be characterized as being wholly an urban canyon with multi-lane streets.

About 13 of the cell sites were located within the boundaries of the test area while the remainder were located within a third of a mile, at the most, from the edges of the test area. Hence, the distance between adjacent cell sites was very small. It varied from a third of a mile to, in many instances, a sixth of a mile.

The CDG test plan was used as a basis for the testing. Twelve (12) scenarios were tested. **Table 1** outlines the scenarios tested in Manhattan. Each scenario was tested in three different locations. Typically, about 90 calls were made for each scenario, i.e., about 30 calls per location. One fix was obtained for each call.

Some of the test calls were generated outdoors, on the sidewalk, and, in both stationary and walking modes. Some were generated indoors, within tall buildings representing the urban canyon-high environment. Other test calls were generated from within a car, both when the car was stationary and when it was in motion.

Accuracy was analyzed by comparing location fixes estimated by the geo-location system to corresponding ground truth locations. To determine the ground truth the following procedure was used. Within the test area, TruePosition had earlier selected 177 test points, which were more or less uniformly distributed throughout the test area. They then employed a surveying company to determine the ground truth of these test points. Hence, whenever a scenario being tested used a location that coincided with one of these test points then the ground truth for that location was the same as that determined earlier by the surveying company for the corresponding test point. In cases where the location was not the same as any of the test points, ground truth for the location was calculated from the ground truth of the test point closest to that location, and by subsequently measuring distance and angle at a series of intermediate points, until the desired location was reached.

In Section 2, the location accuracy of the TruePosition geo-location system is analyzed for each individual scenario that was tested in Manhattan. The details of the analysis are given in Section 2. For each scenario, the following are included:

1. the number of calls that were made for that scenario,
2. the 67th percentile of the location estimation error,
3. the 95th percentile of the location estimation error,
4. photographs capturing the scenario,
5. the probability density function of the location errors, and
6. the cumulative distribution function of the location errors.

Overall compliance with the FCC mandate can only be determined from a weighted combination of the results from each scenario. Hence, in Section 3, the overall location accuracy for the test area is analyzed by combining the results of the scenarios tested. The combined result depends upon the weighting factors that are assigned to the scenarios. Several combinations of weighting factors are examined. Finally, Section 3 also provides a conclusion and recommends next steps for further analysis.

Table 1. Urban Scenarios Tested in Manhattan

Ref. No.	Environment	Condition	No of Locations	No of Location Estimates per Location	Notes
U-1	Urban canyon-high, intersection	Outdoor, stationary	5	40	1, 6
U-2	Urban canyon-high, mid-block	Outdoor, walking	5	40	1, 6
U-3	Urban canyon-med., intersection	Outdoor, stationary	5	40	2, 6
U-4	Urban canyon-med., mid-block	Outdoor, walking	5	40	2, 6
U-7	Urban canyon-high, mid-block	Inside car, stationary	5	40	1
U-8	Urban canyon-high, Multi-Lane Street	Inside car, 10-25mph	5	40	1
U-10	Urban canyon-high, exterior room	Indoor, stationary, top floor	5	40	1, 3
U-12	Urban canyon-high, exterior room	Indoor, stationary, ground floor	5	40	1, 3
U-13	Urban canyon-high, interior room	Indoor, stationary, top floor	5	40	1, 4
U-15	Urban canyon-high, interior room	Indoor, stationary, ground floor	5	40	1, 4
U-16	Urban canyon-high, core	Indoor, stationary, top floor	5	40	1, 5
U-18	Urban canyon-high, core	Indoor, stationary, ground floor	5	40	1, 5

Note(s):

1. Urban canyon-high includes buildings with between 25-50 stories.
2. Urban canyon-medium includes buildings with between 5-10 stories, downtown dense urban area:
3. 4 meters from the window, no interior wall blocking the window access.
4. 10 meters from the window, 1 interior wall between the windows and the mobile station.
5. Near the core of the high-rise building by the elevator.
6. Location estimates should be collected from the safety of the sidewalk, at either the street intersection or mid-block as specified under Environment.

2-1. OUTDOOR TEST SCENARIOS

**Scenario (U2) - Urban canyon high, mid-block, walking
(Summary)**

Locations

# Test Locations:	3
Location 1:	1040 N 6th Ave between 39th and 40th, Roses Only (Fashion District Display and map on pole)
Location 2:	787 7th Ave between 52th and 51st St (Fire hydrant)
Location 3:	Treasure Chest, 3rd Ave, between 47th and 48th (Gray light pole with sign Local Truck Route)
Total # Fixes:	104
67% Error:	142
95% Error:	250

**Scenario (U2) - Urban canyon high, mid-block, walking
(Sample Photographs)**



FIGURE U2A: 1040 N 6TH AVE BETWEEN 38TH AND 40TH, ROSES ONLY
(FASHION DISTRICT DISPLAY AND MAP ON POLE)



FIGURE U2B: 787 7TH AVE BETWEEN 52TH AND 51ST ST (FIRE HYDRANT)

**Scenario (U2) - Urban canyon high, mid-block, walking
(Sample Photographs)**



FIGURE U2C: TREASURE CHEST, 3RD AVE, BETWEEN 47TH AND 48TH
(GRAY LIGHT POLE WITH SIGN LOCAL TRUCK ROUTE)

Scenario (U2) - Urban canyon high, mid-block, walking
(Distribution Functions)

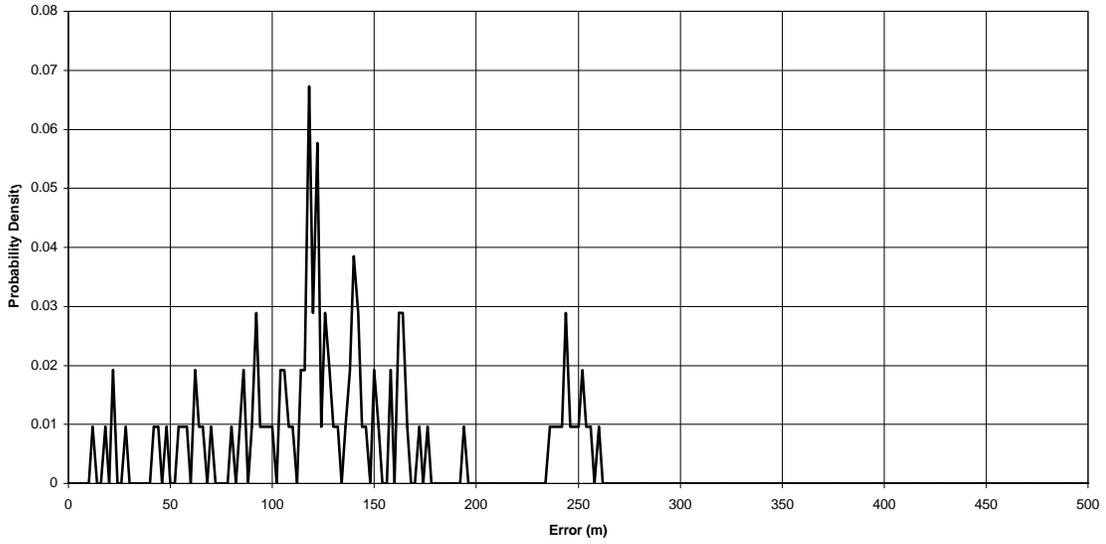


FIGURE U2D: PROBABILTIIY DENSITY FUNCTION FOR LOCATION ERROR

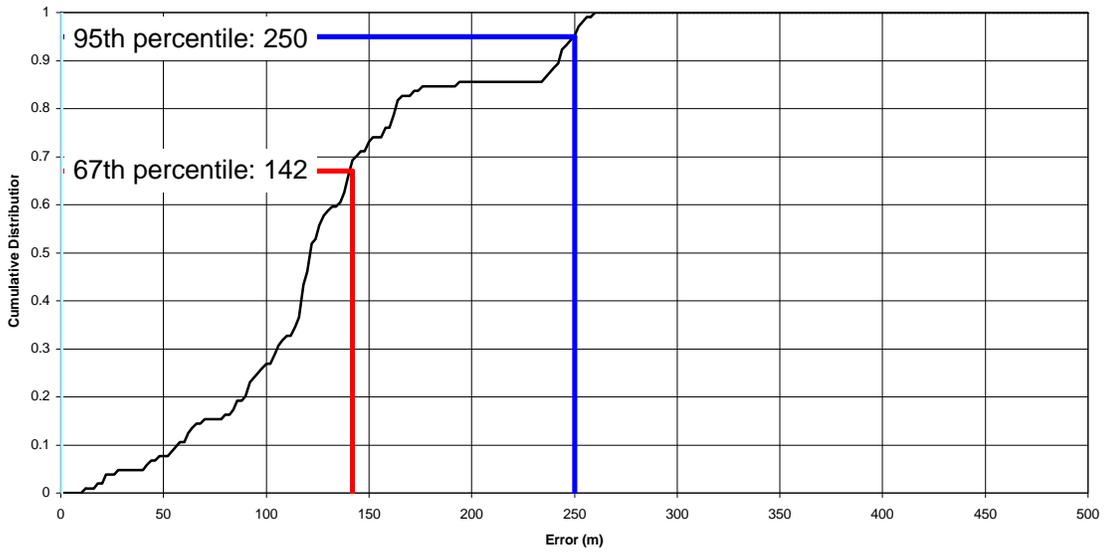


FIGURE U2E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U1) - Urban canyon high, intersection
(Summary)**

Locations

# Test Locations:	3
Location 1:	Andrew's Coffee Shop, Intersection Broadway and 39th (Traffic light pole at corner)
Location 2:	Intersection- NE corner of 49th St and 7th Ave (Traffic light pole)
Location 3:	CitiBank on the SW corner of 46th & 3rd (Traffic light pole)
Total # Fixes:	124
67% Error:	70
95% Error:	122

**Scenario (U1) - Urban canyon high, intersection
(Sample Photographs)**



FIGURE U1A: ANDREW'S COFFEE SHOP, INTERSECTION BROADWAY AND 39TH
(TRAFFIC LIGHT POLE AT CORNER)



FIGURE U1B: INTERSECTION- NE CORNER OF 39TH ST AND 7TH AVE
(TRAFFIC LIGHT POLE)

**Scenario (U1) - Urban canyon high, intersection
(Sample Photographs)**



FIGURE U1C: CITIBANK ON THE SW CORNER OF 46TH & 3RD (TRAFFIC LIGHT POLE)

Scenario (U1) - Urban canyon high, intersection
(Distribution Functions)

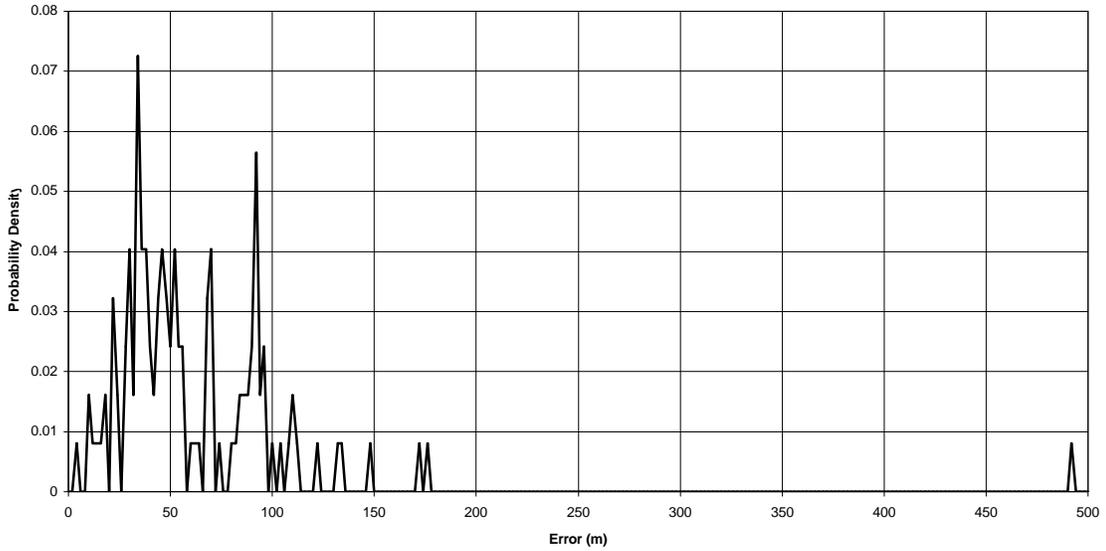


FIGURE U1D: PROBABILTIIY DENSITY FUNCTION FOR LOCATION ERROR

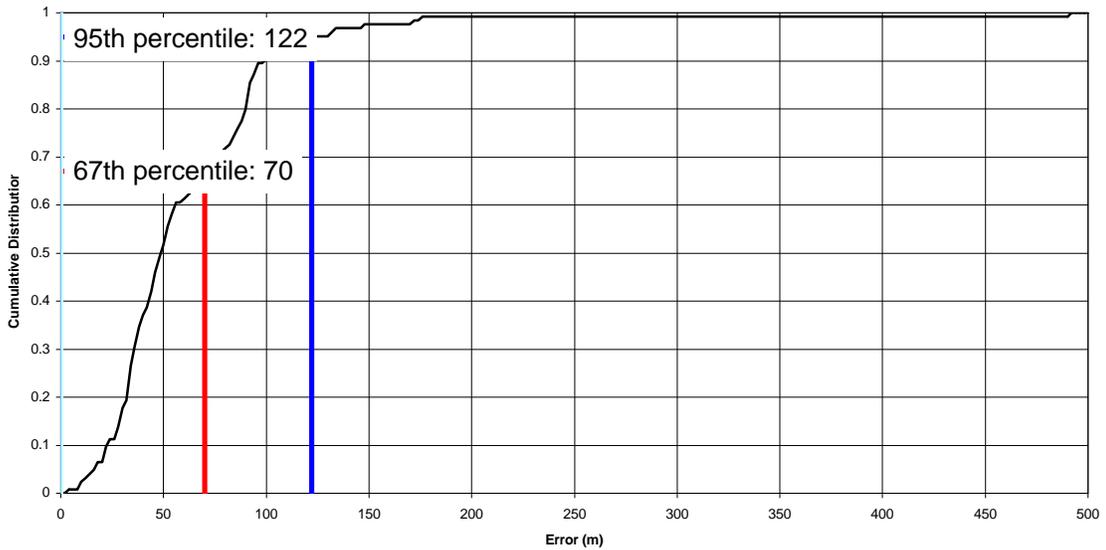


FIGURE U1E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U4) - Urban canyon medium, mid-block, walking
(Summary)**

Locations

# Test Locations:	3
Location 1:	Associated store, between 48 & 49 street, 2nd Ave (Tree with grade just before Stationary store)
Location 2:	Belvedere Hotel, 319 48th St, between 9 & 8 Ave (Fire hydrant)
Location 3:	Parking garage on 36th St between 9 and 8 (Phone on wall)
Total # Fixes:	98
67% Error:	64
95% Error:	370

**Scenario (U4) - Urban canyon medium, mid-block, walking
(Sample Photographs)**



FIGURE U4A: ASSOCIATED STORE, BETWEEN 48 & 49 STREET, 2ND AVE
(TREE WITH GRADE JUST BEFORE STATIONARY STORE)



FIGURE U4B: BELVEDERE HOTEL, 319 48TH ST, BETWEEN 9 & 8 AVE (FIRE HYDRANT)

**Scenario (U4) - Urban canyon medium, mid-block, walking
(Sample Photographs)**



FIGURE U4C: PARKING GARAGE ON 36TH ST BETWEEN 9 AND 8 (PHONE ON WALL)

Scenario (U4) - Urban canyon medium, mid-block, walking
(Distribution Functions)

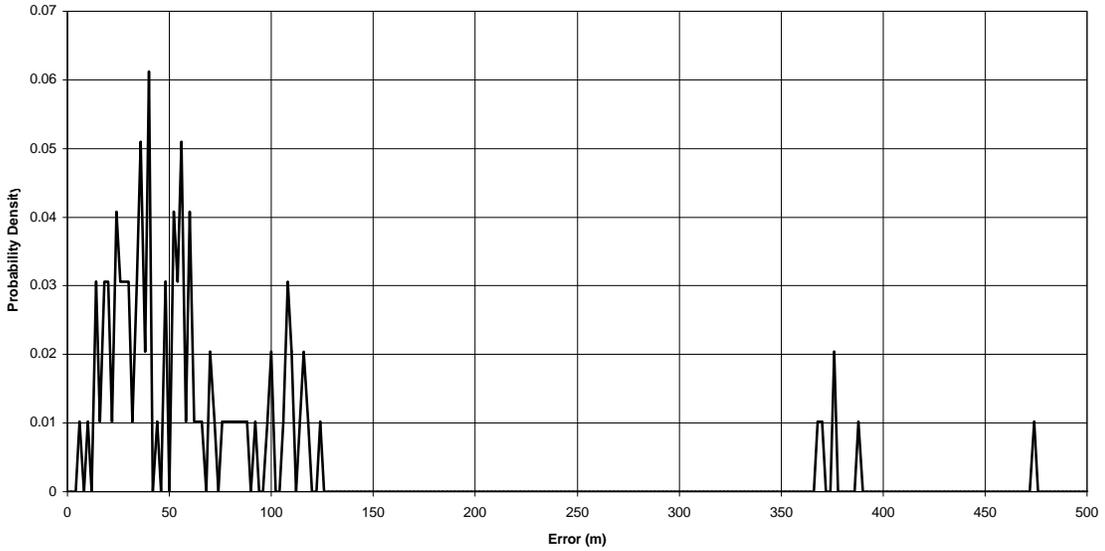


FIGURE U4D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

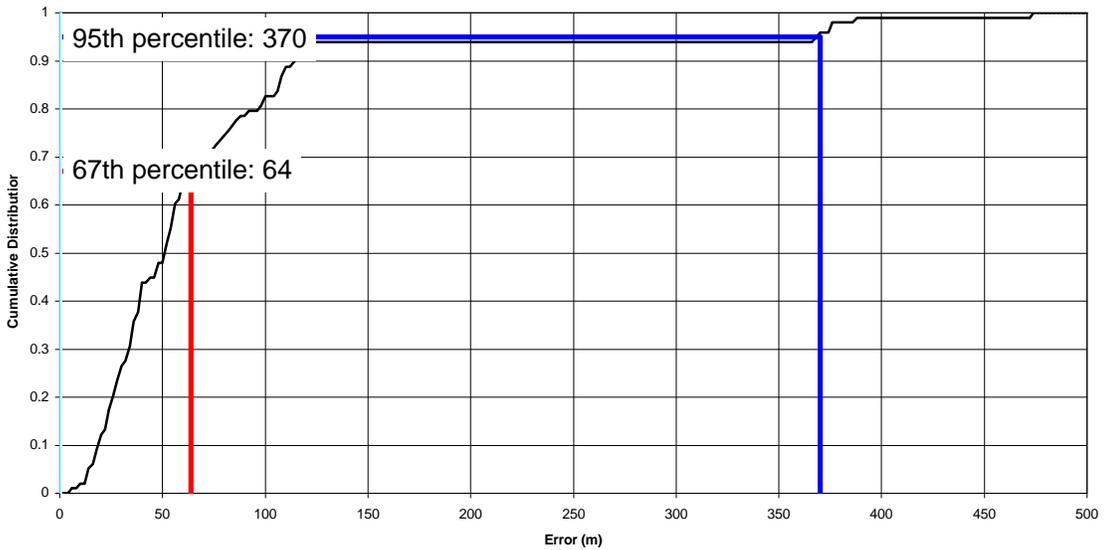


FIGURE U4E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U3) - Urban canyon medium, intersection
(Summary)**

Locations

# Test Locations:	3
Location 1:	NE corner of 52nd & 2nd Ave (Traffic light pole in front of Mimi's restaurant-984 2nd Ave)
Location 2:	SE corner, 51st St and 9th Ave, St Claire Yue Wah restaurant (Traffic light pole)
Location 3:	NW corner of 34th and 8th (Traffic light pole)
Total # Fixes:	101
67% Error:	70
95% Error:	100

**Scenario (U3) - Urban canyon medium, intersection
(Sample Photographs)**



FIGURE U3A: NE CORNER OF 52ND & 2ND AVE
(TRAFFIC LIGHT POLE IN FRONT OF MIMI'S RESTAURANT-984 2ND AVE)



FIGURE U3: SE CORNER, 51ST ST AND 9TH AVE, ST CLAIR YUE WAH RESTAURANT
(TRAFFIC LIGHT POLE)

Scenario (U3) - Urban canyon medium, intersection
(Distribution Functions)

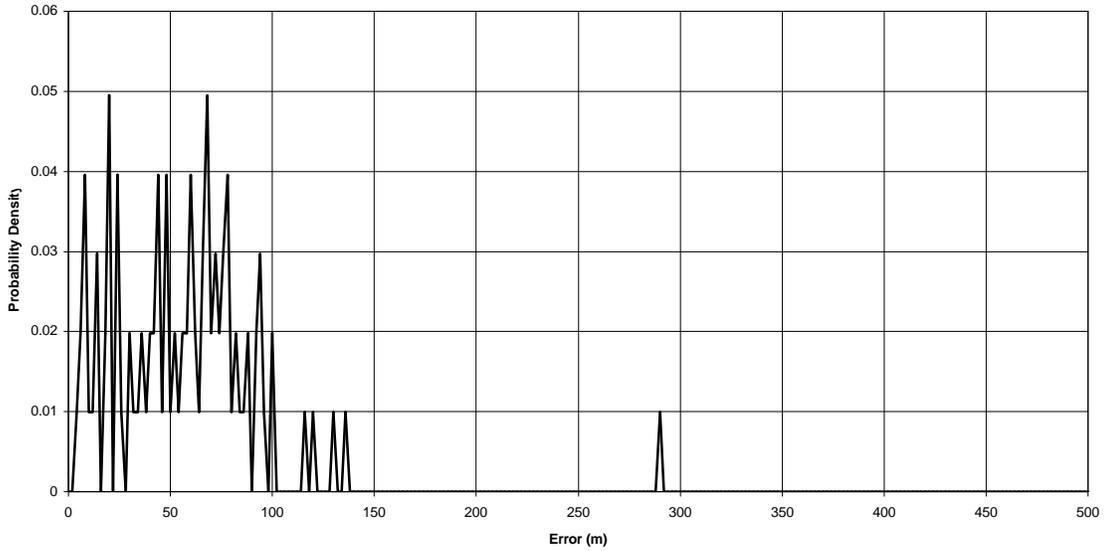


FIGURE U3D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

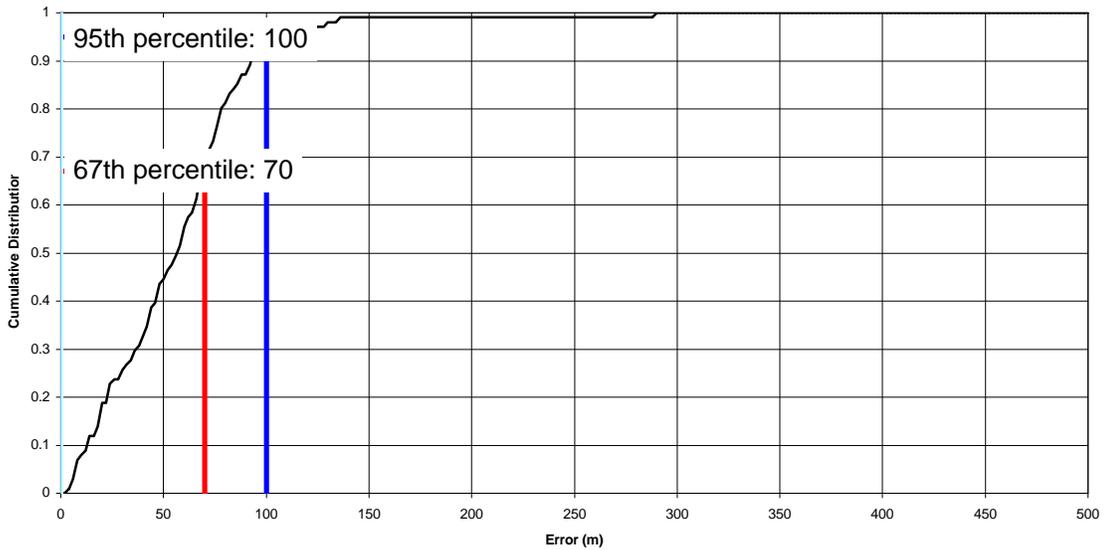


FIGURE U3E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

2-2. IN-VEHICLE STATIONARY TEST SCENARIOS

**Scenario (U7) - Urban canyon high, mid-block, inside car, stationary
(Summary)**

Locations

# Test Locations:	3
Location 1:	Fashion Center Bldg on Madison at #30 West 39th St (Phone booth to your left in line with entrance of 30 W 39th)
Location 2:	7th Ave between 54th and 53rd Streets, Lindy's Griddle and Breakfast (No standing sign)
Location 3:	3rd Ave between 50th and 51st, Starbucks Coffee (Caution recessed crosswalk on 3rd Ave sign)
Total # Fixes:	103
67% Error:	74
95% Error:	204

Scenario (U7) - Urban canyon high, mid-block, inside car, stationary
(Distribution Functions)

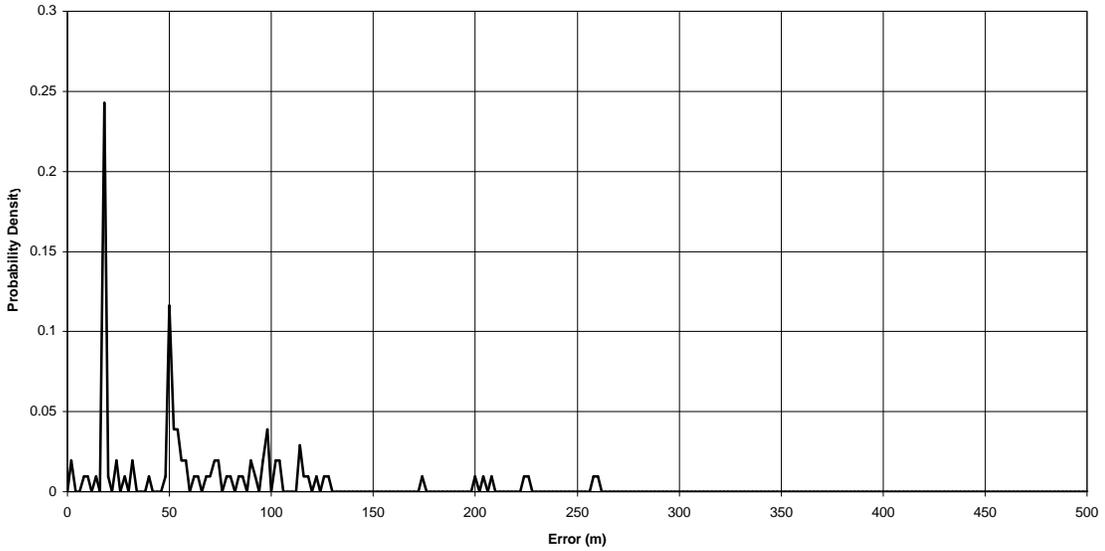


FIGURE U7B: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

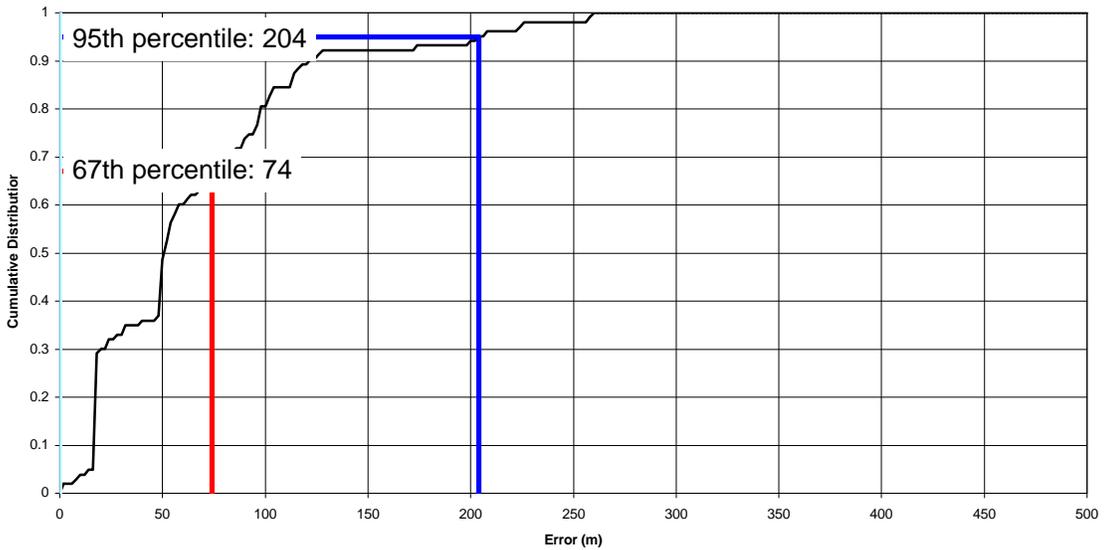


FIGURE U7C: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

2-3. IN-VEHICLE MOVING TEST SCENARIOS

**Scenario (U8) - Urban canyon high, multi-lane street, inside car, 10-25mph
(Summary)**

Locations

# Test Locations:	5 w/3 traveling routes
Location 1:	Route of 2nd Avenue locating at "Night Owls", "Blockheads", "Duane Read Pharmacy", "Savin Building", "Queens Midtown tunnel" between 34th and 57th
Location 2:	Route of 3rd Ave locating at "Au Bon Pain", "Muldoons Irish Pub", "TheTreasure Chest", "CitiGroup Center", "SW corner of 57th"
Location 3:	Route of 57th Street locating at "Rainbow Store", "Lee's Art Shop", "Hotel Parker Meridian", "Turnbull & Asser" and #950 3rd at 57th St
Total # Fixes:	64
67% Error:	72
95% Error:	262

Scenario (U8) - Urban canyon high, multi-lane street, inside car, 10-25mph
(Distribution Functions)

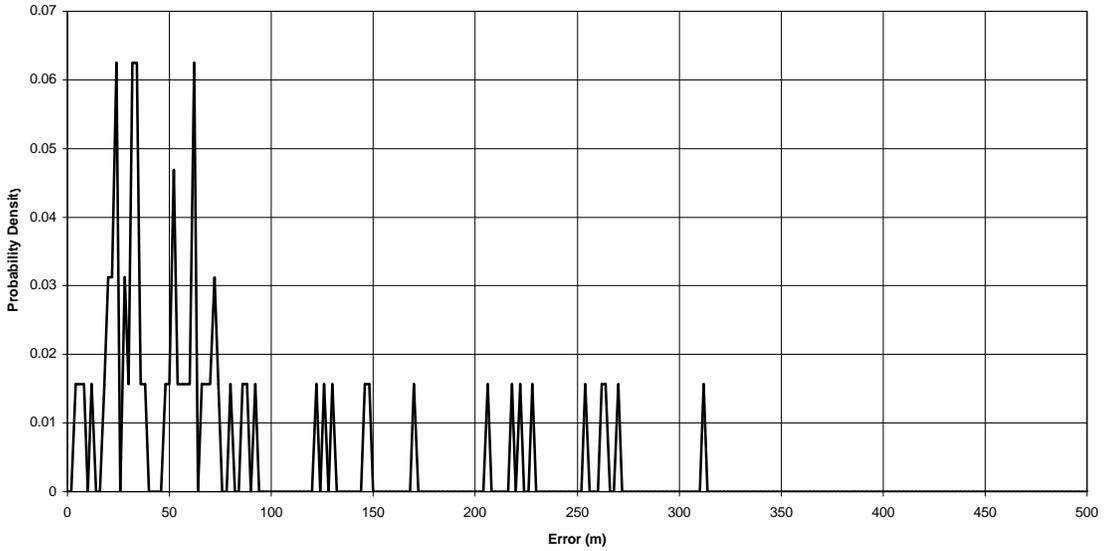


FIGURE U8B: PROBABILTIIY DENSITY FUNCTION FOR LOCATION ERROR

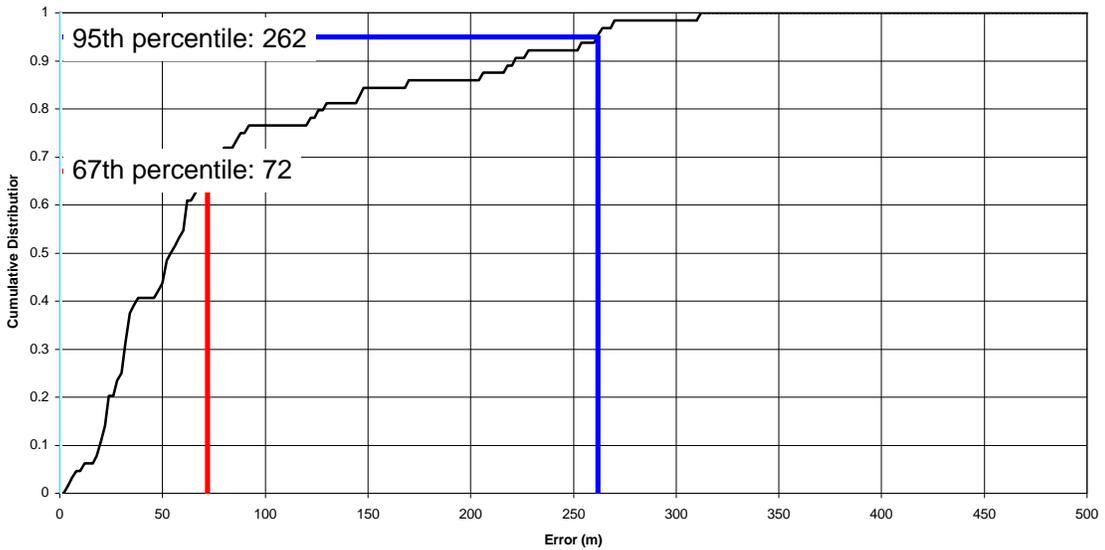


FIGURE U8C: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

2-4. INDOOR TEST SCENARIOS

**Scenario (U10) - Urban canyon high, exterior room, top floor
(Summary)**

Locations

# Test Locations:	3
Location 1:	39th St. at 1410 Broadway (Traffic Light Pole at corner) Maintenance locker room with Window 35th floor
Location 2:	900 3rd Ave between 53rd and 54th St (Pole at the shops at Citigroup Ctr), on top of ground floor window
Location 3:	235 48th St between 8th and Broadway, Ritz Plaza (No Standing sign east side of theater just before parking garage at curb) next to glass door to roof terrace
Total # Fixes:	129
67% Error:	98
95% Error:	134

**Scenario (U10) - Urban canyon high, exterior room, top floor
(Sample Photographs)**



FIGURE U10A: 39TH ST. AT 1410 BROADWAY (TRAFFIC LIGHT POLE AT CORNER)
MAINTENANCE LOCKER ROOM WITH WINDOW 35TH FLOOR



FIGURE U10B-1: 900 3RD AVE BETWEEN 53RD AND 54TH ST
(POLE AT THE SHOPS AT CITGROUP CTR), ON TOP OF GROUND FLOOR WINDOW

**Scenario (U10) - Urban canyon high, exterior room, top floor
(Sample Photographs)**



FIGURE U10B-2: 900 3RD AVE BETWEEN 53RD AND 54TH ST
(POLE AT THE SHOPS AT CITGROUP CTR), ON TOP OF GROUND FLOOR WINDOW



FIGURE U10C-1: 235 48TH ST BETWEEN 8TH AND BROADWAY, RITZ PLAZA (NO
STANDING SIGN EAST SIDE OF THEATER JUST BEFORE PARKING GARAGE AT CURB)
NEXT TO GLASS DOOR TO ROOF TERRACE

**Scenario (U10) - Urban canyon high, exterior room, top floor
(Sample Photographs)**



FIGURE U10C-2: 235 48TH ST BETWEEN 8TH AND BROADWAY, RITZ PLAZA (NO STANDING SIGN EAST SIDE OF THEATER JUST BEFORE PARKING GARAGE AT CURB) NEXT TO GLASS DOOR TO ROOF TERRACE

Scenario (U10) - Urban canyon high, exterior room, top floor
(Distribution Functions)

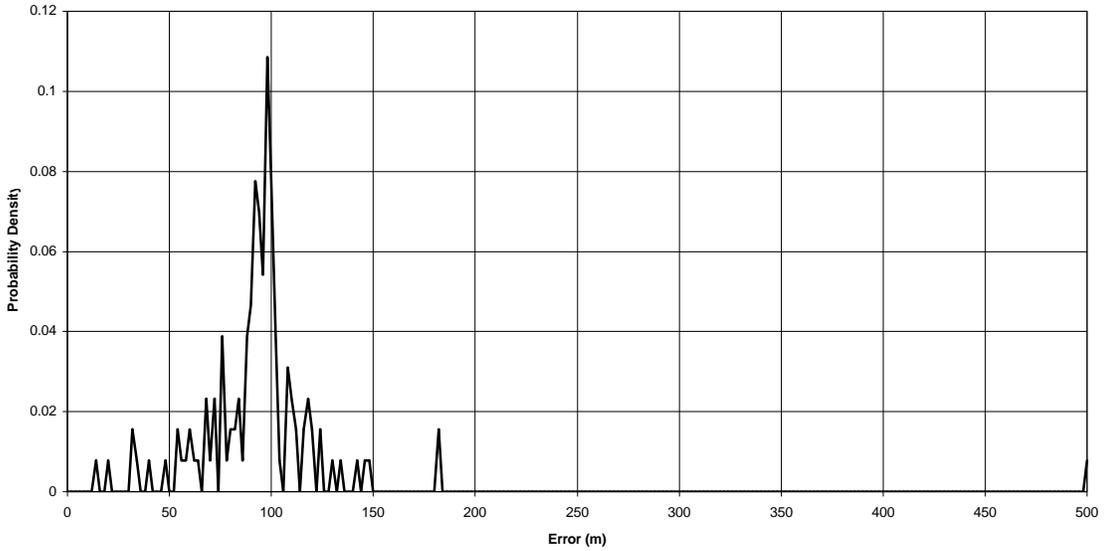


FIGURE U10D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

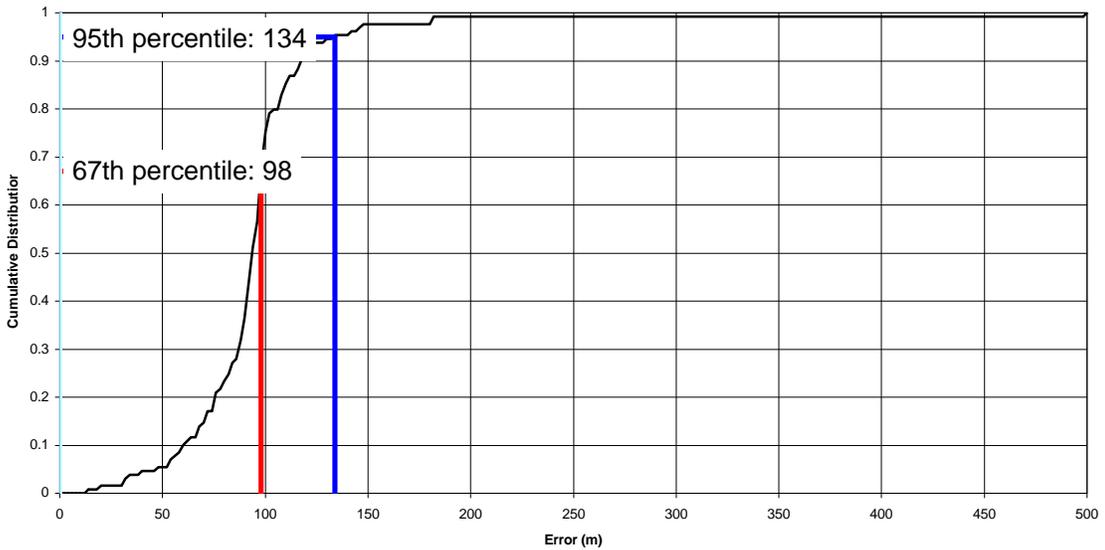


FIGURE U10E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U16) - Urban canyon high, core room, top floor
(Summary)**

Locations

# Test Locations:	3
Location 1:	39th St. at 1410 Broadway, (Traffic light pole at corner), Elevator 4
Location 2:	900 3rd Ave between 53rd and 54th St (Pole at the shops at CitiGroup Ctr) Between elevators
Location 3:	235 48th St between 8th and Broadway, Ritz Plaza, (No Standing Sign east side of theater just before parking garage at curb), Corridor BC to the right of Elevators
Total # Fixes:	130
67% Error:	118
95% Error:	168

**Scenario (U16) - Urban canyon high, core room, top floor
(Sample Photographs)**



FIGURE U16A: 39TH ST. AT 1410 BROADWAY,
(TRAFFIC LIGHT POLE AT CORNER), ELEVATOR 4



FIGURE U16B: 900 3RD AVE BETWEEN 53RD AND 54TH ST
(POLE AT THE SHOPS AT CITIGROUP CTR) BETWEEN ELEVATORS

**Scenario (U16) - Urban canyon high, core room, top floor
(Sample Photographs)**



FIGURE U16C: 235 48TH ST BETWEEN 8TH AND BROADWAY, RITZ PLAZA,
(NO STANDING SIGN EAST SIDE OF THEATER JUST BEFORE PARKING GARAGE AT
CURB), CORRIDOR BC TO THE RIGHT OF ELEVATORS

Scenario (U16) - Urban canyon high, core room, top floor
(Distribution Functions)

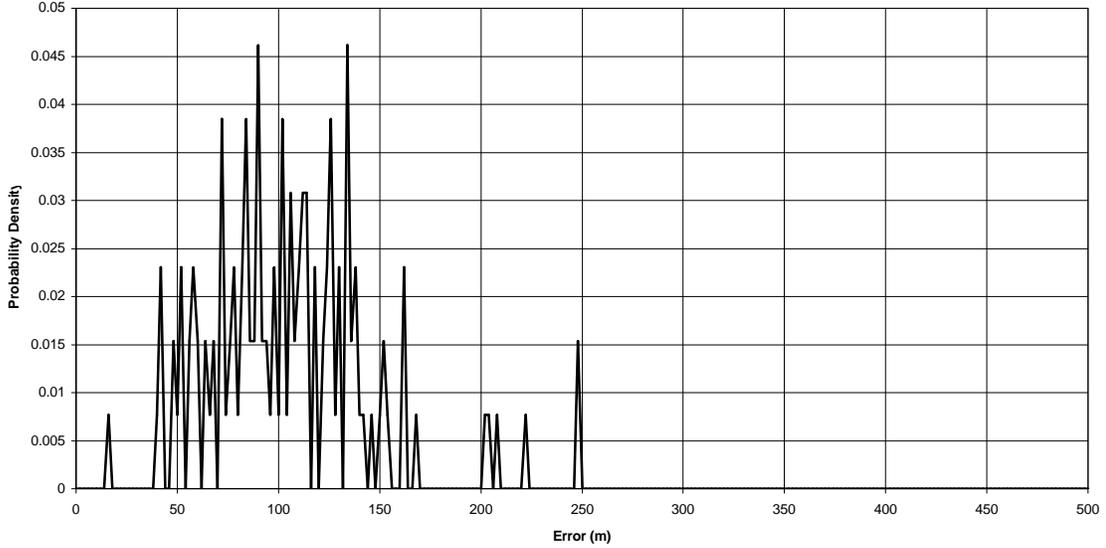


FIGURE U16D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

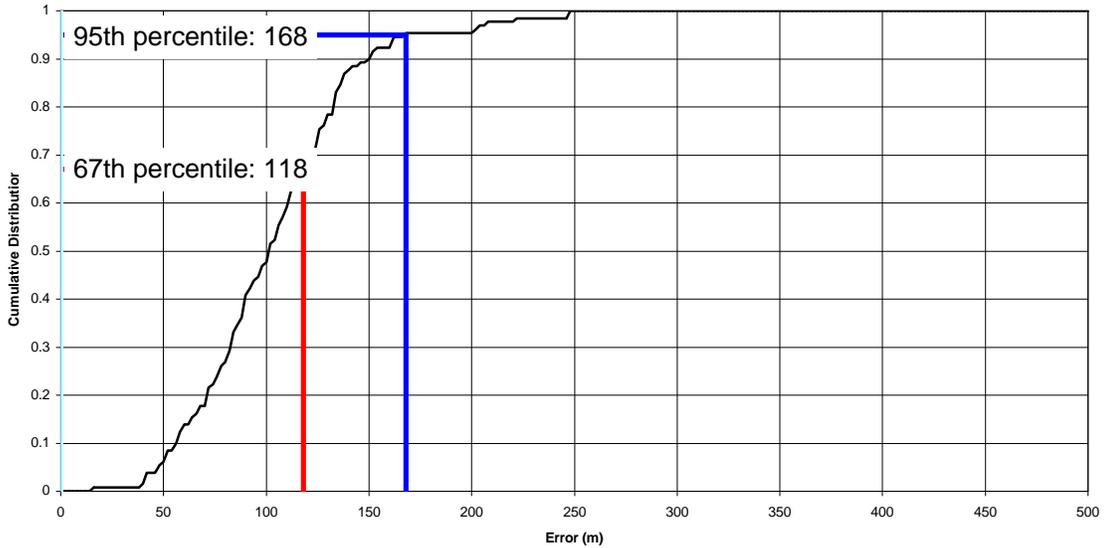


FIGURE U16E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U13) - Urban canyon high, interior room, top floor
(Summary)**

Locations

# Test Locations:	3
Location 1:	39th St. at 1410 Broadway, (Traffic light pole at corner), Rear elevator hallway and then through back door
Location 2:	900 3rd Ave between 53rd and 54th (Pole at the CitiGroup Ctr shops) interior room above ground floor
Location 3:	235 48th St between 8th and Broadway, Ritz Plaza (No Standing sign east side of theater just before parking garage at curb) Stair B through door
Total # Fixes:	120
67% Error:	98
95% Error:	132

**Scenario (U13) - Urban canyon high, interior room, top floor
(Sample Photographs)**



FIGURE U13A: 39TH ST. AT 1410 BROADWAY, (TRAFFIC LIGHT POLE AT CORNER),
REAR ELEVATOR HALLWAY AND THEN THROUGH BACK DOOR



FIGURE U13B: 900 3RD AVE BETWEEN 53RD AND 54TH
(POLE AT THE CITIGROUP CTR SHOPS) INTERIOR ROOM ABOVE GROUND FLOOR

**Scenario (U13) - Urban canyon high, interior room, top floor
(Sample Photographs)**



FIGURE U13C: 235 48TH ST BETWEEN 8TH AND BROADWAY, RITZ PLAZA
(NO STANDING SIGN EAST SIDE OF THEATER JUST BEFORE PARKING GARAGE AT
CURB) STAIR B THROUGH DOOR

Scenario (U13) - Urban canyon high, interior room, top floor
(Distribution Functions)

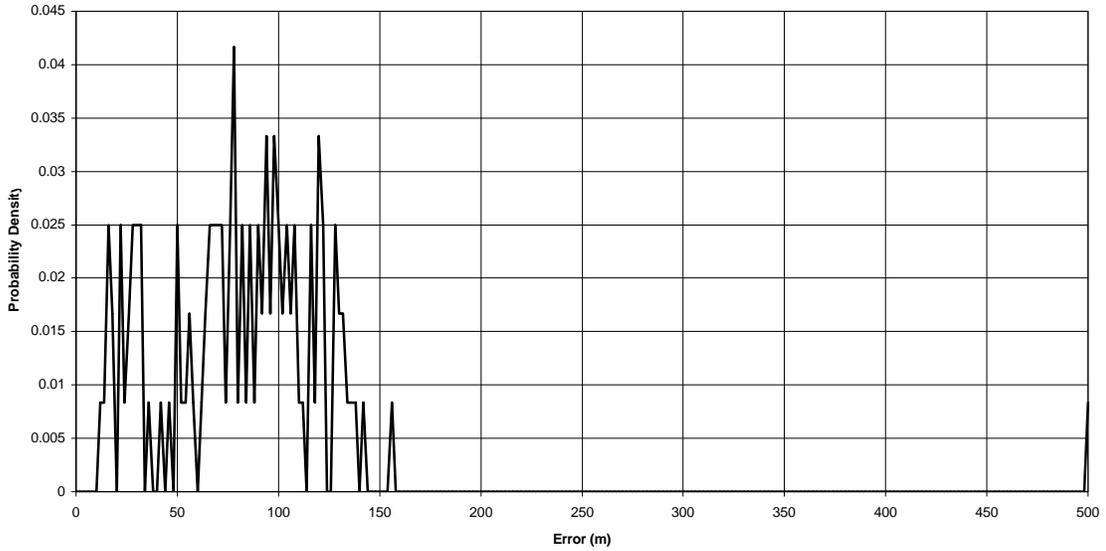


FIGURE U13D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

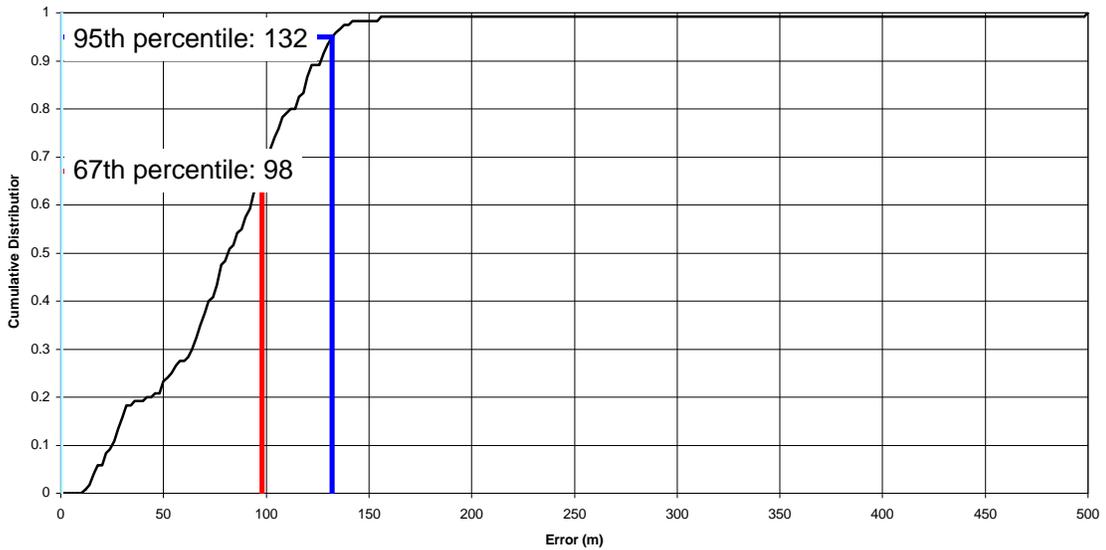


FIGURE U13E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U12) - Urban canyon high, exterior room, ground floor
(Summary)**

Locations

# Test Locations:	3
Location 1:	39th St. at 1410 Broadway (Corner traffic light pole) Window left of entrance door
Location 2:	900 3rd Ave between 53rd and 54th (Pole at CitiGroup Ctr shops)
Location 3:	235 48th St between 8th and Broadway, Ritz Plaza (No Standing sign east side of Theater just before parking garage at curb), Window left of entrance
Total # Fixes:	109
67% Error:	92
95% Error:	204

**Scenario (U12) - Urban canyon high, exterior room, ground floor
(Sample Photographs)**



FIGURE U12A-1: 39TH ST. AT 1410 BROADWAY
(CORNER TRAFFIC LIGHT POLE) WINDOW LEFT OF ENTRANCE DOOR



FIGURE U12A-2: 39TH ST. AT 1410 BROADWAY
(CORNER TRAFFIC LIGHT POLE) WINDOW LEFT OF ENTRANCE DOOR

**Scenario (U12) - Urban canyon high, exterior room, ground floor
(Sample Photographs)**



FIGURE U12B: 900 3RD AVE BETWEEN 53RD AND 54TH
(POLE AT CITIGROUP CTR SHOPS)



FIGURE U12C: 235 48TH ST BETWEEN 8TH AND BROADWAY, RITZ PLAZA
(NO STANDING SIGN EAST SIDE OF THEATER JUST BEFORE PARKING GARAGE AT
CURB), WINDOW LEFT OF ENTRANCE

Scenario (U12) - Urban canyon high, exterior room, ground floor
(Distribution Functions)

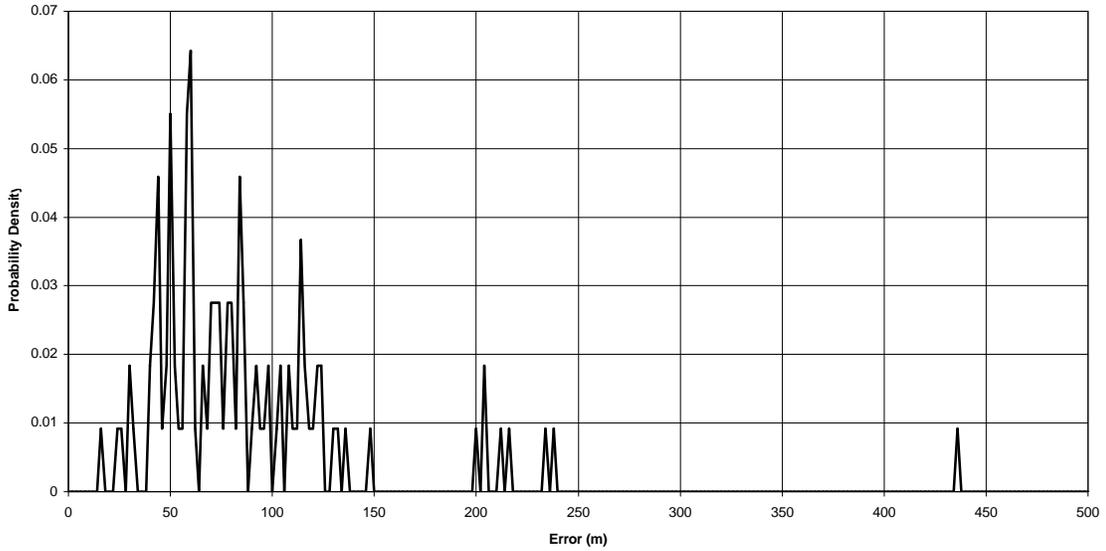


FIGURE U12D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

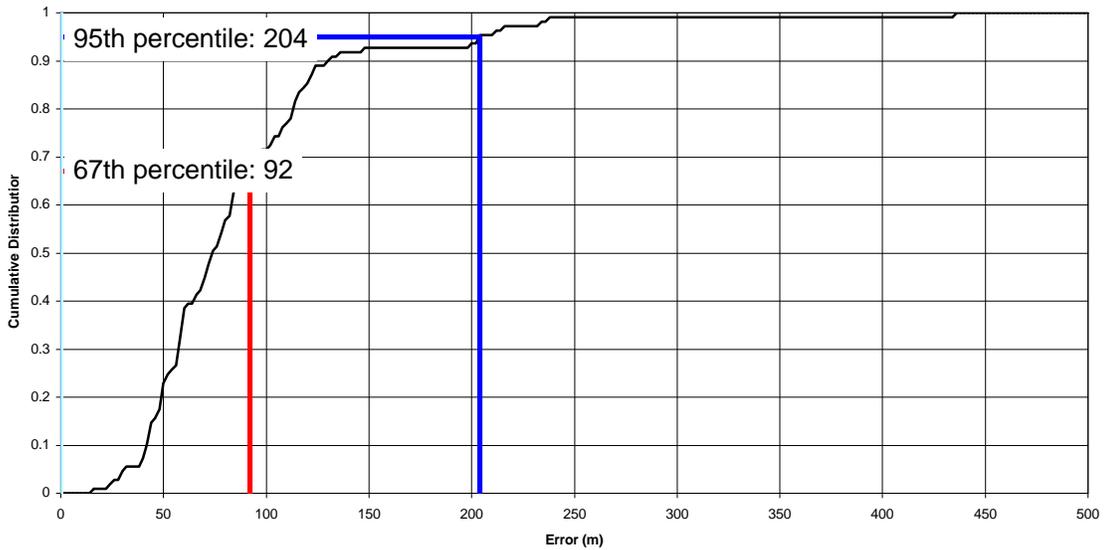


FIGURE U12E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U18) - Urban canyon high, core room, ground floor
(Summary)**

Locations

# Test Locations:	3
Location 1:	39th St. at 1410 Broadway (Traffic light pole at corner) Elevator 4
Location 2:	900 3rd Ave between 53rd and 54th (Pole at shops of CitiGroup) between two elevators
Location 3:	235 48th St Ritz Plaza (No standing sign east side of theater just before parking garage at curb) Near elevator.
Total # Fixes:	106
67% Error:	124
95% Error:	228

**Scenario (U18) - Urban canyon high, core room, ground floor
(Sample Photographs)**



FIGURE U18B: 900 3RD AVE BETWEEN 53RD AND 54TH
(POLE AT SHOPS OF CITIGROUP) BETWEEN TWO ELEVATORS

**Scenario (U18) - Urban canyon high, core room, ground floor
(Sample Photographs)**



FIGURE U18C: 235 48TH ST RITZ PLAZA (NO STANDING SIGN EAST SIDE OF THEATER JUST BEFORE PARKING GARAGE AT CURB) NEAR ELEVATOR.

Scenario (U18) - Urban canyon high, exterior room, ground floor
(Distribution Functions)

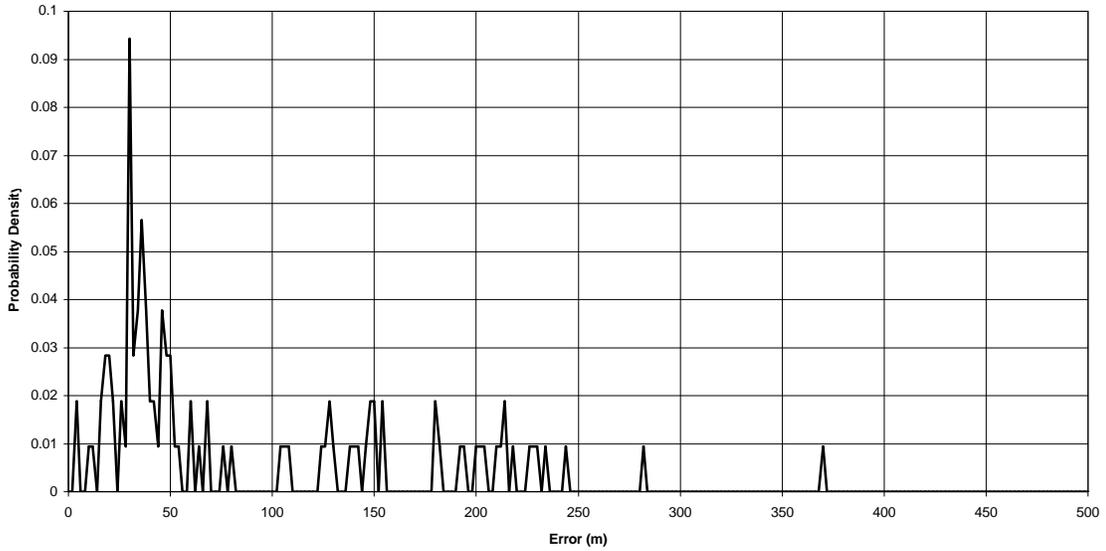


FIGURE U18D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

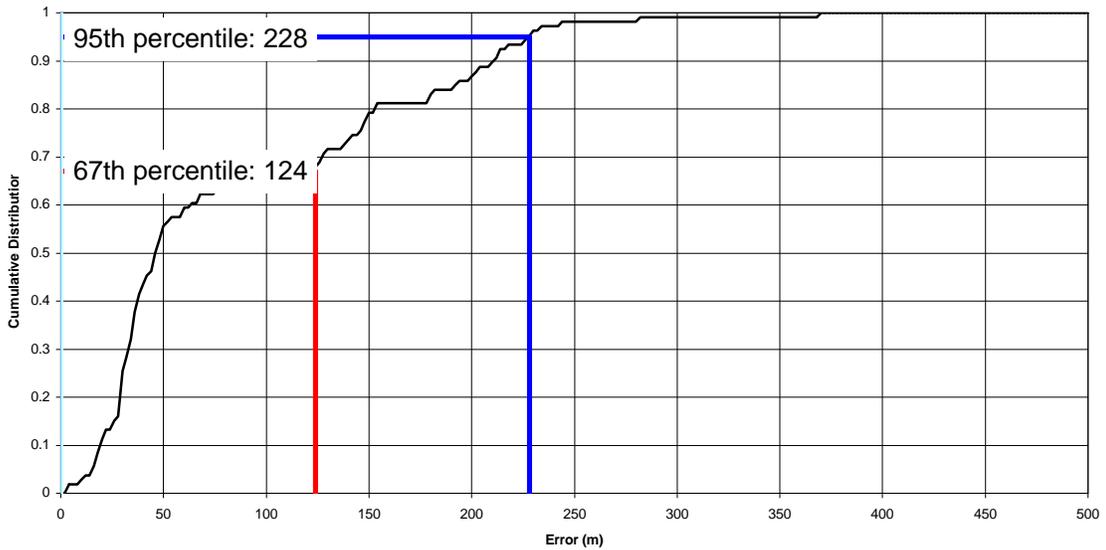


FIGURE U18E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

**Scenario (U15) - Urban canyon high, interior room, ground floor
(Summary)**

Locations

# Test Locations:	3
Location 1:	39th St. at 1410 Broadway (Traffic light pole at corner) End of Hallway A at door A and then second door
Location 2:	900 3rd Ave between 53rd and 54th (Pole at the shops at CitiGroup) Through door at end of hallway to the left.
Location 3:	235 48th St between 8th and Broadway, Ritz Plaza (No standing sign east side of theater, just before parking garage at curb), Next to main outgoing mailbox
Total # Fixes:	119
67% Error:	76
95% Error:	198

**Scenario (U15) - Urban canyon high, interior room, ground floor
(Sample Photographs)**



FIGURE U15A: 39TH ST. AT 1410 BROADWAY (TRAFFIC LIGHT POLE AT CORNER)
END OF HALLWAY A AT DOOR A AND THEN SECOND DOOR



FIGURE U15B: 900 3RD AVE BETWEEN 53RD AND 54TH (POLE AT THE SHOPS AT
CITIGROUP) THROUGH DOOR AT END OF HALLWAY TO THE LEFT

**Scenario (U15) - Urban canyon high, interior room, ground floor
(Sample Photographs)**



FIGURE U15C: 235 48TH ST BETWEEN 8TH AND BROADWAY, RITZ PLAZA (NO STANDING SIGN EAST SIDE OF THEATER, JUST BEFORE PARKING GARAGE AT CURB), NEXT TO MAIN OUTGOING MAILBOX

Scenario (U15) - Urban canyon high, interior room, ground floor
(Distribution Functions)

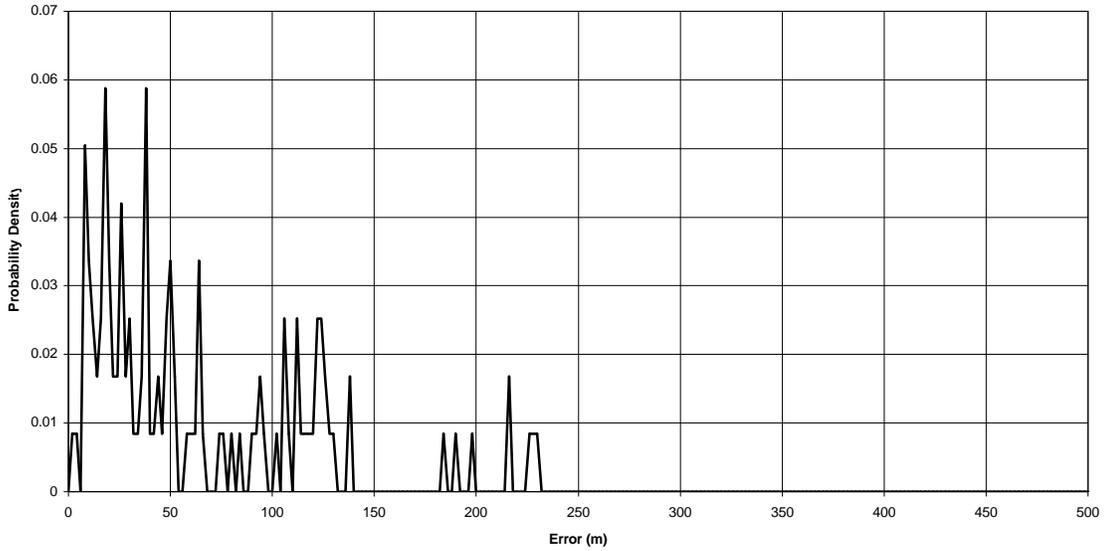


FIGURE U15D: PROBABILITY DENSITY FUNCTION FOR LOCATION ERROR

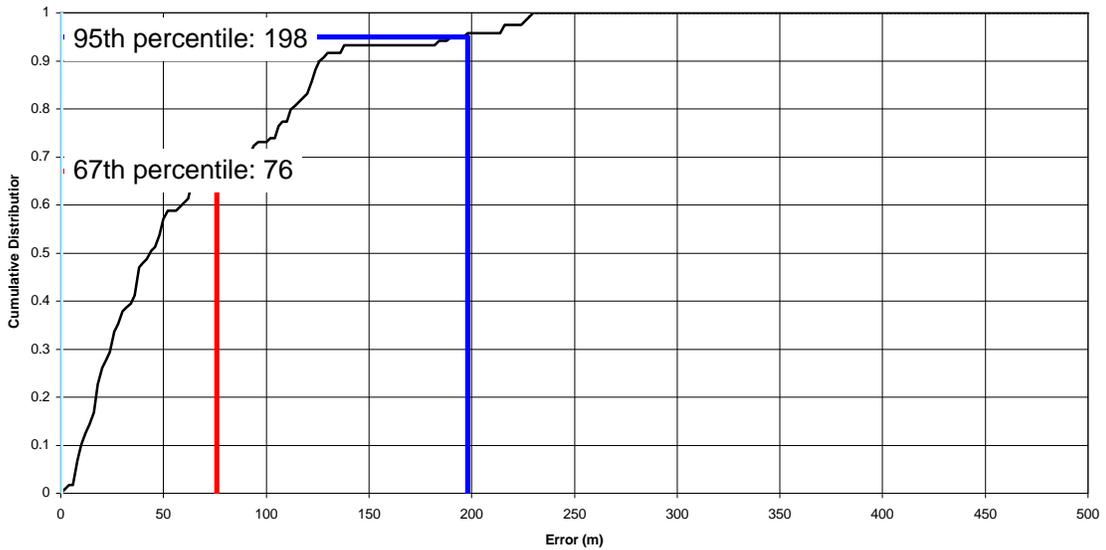


FIGURE U15E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

3. Conclusion

Verizon Laboratories subjected the TruePosition system to a series of location accuracy tests in the very challenging urban environment of Manhattan. Testing focused on assessing the accuracy of the TruePosition system in locating IS-95 callers.

It is important to note that the FCC mandate is to achieve overall compliance for a coverage area, as opposed to compliance by environment, or by scenario. Based on the analysis of test results conducted by Verizon Labs the overall performance of the TruePosition system in the dense urban environment of Manhattan is compliant with the FCC accuracy requirements. The analysis also revealed that the TruePosition system yielded compliant results for the majority of individual scenarios tested with a few exceptions.

Table 3.1 provides a summary of the accuracy analysis results determined by Verizon Labs for each of the scenarios tested in Manhattan. The table also includes input from TruePosition on how performance could be improved with changes in the geolocation algorithm

Table 3.1 Accuracy Analysis Results By Scenario Tested

Scenario	Verizon Labs analysis		TruePosition analysis with improvements to algorithm	
	67% (m)	95% (m)	67% (m)	95% (m)
U1: Urban canyon-high, intersection, outdoor, stationary	70	122	72	119
U2: Urban canyon-high, mid-block, outdoor, walking	142	250	113	166
U3: Urban canyon-medium, intersection, outdoor, stationary	70	100	74	109
U4: Urban canyon-medium, mid-block, outdoor, walking	64	370	90	191
U7: Urban canyon-high, mid block, inside car, stationary	74	204	67	118
U8: Urban canyon-high, multi-lane street, inside car, 10-25 mph	72	262	85	177
U10: Urban canyon-high, exterior room, indoor, stationary, top floor	98	134	92	120
U12: Urban canyon-high, exterior room, indoor, stationary, ground floor	92	204	84	202
U13: Urban canyon-high, interior room, indoor, stationary, top floor	98	132	87	125
U15: Urban canyon-high, interior room, indoor, stationary, ground floor	76	198	67	208
U16: Urban canyon-high, core, indoor, stationary, top floor	118	168	99	129
U18: Urban canyon-high, core, indoor, stationary, ground floor	124	228	120	204

The entries in the table are color coded as follows:

- **Green** corresponds to scenarios that yielded results within the FCC requirement. Location errors for each of these scenarios did not exceed 100 meters 67% of the time, and did not exceed 300 meters 95% of the time.
- **Red** corresponds to test scenarios that yielded results not within the FCC requirement. Location errors for each of these scenarios exceeded 100 meters 67% of the time, or exceeded 300 meters 95% of the time.

TruePosition attributed the high errors in some of the fixes to three reasons. First, some test calls for scenarios U2 and U4 were generated at the edge of the coverage area, which resulted in geometric dilution of precision (GDOP). Second, the multipath mitigation by TruePosition was optimized to deal with strong multipath components at street level whereas for calls from within upper building floors the phones have a direct line of sight to antennas. Third, misconfiguration of a T1 line at a microcell host site which prevented TruePosition from providing coverage at two microcell sites, namely, Time Square 2 and Madison & 37th.

TruePosition informed Verizon Labs that they made improvements to their algorithms since it was tested by the Labs. These improvements involved better handling of GDOP at the edge of the coverage area and modifying their multipath mitigation algorithm to deal with weak multipath signals. TruePosition believes that the new multipath mitigation algorithm significantly improves performance for calls high in the building, while only slightly degrading the performance of the street level calls. The percentiles of error performance resulting from these changes to the algorithm are also included in Table 3.1.

Although the FCC mandate is to achieve overall compliance in a coverage area, the FCC does not provide clear guidelines on how to assess overall accuracy. In order to assess overall accuracy the tested scenarios were classified into four categories: 1) Outdoor / pedestrian, 2) In-vehicle / stationary; 3) In-vehicle / moving; and 4) Indoor. Three weighting profiles of these categories were considered in assessing overall performance. These weighting profiles are summarized in Table 3.2, along with the associated 67th and 95th percentiles.

Table 3.2 Weighting Profiles

Category	1	2	3
Outdoor / pedestrian (scenarios U1, U2, U3, U4)	60%	40%	33%
In-vehicle / stationary (scenario U7)	25%	20%	8%
In-vehicle / moving (scenario U8)	10%	20%	8%
Indoor (scenario U10, U12, U13, U15, U16, U18)	5%	20%	50%
67th percentile	88 m	90 m	96 m
95th percentile	226 m	226 m	204 m

In the first profile it was assumed that the majority of calls are made outdoors (60%+25%+10% = 95%), as opposed to indoor (5%). This is based on the assumption that most 911 callers indoor would use a wireline phone. It was also assumed that in a dense urban environment almost twice as many 911 calls are made by pedestrians (60%) versus in-vehicle calls (25% +10% = 35%). It was further assumed that in a dense urban environment most in-vehicle calls are made from stationary vehicles, as opposed to moving vehicles. For this weighting profile the error is 88 meters 67% of the time and 226 meters 95% of the time, and is compliant with the FCC requirements. Figures 3.1 and 3.2 provide the weighted pdf and CDF for this profile.

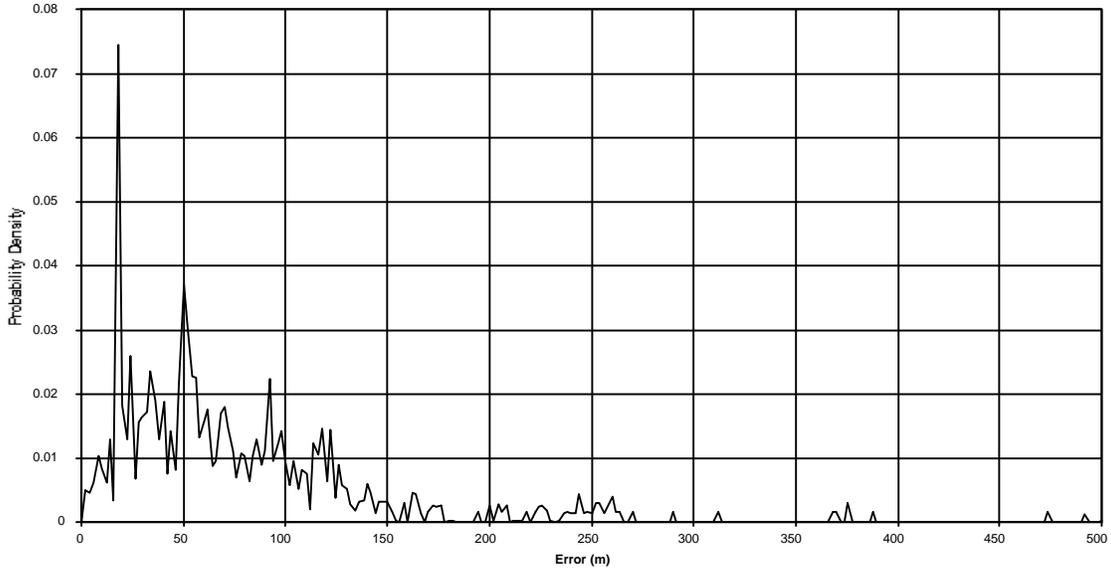


FIGURE 3.1: PROBABILITY DENSITY FUNCTION (PROFILE 1)

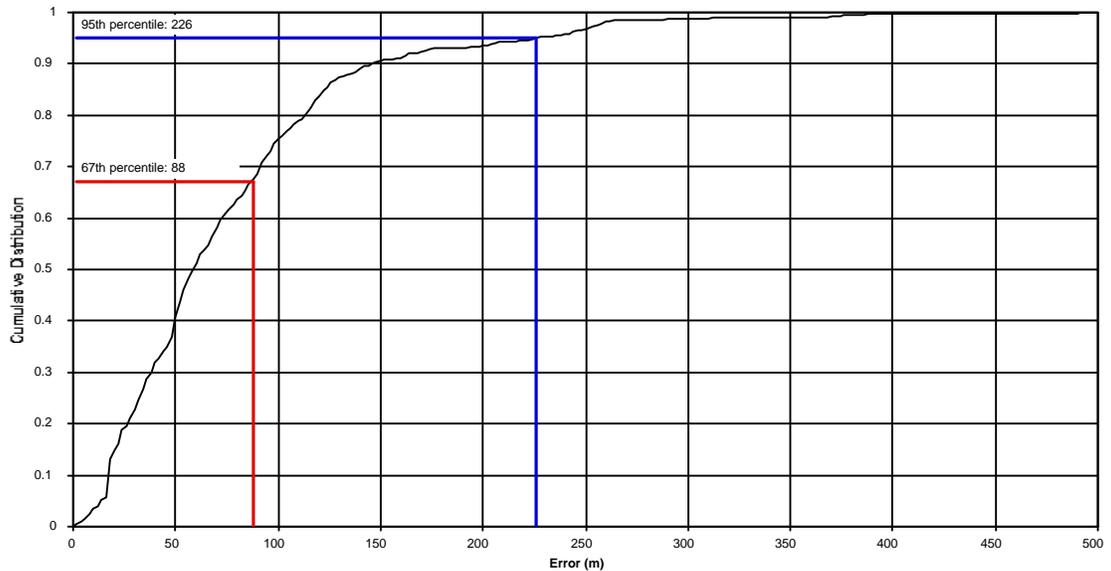


FIGURE 3.2: CUMULATIVE DISTRIBUTION FUNCTION

In the second profile it was assumed that a higher and more significant percentage of calls are made indoor (20%) compared to the first profile (only 5 % indoor). It was also assumed that pedestrians make a comparable number of 911 calls (40%) compared to in-vehicle calls (20% + 20%). It is also assumed that the number of calls from moving vehicles is comparable to the number of calls from stationary vehicles. For this weighting profile the error is 90 meters 67% of the time and 226 meters 95% of the time, and is also compliant with the FCC requirements. Figures 3.3 and 3.4 provide the weighted pdf and CDF for this profile.

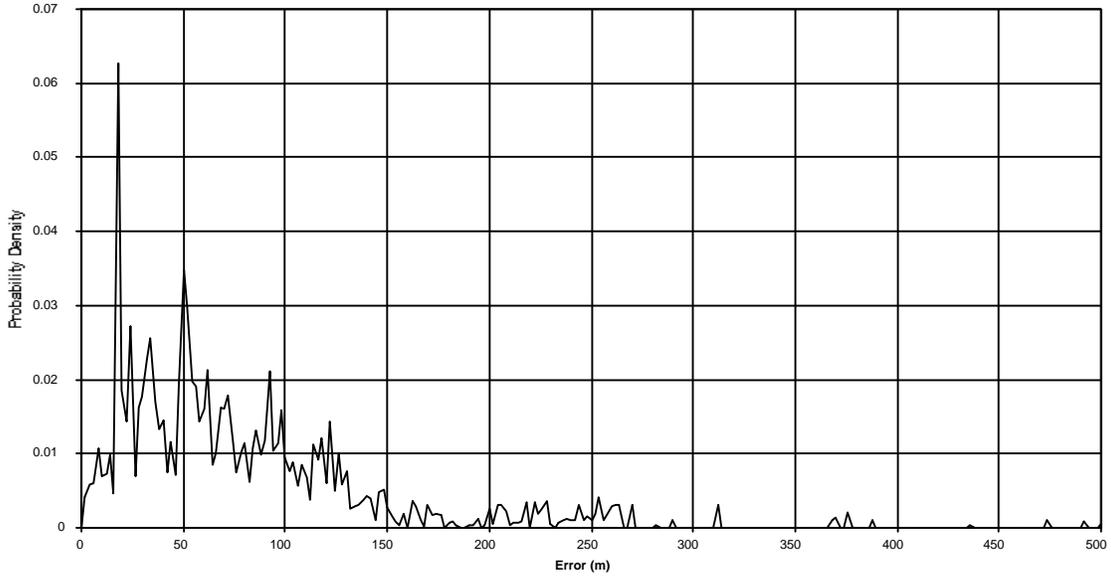


FIGURE 3.3: PROBABILITY DENSITY FUNCTION (PROFILE 2)

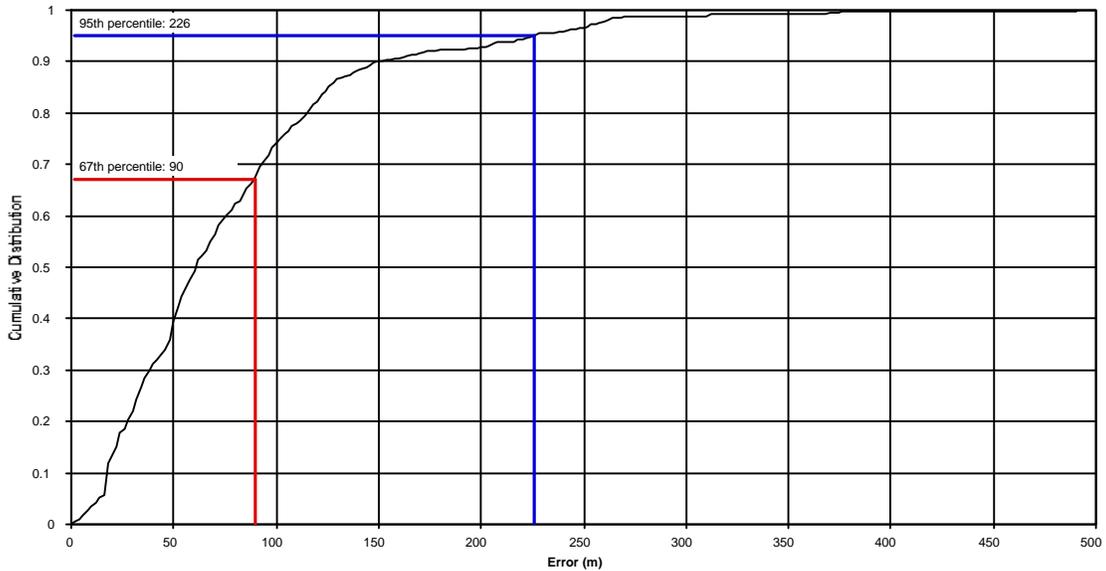


FIGURE 3.4: CUMULATIVE DISTRIBUTION FUNCTION (PROFILE 2)

In the third profile it is assumed that the 12 tested scenario have equal weighting (i.e. $1/12 * 100\%$). For this weighting profile the error is 96 meters 67% of the time and 204 meters 95% of the time, and is compliant with the FCC requirement. Figures 3.5 and 3.6 provide the pdf and CDF for this profile.

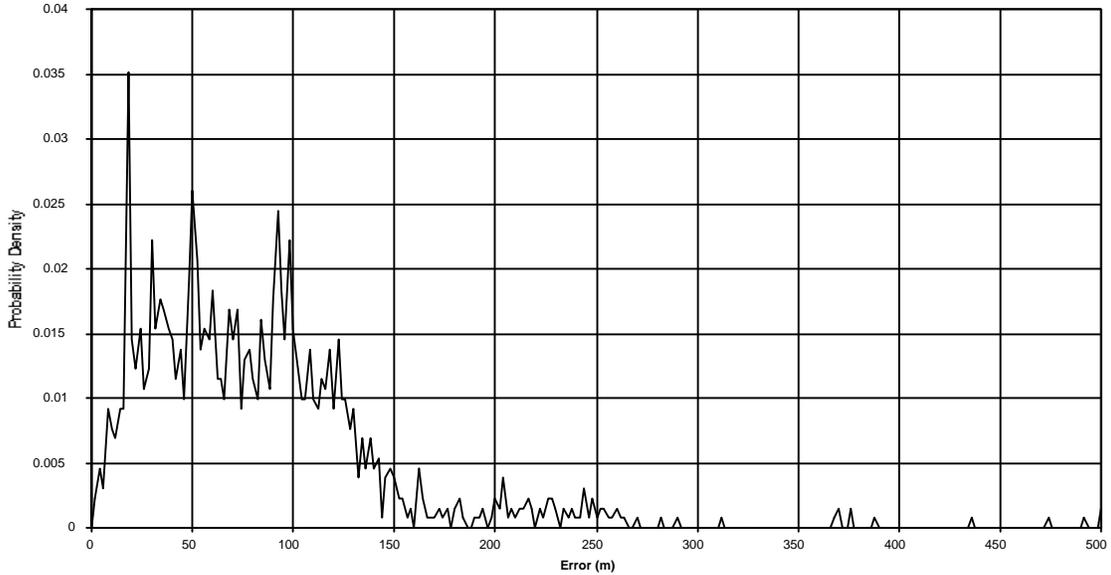


FIGURE 3.5: PROBABILITY DENSITY FUNCTION (PROFILE 3)

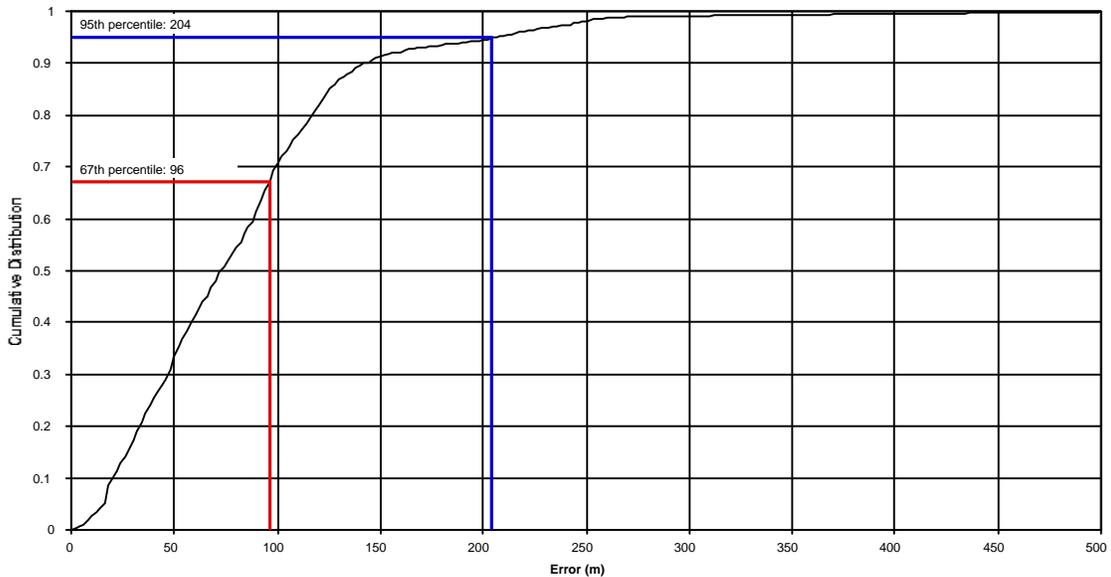


FIGURE 3.6: CUMULATIVE DISTRIBUTION FUNCTION (PROFILE 3)

It could be argued that the first weighting profile is more representative of current wireless 911 call behavior. The other two profiles were also considered to assess overall compliance if in the future more calls are made indoor, or from within a moving vehicle. All three weighting profiles considered indicate that the overall accuracy of the TruePosition system in Manhattan is compliant with the FCC requirements in locating IS-95 callers.

Testing of the TruePosition system in Manhattan was successful. It is further recommended that the system be tested in rural and suburban environments.