Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Amending the Definition of Interconnected VoIP Service in Section 9.3 of the Commission's Rules	)	GN Docket No. 11-117
	)	PS Docket No. 07-114
Wireless E911 Location Accuracy Requirements	)	WC Docket No. 05-196
	)	
E911 Requirements for IP-Enable Service Providers	)	

Comments of TruePosition, Inc.

TruePosition, Inc. (TruePosition), submits these comments in response to the *Second Further Notice of Proposed Rulemaking* in the above proceedings.[1] TruePosition is a leading provider of wireless location solutions and technology. Its Uplink Time Difference of Arrival ("U-TDOA") system is the principal network based location technology deployed in the United States.

Summary

The Commission asks for further comment on whether standards for determining wireless location accuracy of emergency calls should include indoor locations. Current rules establish metrics for locating a wireless 911 call. Yet, the rules are limited to outdoor measurements only, effectively removing application of the standards to indoors. The reality is that calls from several common structures constructed of concrete, steel or glass, as well as urban canyons, tunnels and debris in a disaster zone, cannot be located with Global Positioning System satellite

[1] In the Matter of the Definition of Interconnected VOIP Service in Section 9.3 of the Commission's Rules, et seq., *Notice of Proposed Rulemaking, Third Report and Order and Second Further Notice of Proposed Rulemaking,* FCC 11-107, GN Docket No. 11-117, PS Docket No. 07-114 and WC Docket No. 05-196 (July 13, 2011) ("*Second Further Notice*").

(GPS) technology. The record is emphatic that GPS technology cannot locate a 911 call in such circumstances.

The Commission should apply location accuracy metrics to indoor environments and test for compliance. Failing to extend accuracy requirements to indoors defeats 911's objective to speed emergency response. Opposition equivocating over the quantity of indoor calls and the cost benefits of location accuracy belies the history and purpose of E911 and consumer expectation of services dominated by wireless. TruePosition shows that cost effective solutions and testing protocols exist to make a meaningful difference to emergency response and to citizens relying on 911 as the universal emergency number. TruePosition urges the Commission not to abandon E 911's future but to embrace locating all emergency calls.

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The Case for Indoor Accuracy

There is a paradox between the Commission's mandate of a unitary location accuracy standard[2] and eliminating the accuracy gap between indoor and outdoor environments with regard GPS only location technology. The Commission's July 2011 decision sunsets the network-based accuracy rule at an appropriate point sometime after 2019 and will require a single accuracy standard of 50 meters and 150 meters, regardless of technology. New wireless carriers must meet the revised standard immediately. The tightened location accuracy standard intends that every 911 caller in the United States can expect to be located regardless of environment, the type of device, or which wireless carrier they have selected. TruePosition commends the Commission's action and is confident it will meet the new performance requirements.

A unitary standard will promote improvement only if accuracy standards apply to indoors, otherwise a large portion of 911 calls will not be located. The paradox is that while acknowledging GPS' severe deficiency in several common environments, carriers pursue aggressively indoor use by subscribers. Virtually all carriers market equipment capable of reaching within challenged areas, but for those using GPS only solutions, they make no account for E 911 service. While validated demographic studies affirm the acumen of promoting indoor use, the result is that a large number of wireless 911 calls cannot be accurately located.

Carriers present with clarity GPS' deficiencies. These include a device's inability to see sufficient number of GPS satellites, multipath delays, the limited search window for acquiring

[2] *Notice of Proposed Rulemaking, Third Report and Order and Second Further Notice of Proposed Rulemaking,* at paragraph 19.

satellite signals and the inherent difficulties of weak GPS signal strength.[3] Carriers warn that GPS is not a solution for indoor service or in urban environments, reiterating that satellite transmissions reflect off buildings and other obstructions or satellite connectivity is lost when users are deeper indoors.[4] The consensus is emphatic; GPS does not perform reliably where the view of the sky is significantly obstructed, such as in dense urban areas or in areas inside buildings made of concrete, steel and glass.[5]

TruePosition provided quantitative data and analysis affirming these limitations and lack of E 911 service. It worked with 911 Centers in Austin and Frisco, Texas to test the performance of location technologies in various environments in multiple circumstances where challenges can be encountered. The data makes clear that A-GPS solutions struggle in urban environments and where building materials consist of concrete, metal or glass.[6] This data also show that network based solutions only degrade slightly within indoor environments relative to outdoor performance in the same areas.[7]

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[3] Comments of Verizon and Verizon Wireless at pages 3-4, PS Docket 07-114 (January 19, 2011), Comments of Sprint Nextel at page 5, PS Docket 07-114 (January 19, 2011).

[4] AT&T Comments at page 20 (January 19, 2011).

[5] A discussion addressing why GPS is challenged in these environments is set forth in TruePosition's Comments at 8-12 (January 19, 2011).

[6] Comments of TruePosition at pages 13-17 (January 19, 2011).

[7] Contrary to the Public Safety Communications Office of the California Technology Agency statement in its September 20, 2011 comments, the Communications Security, Reliability and Interoperability Council (CSRIC) Location Accuracy Subgroup (4C) did not determine that A-GPS technology has superior location accuracy. The Subgroup actually embraced the importance of a scientific ground truth measurement method.

In its initial submission to CSRIC Working Group 4C (August 9, 2010), the California 9-1-1 Emergency Communications Division provided a report on its "Routing on Empirical Data" (RED) project, which netted significant 911 call routing efficiencies by carefully reviewing call origination patterns against call routing criteria, and adjusting the call routing rules accordingly.

The report suggested A-GPS should be the <u>only</u> location technology; it went on to say that a scientific approach to reporting accuracy <u>should not be used</u>, instead accuracy compliance should be gauged upon the reported location uncertainties for each carrier. After many conference calls, Working Group 4c agreed to accept only the factual call

Carriers Pursue Indoor Use

While recognizing GPS' deficiencies, subscriber use in these environments is pursued aggressively. Carriers embrace well designed and installed signal boosters that expand wireless networks in poor signal coverage areas.[8] Similarly, carriers and equipment manufacturers promote microcells to extend wireless network in homes or businesses for improved cellular performance.[9] Yet, E911 services, relying solely on GPS, lag far behind in these common areas from where calls are made.

The 2010 US Census and related studies refute claims that subscribers do not make 911 calls from structures constructed of glass, concrete or metal or from urban environments.[10] 25% of the Nation's population live in multi-unit structures. Multi-unit structures are the primary source of new construction.[11] In Manhattan, with a 2010 population of 1,585,873, 98% of

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routing analysis from Project RED, and added a statement that a scientific ground truth measurement method should be used to determine the statistical accuracy to demonstrate compliance with the Commission's wireless location accuracy rules.

[8] Reply Comments, WT Docket 10-4 of Sprint Nextel at 1, August 24, 2011, Comments of Verizon Wireless at 1, (July 25, 2011).

[9] *AT&T 3G Microcell- Wireless Signal Booster.* http://www.att.com/shop/wireless/devices/3gmicrocell.jsp?fbid=r2FMGq4Z0iI

Expand Your Indoor Coverage with the Network Extender- http://www.verizonwireless.com/b2c/store/accessory?action=gotoFeatures,

T-Mobile Cel-Fi Signal Booster, http://support.t-mobile.com/docs/DOC-1984

Cisco Femtocell Solution, http://www.cisco.com/en/US/netsol/ns941/networking_solutions_solution_category.html

[10] Claims that indoor wireless calls represent only a small percentage of total 911 calls should be rejected. TruePosition Comments at 24 (January 19, 2011). Regardless of what numbers might be more accurate, it is clear that indoor wireless 911 calls are of a sufficient magnitude that they should not be ignored. Even at the lowest estimate, the quantity is approximately 25 million indoor wireless 911 calls a year. These callers should not be excluded from the Commission's rules requiring accurate location of 911 callers.

[11] U.S. Census Bureau: New Residential Construction, Table Q1. New Privately Owned Housing Units Started in the United States by Purpose and Design http://www.census.gov/const/www/quarterly_starts_completions.pdf

housing units are in multi-unit structures; there are 9,999 persons per square mile. In adjoining suburban Westchester County, New York, with a 2010 population of 949,113, 49% of housing units are in multi-unit structures, with 2,192 persons per square mile. In greater Cook County, Illinois, including Chicago, an urban/suburban setting, with a population of 5,194,675, 54% of housing units are multi-unit structures with over 5,493 persons per square mile. Bexar County, Texas, including San Antonio, with a population of 1,714,773, has 27% of housing units in multi-unit structures and 1,246 persons per square miles.[12] These examples, showing the density of multi-unit structures, are replicated across the US in any significant population center where concrete, steel and glass structures are pervasive.

Further affirmation of how dominant wireless use is in these challenged environments is found in Center for Disease Control analysis. Results from the January–June 2010 National Health Interview Survey (NHIS) indicate that the number of American homes with only wireless telephones continues to grow. More than one of every four American homes (26.6%) had only wireless telephones during the first half of 2010—an increase of 2.1 percentage points since the second half of 2009. In addition, nearly one of every six American homes (15.9%) received all or almost all calls on wireless telephones despite having a landline. The percentage of adults living in wireless-only households also increased steadily as did the percentage of children. More than half of adults aged 25–29 years (51.3%) live in households with only wireless

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[12] U.S. Census Bureau: State and County QuickFacts. Data derived from Population Estimates, Census of Population and Housing, Small Area Income and Poverty Estimates, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits, Consolidated Federal Funds Report
Last Revised: Friday, 03-Jun-2011 15:32:00 EDT, http://quickfacts.census.gov/qfd/states/36/36119.html

telephones and nearly half of all adults renting their home (47.1%) had only wireless telephones.[13]

E911 service must align with wireless' dominance and the large population residing and working in multi-unit structures. To ignore location accuracy in apartment houses, office buildings and malls is to abandon E 911.

Competitive Solutions Exist

The record confounds any claim that calls to 911 are not coming from challenged environments in such numbers to justify ignoring the need to locate these calls. Pervasive wireless use by residents and workers in multi-unit structures is accompanied by an expectation that the call to 911 will be located. Nor is there merit in claims that no solution is possible.

TruePosition has presented its A-GPS /U-TDOA hybrid that combines the strengths of both location technologies. The hybrid captures A-GPS' strength when there is an unobstructed view of the sky such as in rural areas, where network technologies are challenged because of the reduced number of cell sites. The hybrid uses U-TDOA's strength in urban and suburban areas to penetrate buildings.

The rapid deployment of A-GPS-enabled handsets combined with an overlay of a U-TDOA network in urban and suburban areas where there are significant structures that hamper the ability of A-GPS to provide accurate location, provides a solution that accurately locates all 911 callers. This "geographic hybrid" solution, using a mix of technologies in different environments where they are best suited, can be implemented cost effectively by network sharing amongst several wireless operators in the areas where the network overlay is needed to augment

[13] Blumberg SJ, Luke JV. Wireless substitution: Early release of estimates from the National Health Interview Survey, January–June 2010. National Center for Health Statistics. December 2010. Available from: http://www.cdc.gov/nchs/nhis.htm.

A-GPS capabilities. With minor software changes a hybrid can be implemented, in which both U-TDOA and AGPS are attempted, and the best position is used. The current deployed implementations allow for the location server (SMLC) to initiate either an A-GPS location or a U-TDOA location based on system configuration and handset capabilities. The necessary software changes would initiate both an A-GPS location and a U-TDOA location based on handset capabilities and select the location estimate with a lower uncertainty value. TruePosition will be performing a test of an A-GPS/UTDOA hybrid solution with AT&T to show how the hybrid performs against these suggested requirements.

Boeing has pursued its Time and Location technology (BTL), which is based on its satellite augmentation of GPS. Boeing states that BTL can improve E 911 location performance in the near term, particularly in challenging indoor and urban environments. It relates ability to validate a femocell for E 911 location.[14]

EGNOS, the European satellite-based augmentation system that will deploy GALILEO, has been in service since October 2009.[15] The European Union states that GALILEO service covering the US will benefit GPS users as the two systems will be interoperable through a common signal design providing significantly improved coverage and accuracy in urban environments. The improved characteristics of its signals will make it more efficient in challenging environments than a traditional GPS receiver. Combined with GPS, associated benefits will be delivered in both accuracy and availability.[16]

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[14] *Ex Parte* Presentation of The Boeing Company, GN Docket No. 11-117, PS Docket No. 07-114 and WC Docket No. 05-196 (September 1, 2011).

[15] EGNOS: European Geostationary Navigation Overlay Service. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0308:FIN:EN:PDF

[16] Letter to the Honorable Julius Genachowski, Chairman for the Federal Communications Commission from Heinz Zourek, Directorate General for Enterprise and Industry, European Commission, IB Docket 11-109 (July 19, 2011).

CommScope has announced an upgrade to its mobile location technology to include combined dual plane functionality to determine the location of mobile devices in difficult-to-reach areas. In environments where A-GPS is not able to locate a device, CommScope states that its indoor location systems, integrated with its location platform, allows a device's location to be determined with greater accuracy.[17]

Investment has been made in competitive technologies able to locate 911 calls where GPS is challenged. Yet the paradox demonstrates that until the Commission acts, calls within challenged environments will not be located where only GPS is used. And by not acting, the Commission places those carriers using technology that can penetrate concrete, metal and glass structures at significant economic disadvantage.

With pervasive indoor use, failing to move to indoor accuracy metrics and testing will lead carriers to abandon E911 services in these structures. Consumer expectation will be reversed. It will require the Commission to mandate, as it does in the VOIP environment, notice, labeling and subscriber acknowledgement of circumstances where E911 service is not available--the large population residing and working in multi-unit structures. To ignore location accuracy in apartment houses, office buildings and malls is to abandon E911.[18]

Cost Benefit Analysis

The Commission inquires as to the cost benefits of extending location accuracy rules indoors. Analyzing costs and benefits is important to the credibility of any regulatory structure. At a core level, costs and benefits must be examined in the context of what carriers do to deploy

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[17] CommScope Boosts the Capabilities of GeoLENs Mobile Location Center (July 25, 2011), http://news.commscope.com/press-release/carrier-wireless-market/commscope-boosts-capabilities-geolens-mobile-location-center. See also Ex Parte Letter to Marlene H. Dortch, Secretary, Federal Communications Commission, from Catherin Wang, Esquire, GN Docket No. 11-117, PS Docket 07-114 and WC Docket No. 05-196 (July 25, 2011).

[18] Section 9.5(d) of the Commission's rules.

and maintain their networks; their E 911 services should not be considered distinct and separate but as integral elements of network maintenance and integrity. TruePosition's experience, based on deployment of its location technology and relationship with carriers, is that the costs of location accuracy are an incremental and extremely limited addition to network deployment and maintenance.

There are studies analyzing costs and quantifying E 911 benefits. Professors Athley and Stern examined coronary victims who had called 911 to discern the value of knowing the location of the call. They compared counties where E 911 was adopted versus those counties where it had not. Their fundamental finding was that E911 significantly increases the survival rates for patients with cardiac diagnoses. They confirm the Commission's historic premise that locating an emergency speeds response and raises quality of care.[19]

Any cost benefit analysis must capture the risk that a significant portion 911 calls cannot be located. With enormous monies spent by state and local governments and carriers for E911 infrastructure and operations, credible analysis must examine the cost of failing to address indoor calls. Doing nothing will endanger the entire system. It will squander sunk costs, reverse public expectation and remove any motivation that advanced services must provide E 911 service. The Congress and the Commission have long recognized the critical value of locating an individual confronting an emergency and that modern communications technologies meet citizen expectation that their mobile devices be located. By law and regulation, the speed and quality of response is enhanced immeasurably by knowing where a call is made from.

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[19] The Adoption and Impact of Advanced Emergency Response Services,The Changing Hospital Industry: Comparing Not-for-Profit and For-Profit Institutions, 1999 , and Information Technology and Training in Emergency Call Centers, IRRA Papers and Proceedings, 1999 , The Impact of Information Technology of Emergency Health Care Outcomes, RAND Journal of Economics, 2002, Research and Teaching Statement of Scott Stern, December 2008 at pages 10-11. www.kellogg.northwestern.edu/. *See also Notice of Proposed Rulemaking, Third Report and Order and Second Further Notice of Proposed Rulemaking at paragraph 19.*

Location in Residential and Office Buildings

The Commission notes that indoor locations pose challenges as the location of an emergency may not be as obvious as emergencies occurring outdoors. It inquires about location accuracy in a urban/suburban environment with thousands of residential or office units within a confined geographic area and how it will contribute to emergency response. It suggests development of indoor technical solutions and testing methodologies to verify the effectiveness of such solutions.[20]

E 911's most critical advancement is providing accurate information to 911 call takers and dispatchers. Locating an incident within the Commission's current location accuracy rules in a congested urban/suburban environment brings a clarity that is not otherwise present, expedites response and raises its quality. Notably, in TruePosition's Austin and Frisco, Texas indoor tests, U-TDOA network technology provided location accuracy of 77.5 meters for 67 percent of calls and 178.5 meters for 90 percent of calls.[21] Confronted with an emergency, an individual is frequently confused and unsure. Knowing that an incident is within these metrics places emergency responders at a much enhanced starting point and limits enormously the challenge of having to determine what and where is the emergency.[22]

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[20] *Notice of Proposed Rulemaking, Third Report and Order and Second Further Notice of Proposed Rulemaking,* at paragraph 86.

[21] TruePosition Comments at pages 16-17 (January 19, 2011).

[22] EmFinders,™ a technology company that TruePosition has investment interest in, is dedicated to the rapid location and recovery of wandering or missing adults and children. The EmFinders EmSeeQ is a small, watch-like, wireless device without buttons or a screen and is under the secure and remote control of the EmFinders operations center. It is worn by individuals with medical impairments like Autism, Down syndrome or Alzheimer's disease. The device can only be activated at the request of the caregiver. It will only call 911 after a caregiver has reported the individual missing to the police. A call from the EmFinders device is a pre-screened 911 call. As noted in its December 4, 2009 Reply Comments, EmFinders solution uses network based Uplink Time Difference of Arrival (U-TDOA) technology. U-TDOA technology provides accurate location estimates for the environments where missing persons are most likely. These include urban and suburban neighborhoods, particularly inside buildings, shopping malls and parking garages. Wandering or disoriented individuals tend to seek shelter is such areas and narrowing the location contributes significantly to locating the individual. See www. Emfinders.com As EmFinders noted, A-

With location much more precise, subscriber information will contribute significantly. Information as to where a subscriber resides and works can be discrete elements of a database capable of being transmitted to 911 and encompass many emergency incidents. Several states require multiline or VOIP telecommunications systems to assure that the system provides automatic number and distinct location identification addressing the source of an emergency.[23] Strong support for E 911 resonates in consumer expectation and will translate to vigorous subscriber participation and, when combined with greatly enhanced location accuracy, will bring about pervasive E 911 service.

GPS technology encounters severe challenges in urban and suburban areas. Concrete, steel and glass structures, as well as skyscrapers obstruct and degrade A-GPS location accuracy.

[23] Illinois, Section 15.6 6 of the Emergency Telephone System Act, 50 ILC 750, Alaska Stat. § 29.35.134, Florida, 365.175, Emergency Telephone Number 911 Private Branch Exchange – Automatic Number Information, Massachusetts, M.G.L.C 6A, section 18J, 560 CMR 4:00, Regulations Governing Enhanced 911 Service for Multiline Telephone Systems. See Summary of States with MLTS Legislation Rules as of July 30, 2009. *www.nena.org/.../20090730*

An Indoor Accuracy Rule and Testing

In the *Second Further Notice*,[24] the Commission summarizes carrier opposition to extending accuracy metrics and testing to indoors. Several reasons are presented- there is no feasible way to perform indoor testing on a large scale as calls placed to 911 from indoors vary across jurisdictions,[25] adopting a specified level of indoor testing is not reasonable without further data,[26] technology to perform indoor testing is still being developed,[27] gaining indoor building access for testing is difficult[28] and the number of 911 wireless calls made indoors versus outdoors is not quantified.[29]

Carriers test indoors as a fundamental part of marketing and ensuring service to subscribers. As the Commission notes in the *Third Report and Order*,[30] periodic testing is important to ensure that test data does not become obsolete as a result of environmental changes and network reconfiguration. A major network change can significantly impact location accuracy and trigger testing. Providing the test results to 911 centers enable them to better gauge whether they are receiving accurate location information and base responses accordingly. Disclosure to the Commission allows it to monitor trends in location accuracy and ensure that its regulations are appropriately tailored. All these reasons apply to indoor testing.

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[24] *Notice of Proposed Rulemaking, Third Report and Order and Second Further Notice of Proposed Rulemaking,* at paragraph 84.

[25] T-Mobile Comments at 22. (January 19, 2011).

[26] Sprint Nextel Comments at 7 (January 19, 2011).

[27] Sprint Nextel Comments at 7-8 (January 19, 2011).

[28] AT&T Comments at 9 (January 19, 2011).

[29] Qualcomm Comments at 13 (January 19, 2011.

[30] *Notice of Proposed Rulemaking, Third Report and Order and Second Further Notice of Proposed Rulemaking,* at paragraph 36.

The main goal of testing guidelines is to ensure that the testing is performed in areas that are representative of the environment that exists in each County/PSAP. There is a challenge in defining specific indoor test scenarios. Logistic and cost concerns associated with indoor testing are legitimate. The difficulty in obtaining access privileges into many in-building areas along with the time and expense of establishing ground truth indoors make indoor testing more complex than outdoor testing in the same areas. Building on the significant indoor testing performed by major carriers over the years, requirements can be adjusted. There are several approaches that can mitigate the challenge.

First, indoor accuracy rules consistent with the current network-based accuracy rules of 100 meters and 300 meters at the 67th and 90th percentile for indoor calls will provide flexibility and transition to an indoor metric. The percentage of Counties/PSAPs where the rules are applicable can be phased in over time in a similar manner to the current rules.

Second, indoor testing can be performed much less frequently than outdoor testing in the same areas once a statistical relationship is initially established between the indoor and outdoor accuracy performance in an area. Thereafter, the indoor accuracy can be extrapolated from the observed outdoor accuracy using the previously established statistical relationship.

Third, a very thorough treatment of testing has been completed by the CDMA Development Group (CDG). In its "CDG Test Plan for Location Determining Technologies Evaluation" document, the CDG define various indoor and outdoor test scenarios in rural (Table 5.1), suburban (Table 5.2), and urban (Table 5.3) environments.[31] The various indoor testing scenarios described in the CDG Test Plan can be reduced to a much smaller set by using type testing. For example, if it can be established that A-GPS accuracy in residential wood houses

[31] Oguz Sunay, Chair, Test Plans and Criteria Subgroup, *CDG Test Plans for Location Determination Technologies Evaluation* (2000) ftp://ftp.3gpp2.org/TSGC/Working/2000/TSG-C_0012/TSG-C/Wg4/CDG%20Test%20Plan%20for%20Location%20determination%20Tech.pdf

(scenarios S-5 and S-6 in the CDG Test Plan) is the same as in outdoor environments, then there would be no need to test both types of environments.

In each county where accuracy is being assessed, only the scenarios that are prevalent in that county would be applicable for testing. For example, there would be no need to test in wood frame residential houses in mid-town Manhattan. Similarly, there would be no need to test in glass and steel office buildings in rural counties that contained predominately farm land.

It should be noted that these testing scenarios were developed by an industry working group, and have been used in the past to evaluate accuracy performance of various location technologies in a wide variety of environments. In those tests, procedures similar to what is described above were used to limit the test scenarios to a reasonable set that well represented the test area, and still provided good statistical significance to the test results.

For a concrete example of the testing approach described above, consider the performance evaluation of U-TDOA that Verizon conducted in 2000 and 2001. In September of 2000, testing was conducted in New York City.[32] The testing used a subset of the urban scenarios as described in the CDG test plan, including indoor areas in building that are prevalent in this area. The results were then evaluated per scenario, as well as with various combinations which included different percentages of each of the scenarios. The specific scenarios used in this urban test are shown in table 1.

[32] *Location Accuracy Testing of TruePosition in Manhattan, New York, September 5, 2000 to September 8, 2000*, Verizon Laboratories, Network Services Technology Department, Wireless Access Technologies. The confidential characterization placed on the document has expired. See Addendum.

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

Table 1. Test scenarios used for urban testing in New York City

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.

Similarly, in May of 2001, testing was conducted in a suburban/rural area of southern Delaware.[33] In this case the testing used a subset of the suburban and rural test cases from the CDG test plan that are more appropriate for this environment. Results were evaluated in a similar manner as before. The specific scenarios used in this rural test are shown in table 2.

[33] TruePosition Trial/Delaware Bay (April 30-May 4, 2001), Verizon Technology Organizations. The confidential characterization placed on the document has expired. See Addendum.

Scenario	In CDG Test Plan?	No of Locations	No of fixes
H2: Highway, Inside car, 30 - 40 MPH	Yes	3	97 CDMA
H3: Highway, Inside car, Maximum speed	Yes	3	94 CDMA
H5: Highway, near base station, inside car	No	9	99 CDMA 98 AMPS
H6: Highway, outdoor, stationary, near base station	No	9	99 CDMA
H7: Highway, Inside car, stationary, away from base station	No	9	99 CDMA 96 AMPS
H8: Highway, outdoor, stationary, away from base station	No	9	98 CDMA
W1: Boat within 2 miles of shore, stationary	Yes	3	95 CDMA
W2: Boat within 2 miles of shore, 5 - 20 knots	Yes	3	95 CDMA
W3: Waterfront building, exterior room, Indoor stationary	Yes	3	99 CDMA
W4: Waterfront building, interior room, Indoor stationary	Yes	3	97 CDMA
W5: Waterfront, Inside car, 20 - 40 MPH	Yes	3	99 CDMA
W6: Waterfront, Outdoor, stationary	Yes	3	99 CDMA 99 AMPS
W7: Waterfront, Inside car stationary	Yes	3	96 CDMA

Table 2. Test scenarios used for rural testing in southern Delaware

By utilizing only the test scenarios that are appropriate for a test area, the testing can be performed in a more cost efficient manner, and the results will better reflect the performance that will be experience by end users in that environment.

TruePosition recommends that the Commission adopt a rule requiring indoor measurements as well as guidelines, as an update to OET-71 bulletin.[34] TruePosition proposal is that those rules should require 100m/300m accuracy at the 67th/90th percentile, respectively,

[34] OET 71, the Commission's *Guidelines for Testing and Verifying the Accuracy of Wireless E911 Locations Systems.*

for indoor calls. The percentage of counties and the population covered can be phased in over time in a similar manner to the network-based rules adopted in the *Second Report and Order*.[35]

Compliance with the Commission's rules is vital to achieving the improvements the Commission seeks. Testing the location information a device transmits to the 911 Center is the only reasoned means to ensure that policies and rules to assist public safety actually do so. A pragmatic and effective testing structure encompassing the sources of calls, both indoors and outdoors, should be implemented by the Commission.

Conclusion

There is a defined record, comprised of carrier actions and validated demographics, demonstrating the growing number of calls made from indoor environments. There is a similar defined acknowledgement by carriers showing the severe limitation GPS encounters in several common environments where subscribers make calls from. The record presents solutions where

[35] In the Matter of Wireless E911 Location Accuracy Requirements, *Second Report and Order*, PS Docket No. 07-114, FCC 10-176 (September 23, 2010).

investment has been committed to improve meaningful location accuracy. There is real opportunity to make a difference to emergency response and meet consumer expectation that all 911 calls be located. Yet, investment will not be made until the Commission acts. It is the Commission's actions that present the path to meaningful improvements.

Respectfully submitted,

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October 3, 2011

ADDENDUM

Laboratories Inc.

Network Services Technology Department
Wireless Access Technologies

Location Accuracy Testing of TruePosition in Manhattan, New York

September 5, 2000
to
September 8, 2000

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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. TruePostion 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 <u>overall</u> 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.

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.

FIGURE 1. MANHATTAN, NEW YORK TEST AREA COVERAGE

2-1. OUTDOOR TEST SCENARIOS

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	1040 N 6th Ave between 39th and 40th, Roses Only (Fashion District Display and map on pole) 787 7th Ave between 52th and 51st St (Fire hydrant) 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)

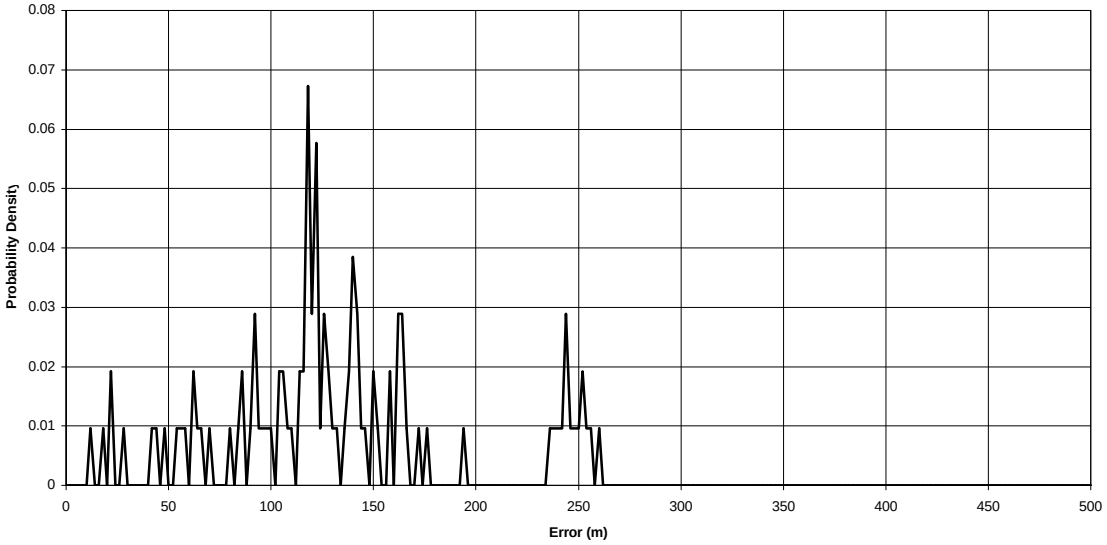

FIGURE U2D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

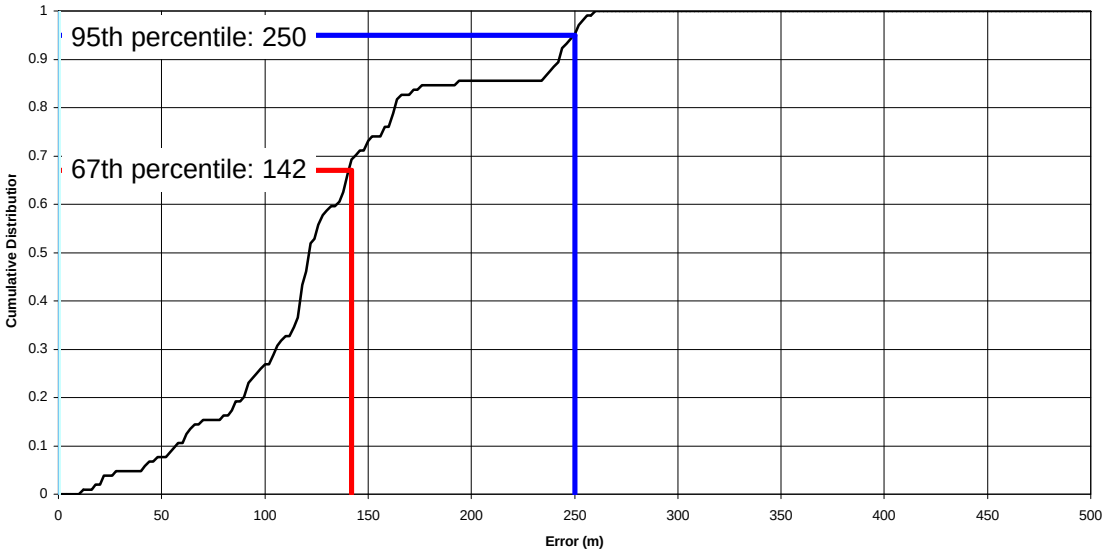

FIGURE U2E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

Scenario (U1) - Urban canyon high, intersection

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	Andrew's Coffee Shop, Intersection Broadway and 39th (Traffic light pole at corner) Intersection- NE corner of 49th St and 7th Ave (Traffic light pole) 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)

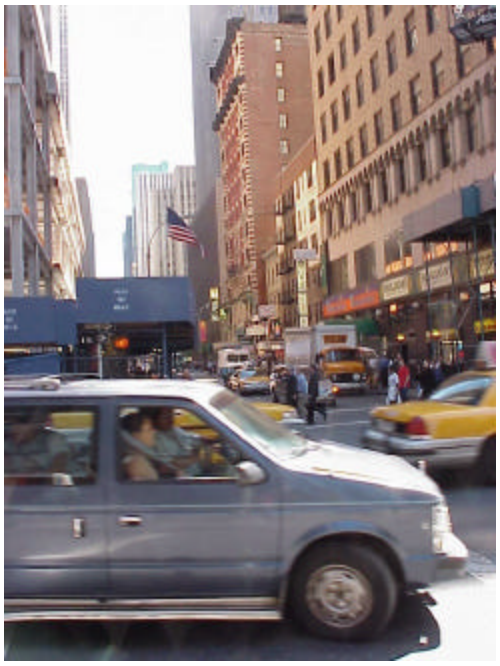

FIGURE U1B: INTERSECTION- NE CORNER OF 39TH ST AND 7TH AVE
(TRAFFIC LIGHT POLE)

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)

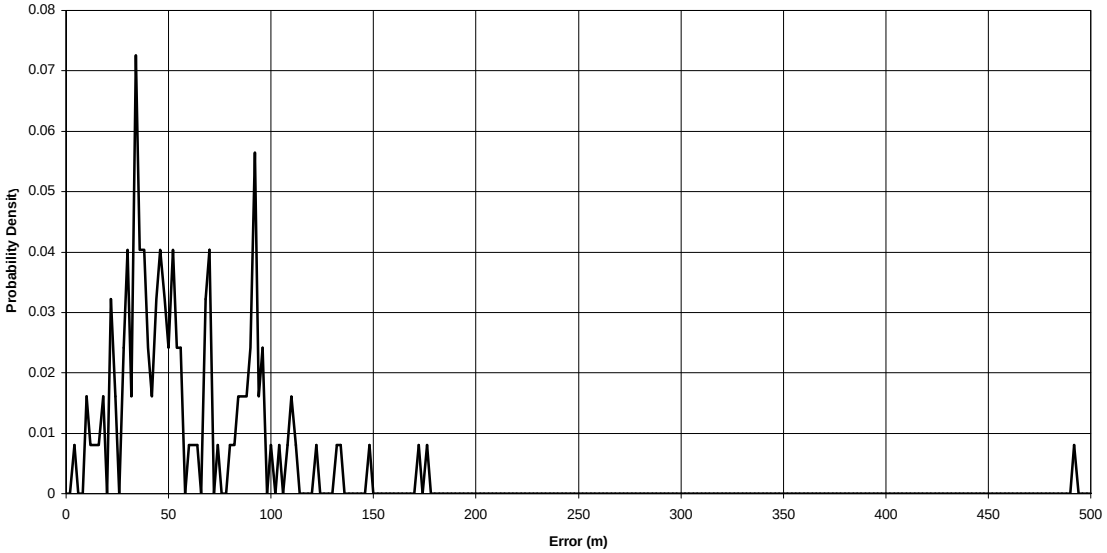

FIGURE U1D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

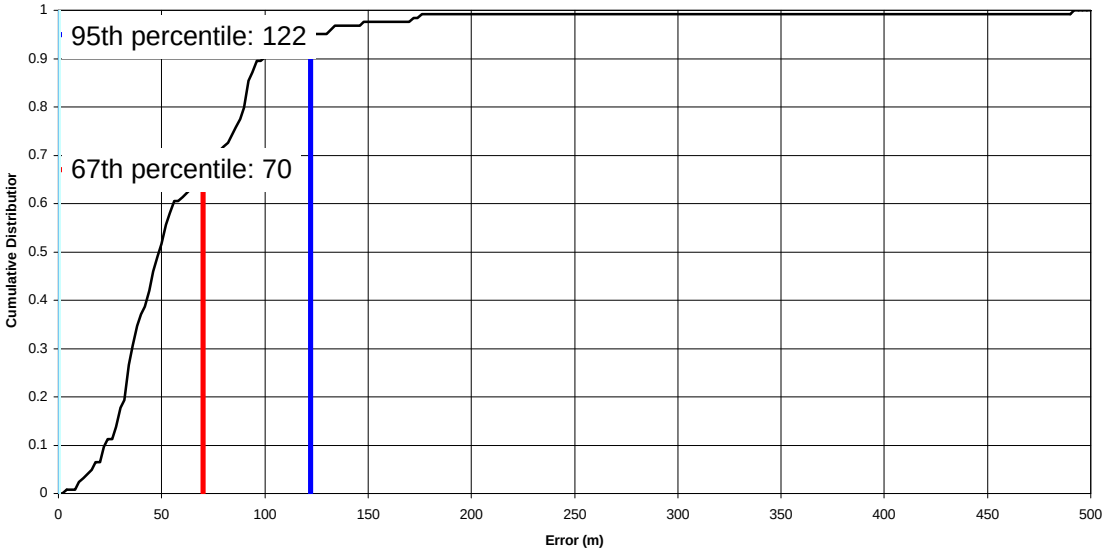

FIGURE U1E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	Associated store, between 48 & 49 street, 2nd Ave (Tree with grade just before Stationary store) Belvedere Hotel, 319 48th St, between 9 & 8 Ave (Fire hydrant) 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)

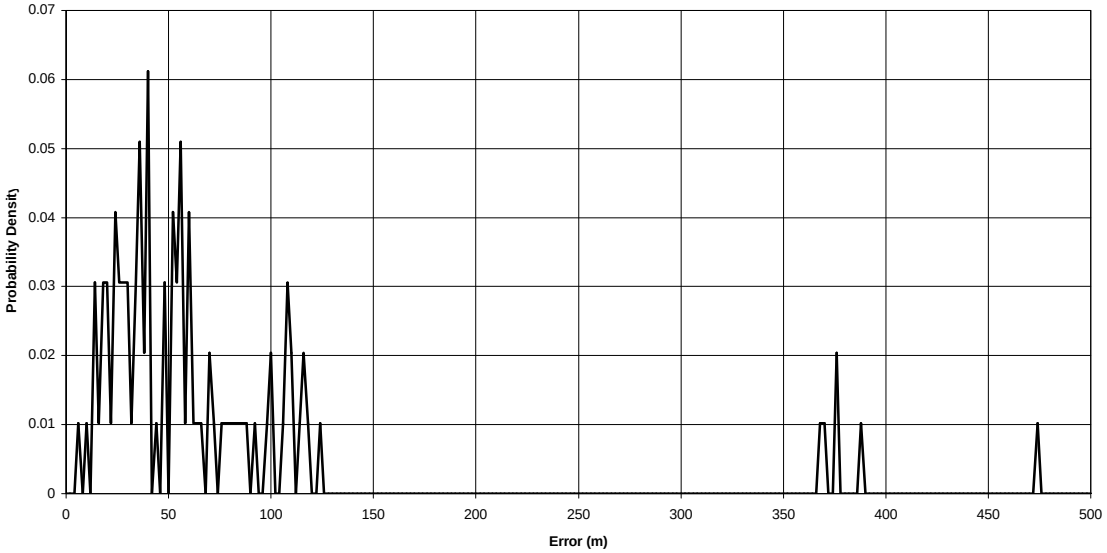

FIGURE U4D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

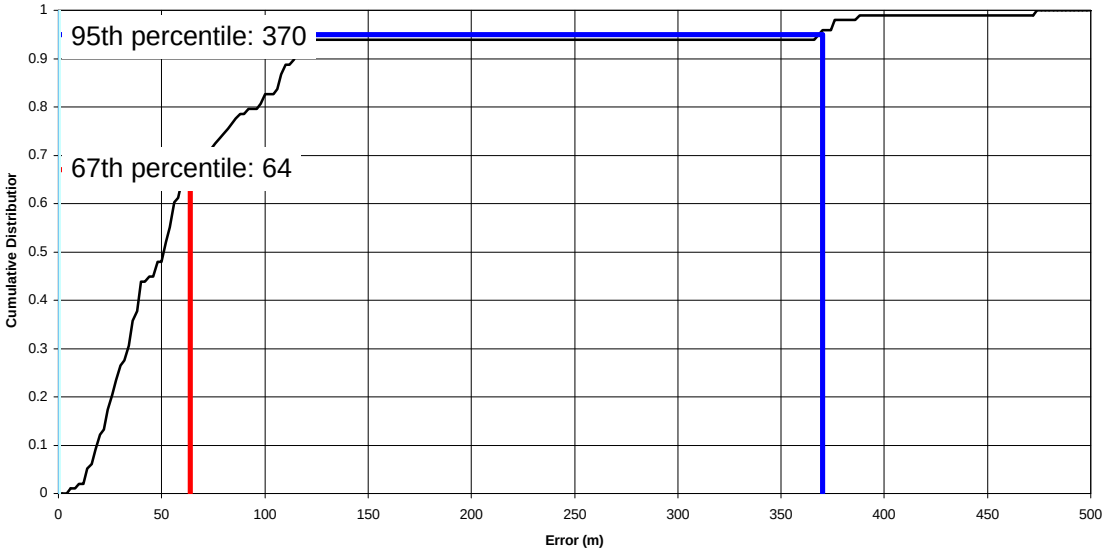

FIGURE U4E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

Scenario (U3) - Urban canyon medium, intersection

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	NE corner of 52nd & 2nd Ave (Traffic light pole in front of Mimi's restaurant-984 2nd Ave) SE corner, 51st St and 9th Ave, St Claire Yue Wah restaurant (Traffic light pole) 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 CLAIRE YUE WAH RESTAURANT
(TRAFFIC LIGHT POLE)

Scenario (U3) - Urban canyon medium, intersection

(Distribution Functions)

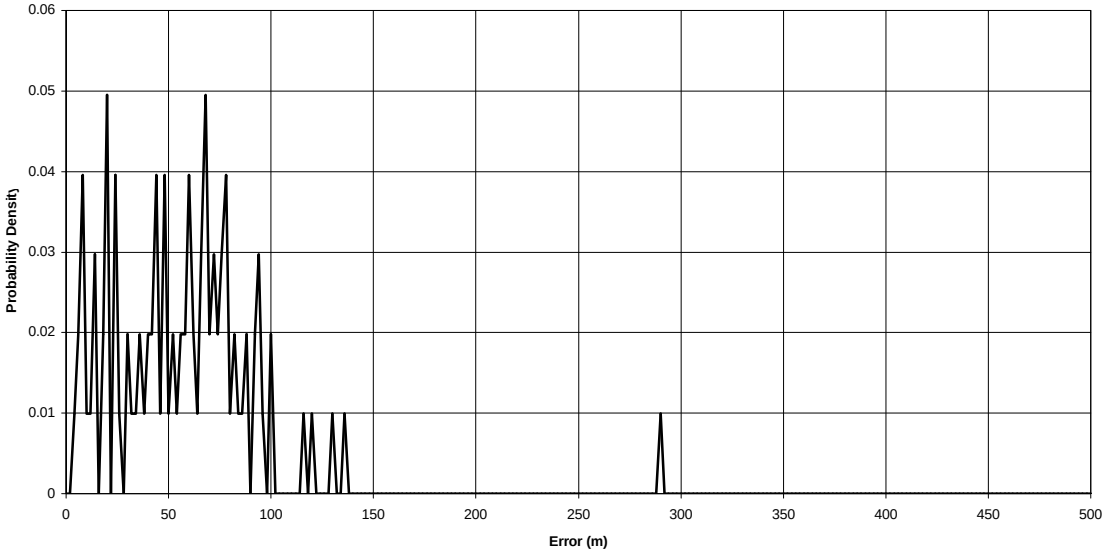

FIGURE U3D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

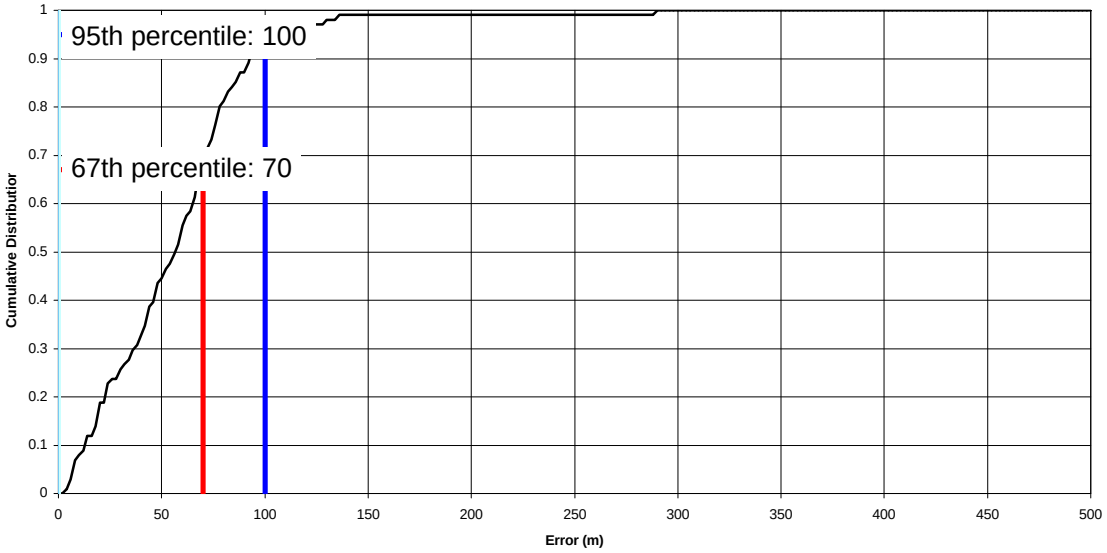

FIGURE U3E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

2-2. IN-VEHICLE STATIONARY TEST SCENARIOS

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	Fashion Center Bldg on Madison at #30 West 39th St (Phone booth to your left in line with entrance of 30 W 39th) 7th Ave between 54th and 53rd Streets, Lindy's Griddle and Breakfast (No standing sign) 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)

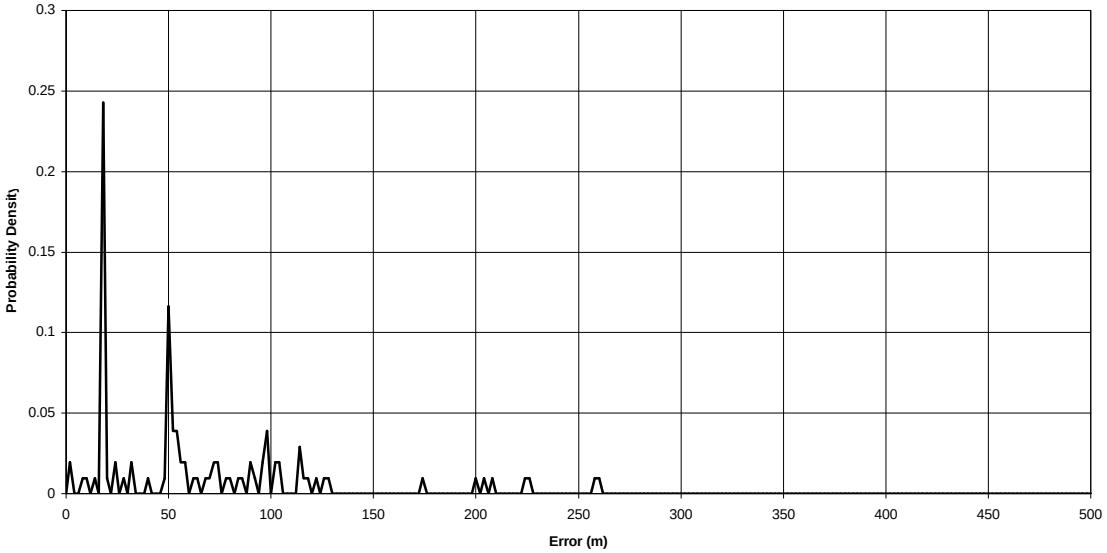

FIGURE U7B: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

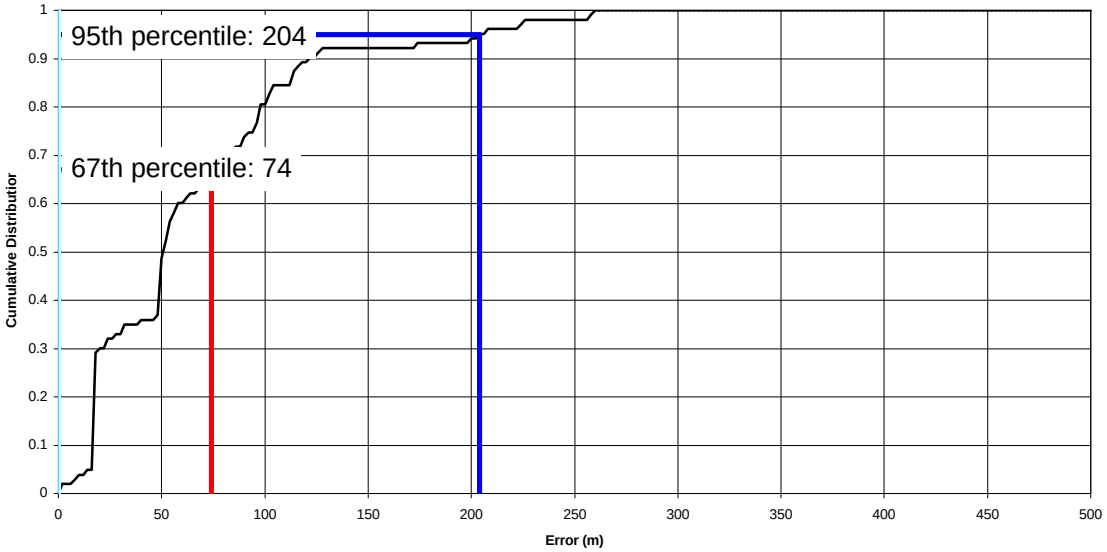

FIGURE U7C: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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: Location 2: Location 3:	Route of 2nd Avenue locating at "Night Owls", "Blockheads", "Duane Read Pharmacy", "Savin Building", "Queens Midtown tunnel" between 34th and 57th Route of 3rd Ave locating at "Au Bon Pain", "Muldoons Irish Pub","TheTreasure Chest", "CitiGroup Center", "SW corner of 57th" 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)

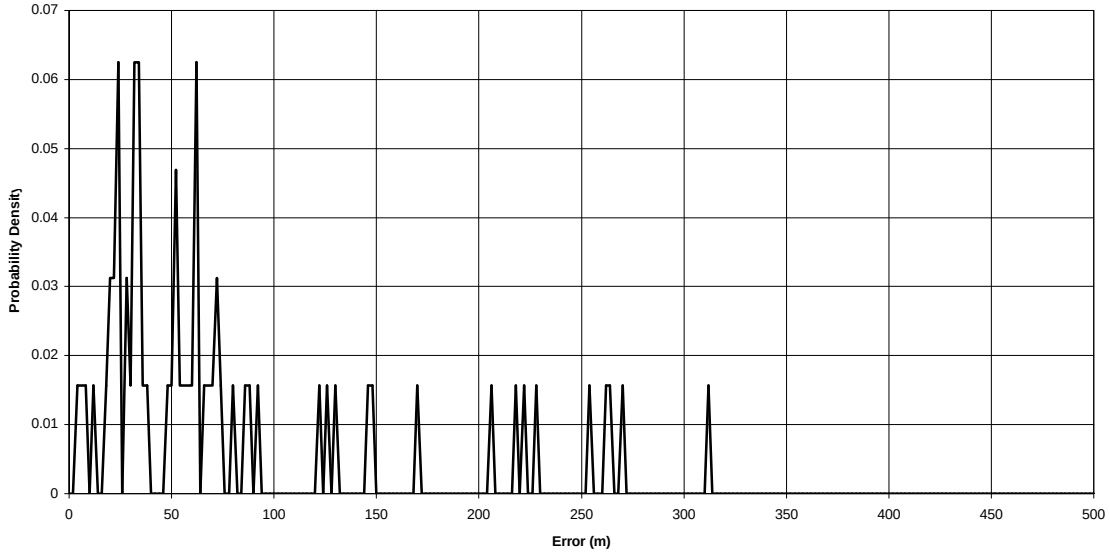

FIGURE U8B: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

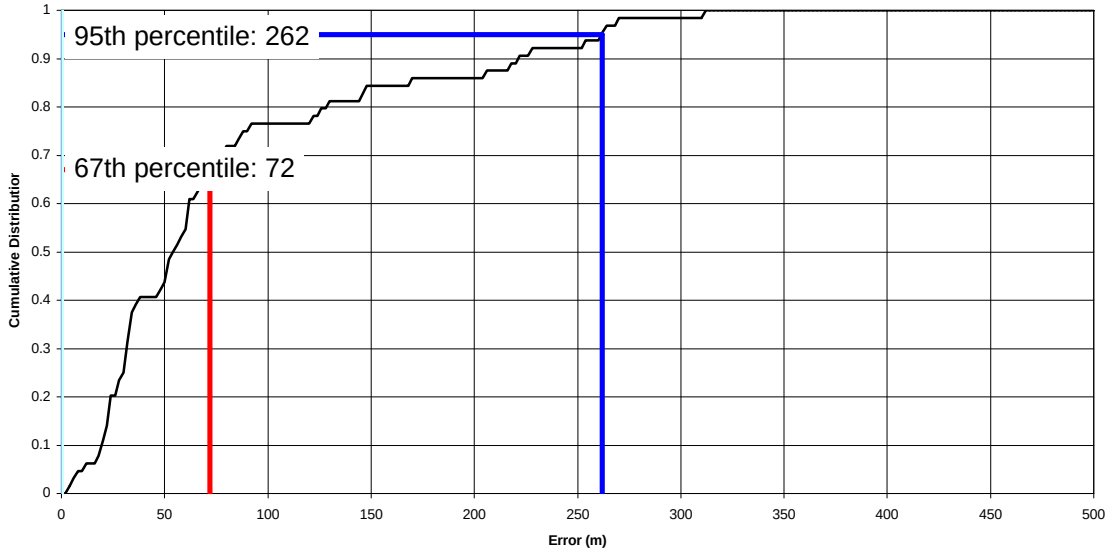

FIGURE U8C: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

2-4. INDOOR TEST SCENARIOS

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	39th St. at 1410 Broadway (Traffic Light Pole at corner) Maintenance locker room with Window 35th floor 900 3rd Ave between 53rd and 54th St (Pole at the shops at Citgroup Ctr), on top of ground floor window 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)

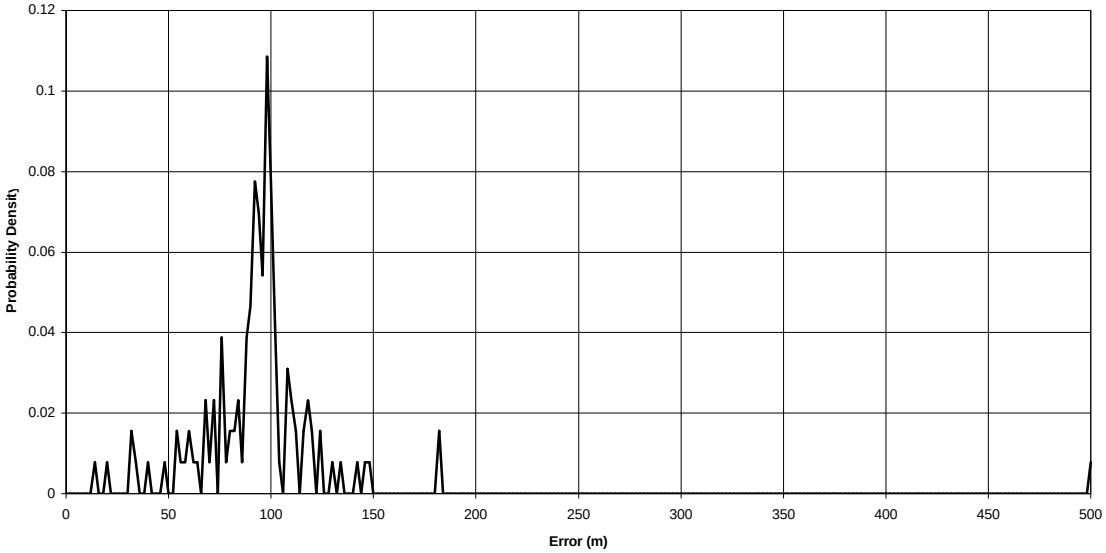

FIGURE U10D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

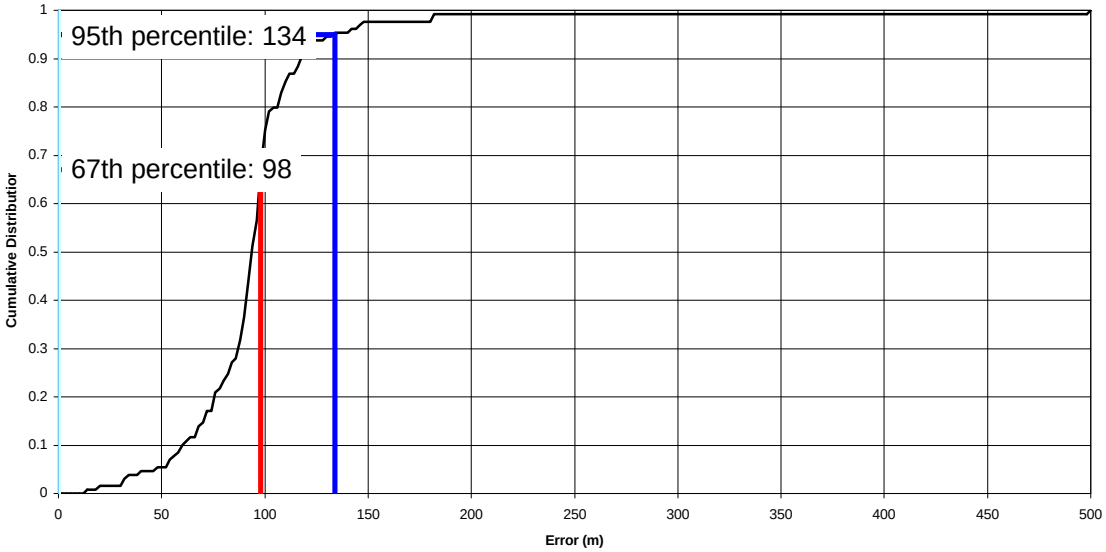

FIGURE U10E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	39th St. at 1410 Broadway, (Traffic light pole at corner), Elevator 4 900 3rd Ave between 53rd and 54th St (Pole at the shops at CitiGroup Ctr) Between elevators 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)

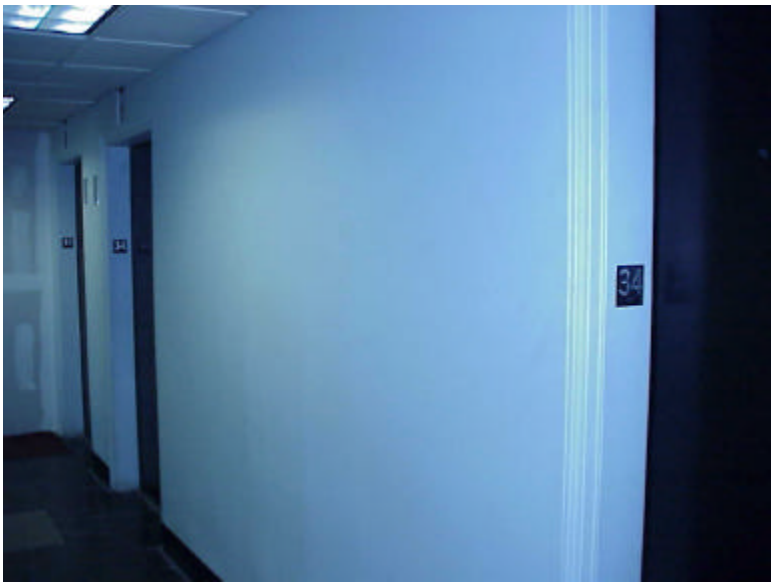

FIGURE U16A: 39TH ST. AT 1410 BROADWAY,
(TRAFFIC LIGHT POLE AT CORNER), ELEVATOR 4

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)

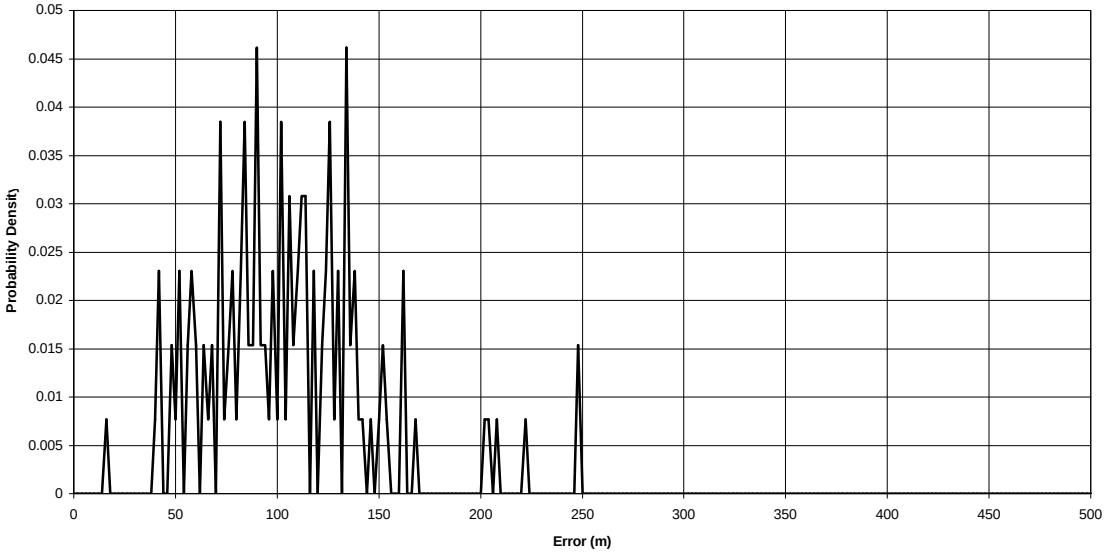

FIGURE U16D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

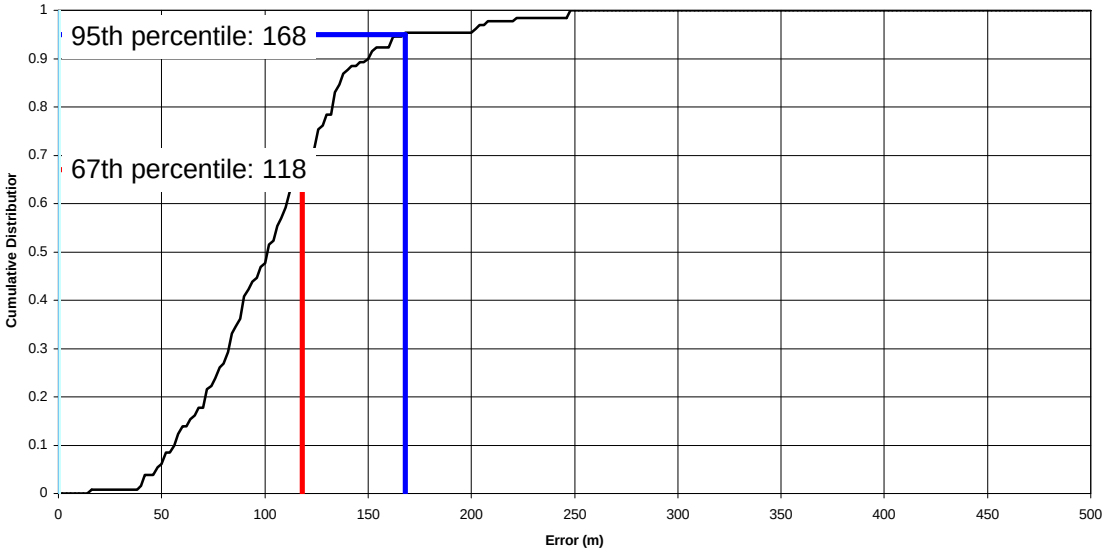

FIGURE U16E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	39th St. at 1410 Broadway, (Traffic light pole at corner), Rear elevator hallway and then through back door 900 3rd Ave between 53rd and 54th (Pole at the CitiGroup Ctr shops) interior room above ground floor 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)

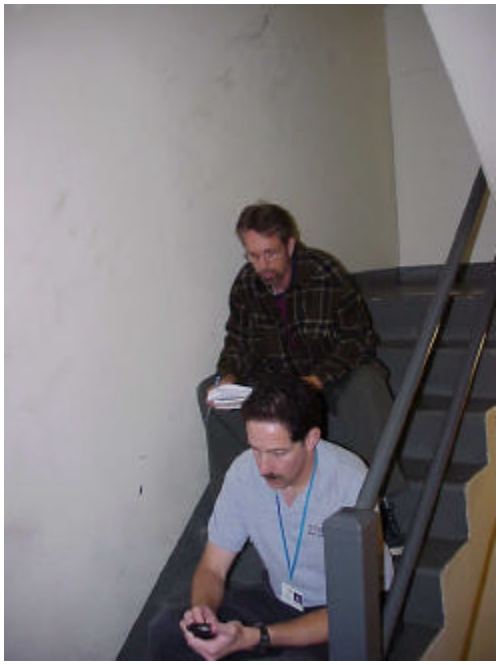

FIGURE U13C: 235 48TH ST BETWEEN 8TH AND BROADWAY, RITZ PLAZA (NO STANDING SIGN EAST SIDE OF THEATER JUST BEFORE PARKING GARAGE AT CURB) STAIR B THROUGH DOOR

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

(Distribution Functions)

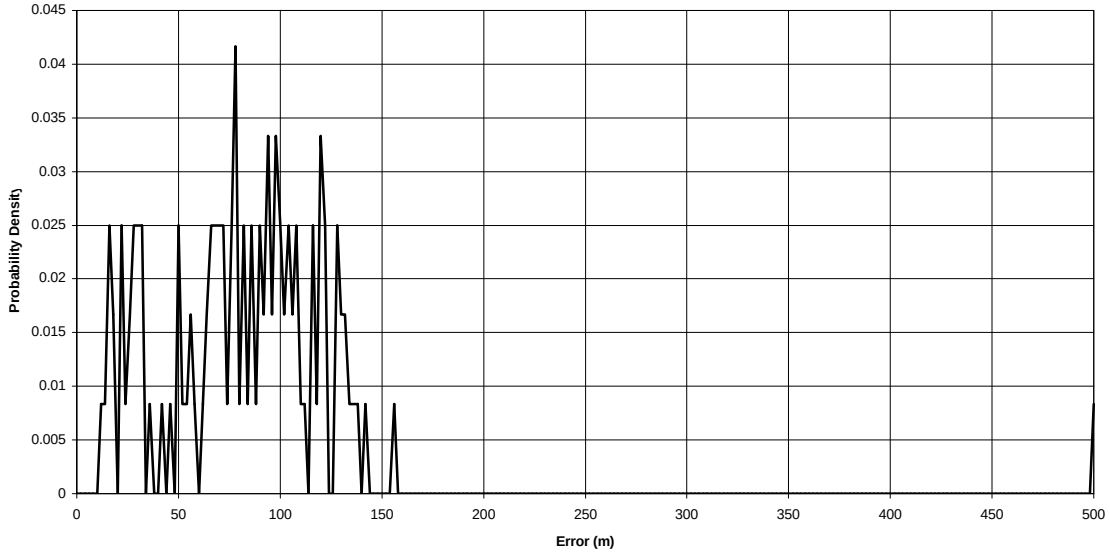

FIGURE U13D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

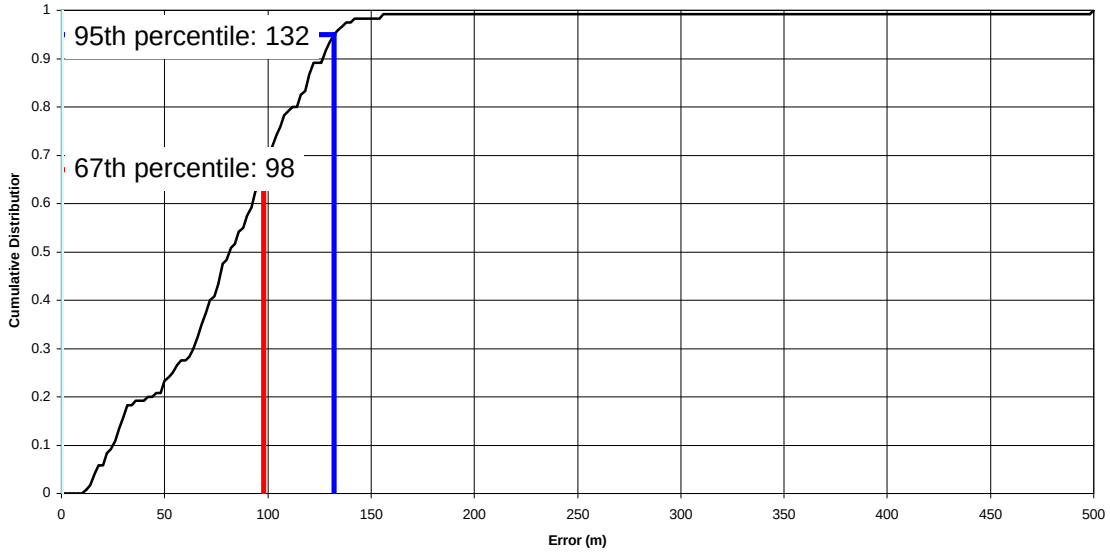

FIGURE U13E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	39th St. at 1410 Broadway (Corner traffic light pole) Window left of entrance door 900 3rd Ave between 53rd and 54th (Pole at CitiGroup Ctr shops) 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)

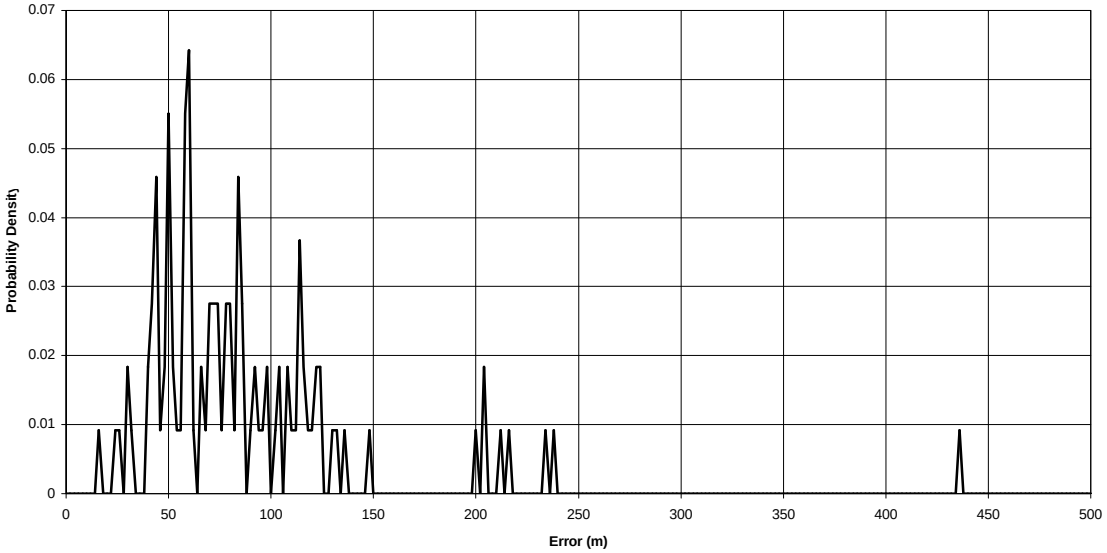

FIGURE U12D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

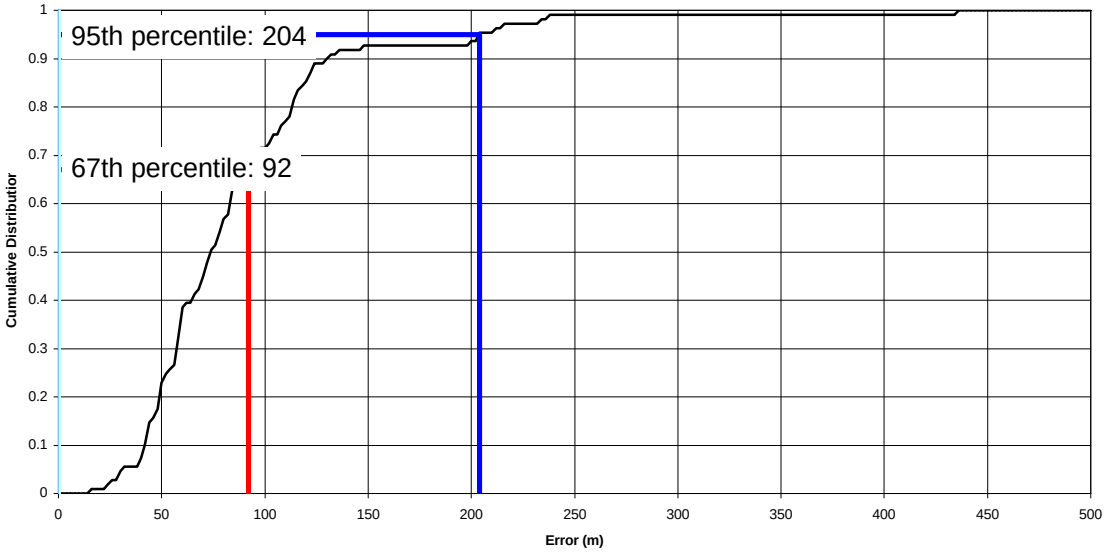

FIGURE U12E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	39th St. at 1410 Broadway (Traffic light pole at corner) Elevator 4 900 3rd Ave between 53rd and 54th (Pole at shops of CitiGroup) between two elevators 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)

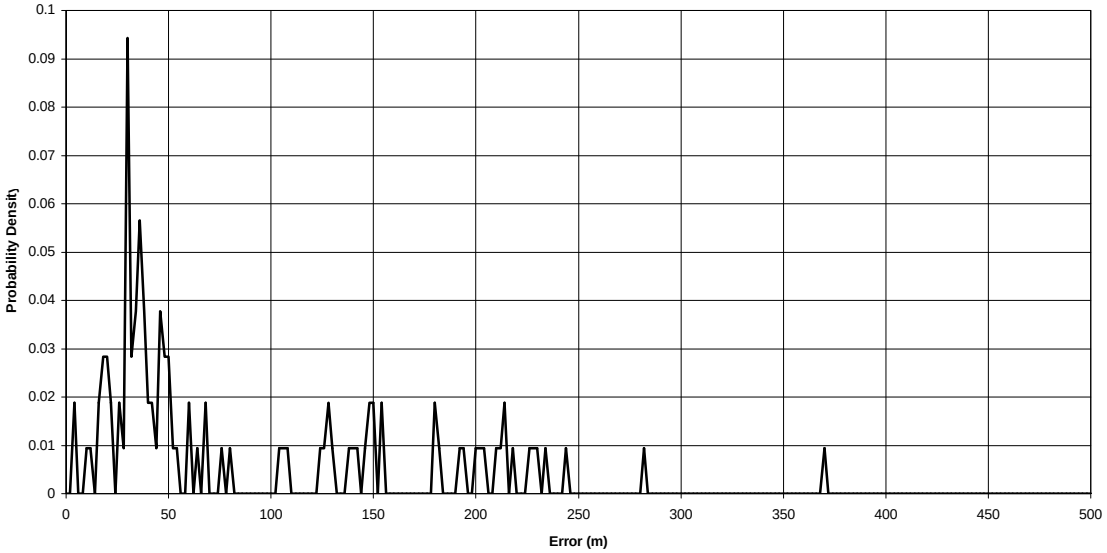

FIGURE U18D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

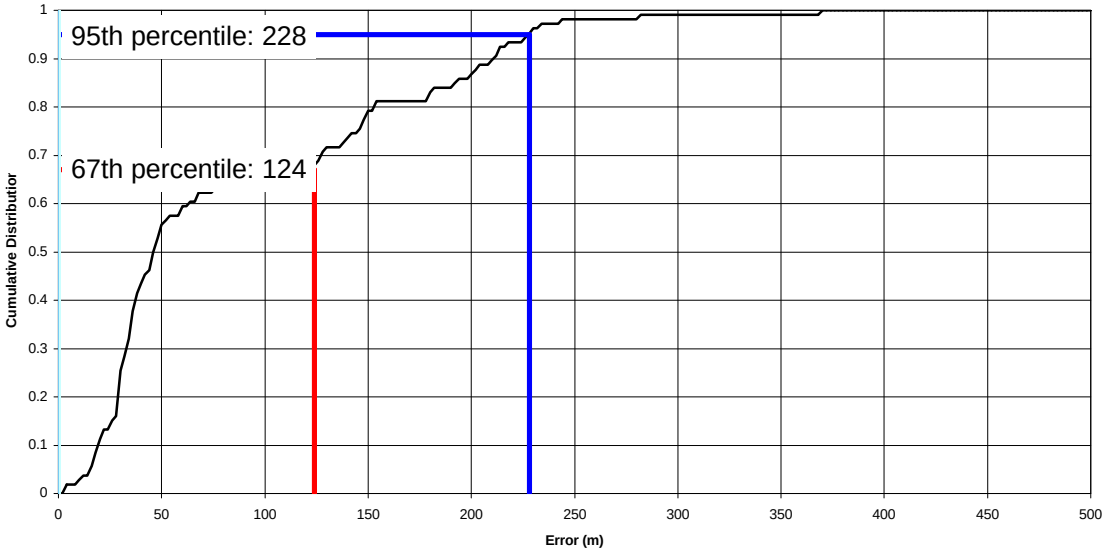

FIGURE U18E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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

(Summary)

Locations

# Test Locations:	3
Location 1: Location 2: Location 3:	39th St. at 1410 Broadway (Traffic light pole at corner) End of Hallway A at door A and then second door 900 3rd Ave between 53rd and 54th (Pole at the shops at CitiGroup) Through door at end of hallway to the left. 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 HALLAWY A AT DOOR A AND THEN SECOND DOOR

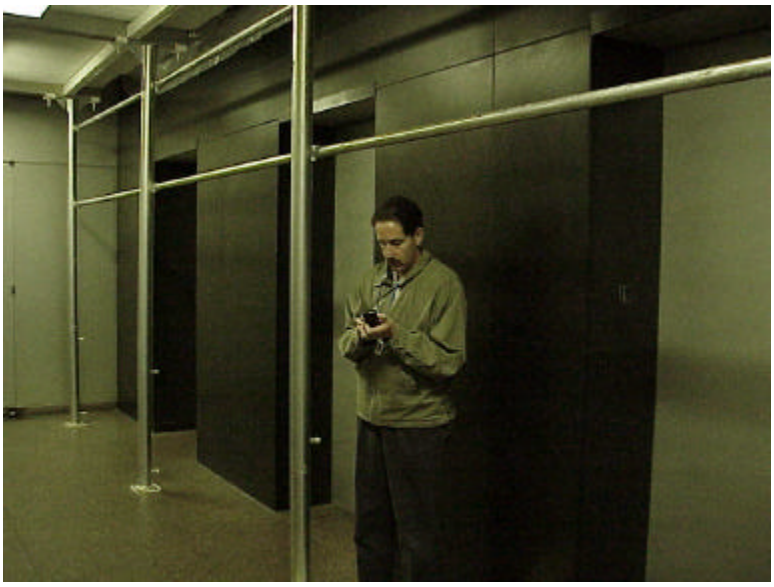

FIGURE U15B: 900 3RD AVE BETWEEN 53RD AND 54TH (POLE AT THE SHOPS AT CITIGROUP) THROUGH DOOR AT END OF HALLWAY TO THE LEFT

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)

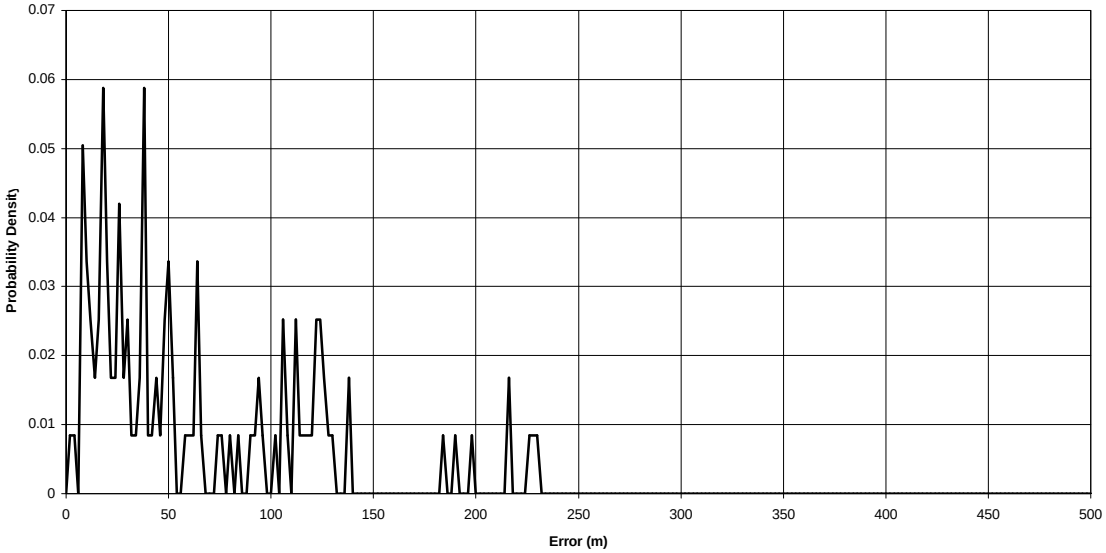

FIGURE U15D: PROBABILTIY DENSITY FUNCTION FOR LOCATION ERROR

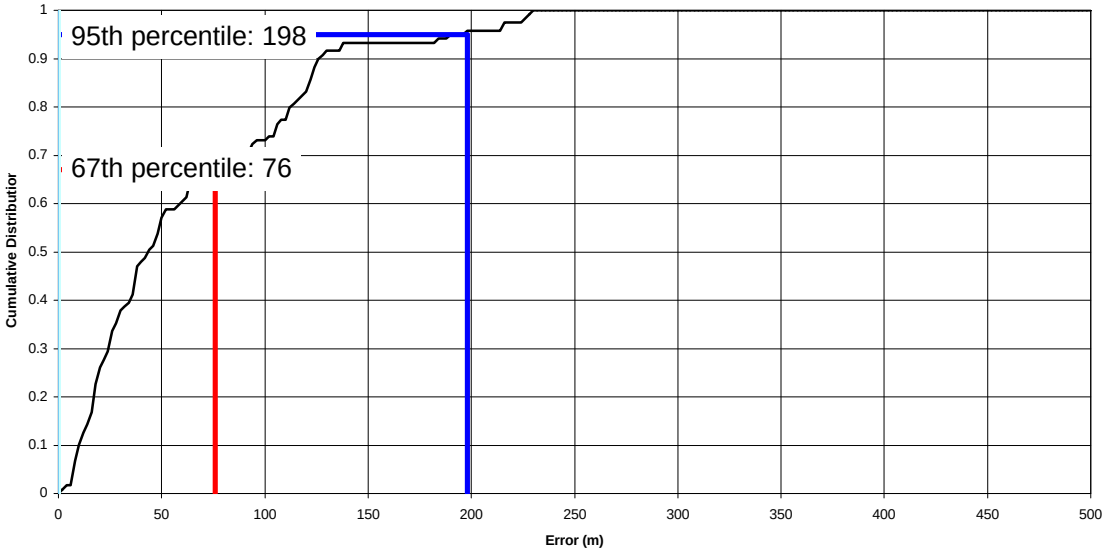

FIGURE U15E: CUMULATIVE DISTRIBUTION FUNCTION FOR LOCATION ERROR

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.

TruePostion 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 form 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.

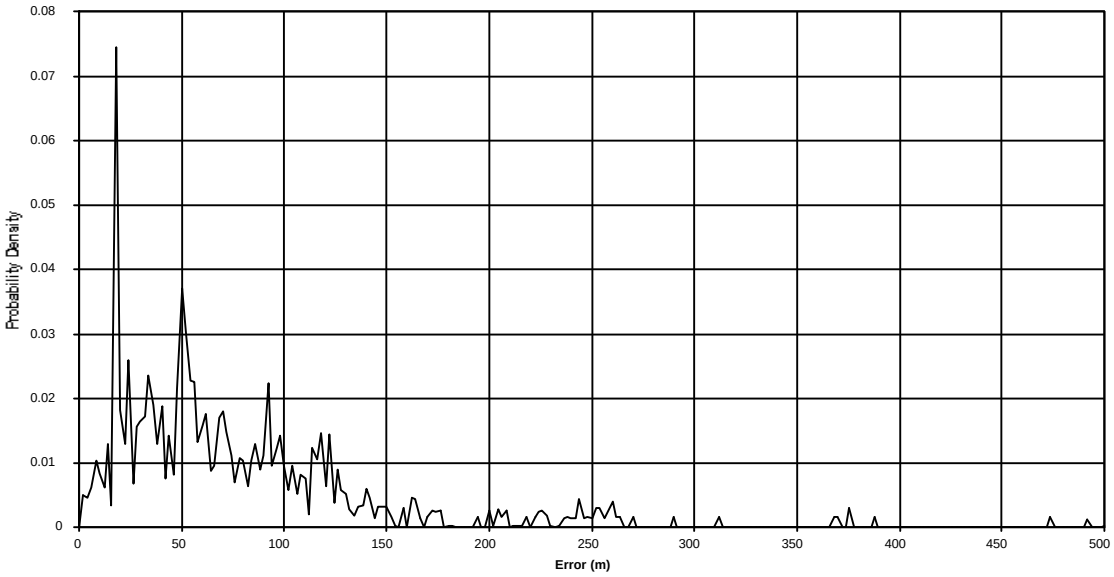

FIGURE 3.1: PROBABILITY DENSITY FUNCTION (PROFILE 1)

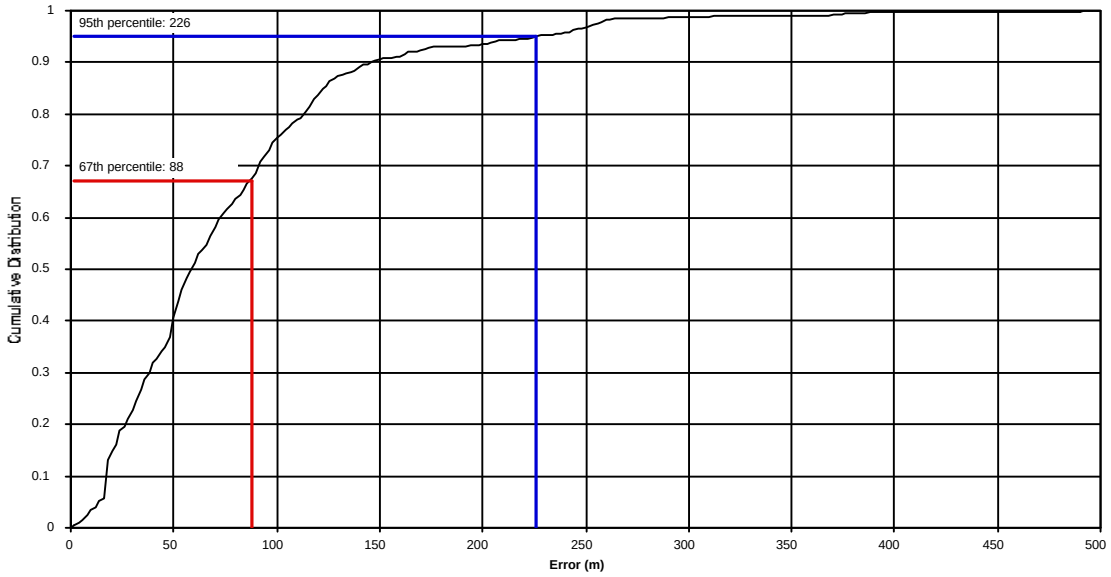

FIGURE 3.2: CUMULATIVE DISTRIBUTION FUNCTION

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.

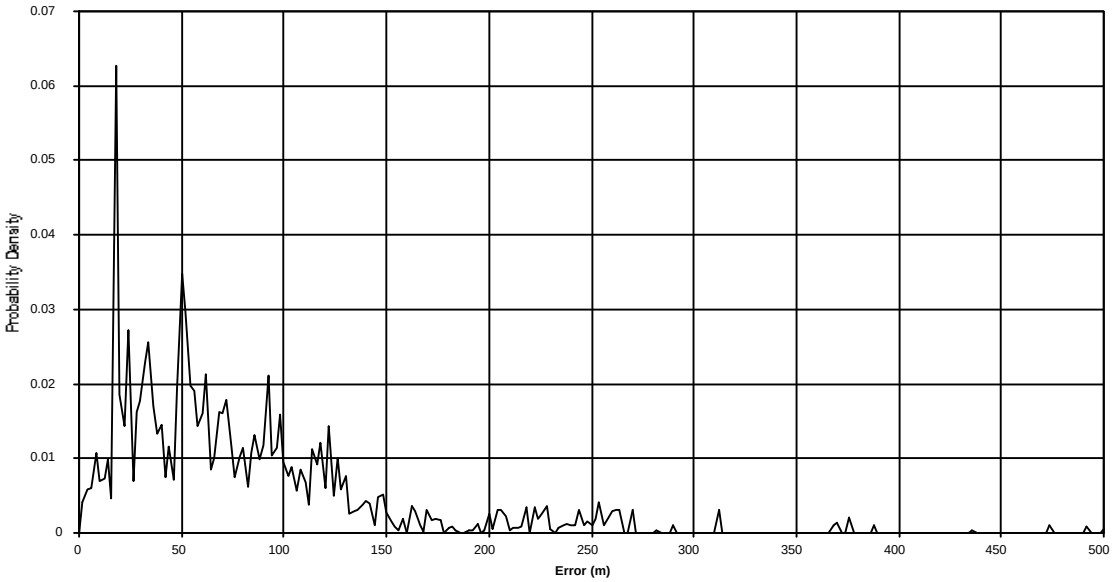

FIGURE 3.3: PROBABILITY DENSITY FUNCTION (PROFILE 2)

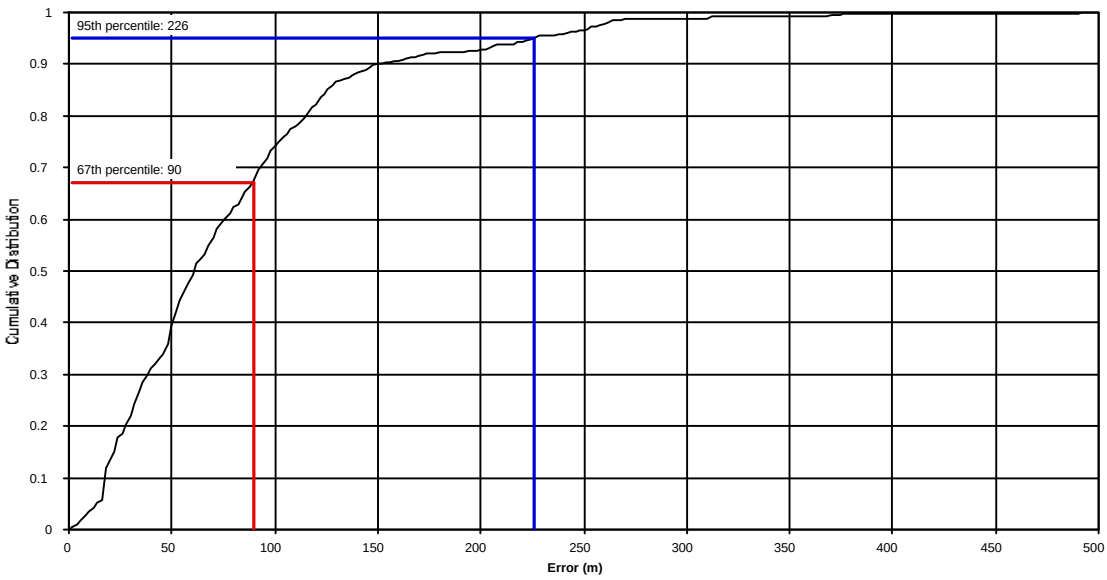

FIGURE 3.4: CUMULATIVE DISTRIBUTION FUNCTION (PROFILE 2)

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.

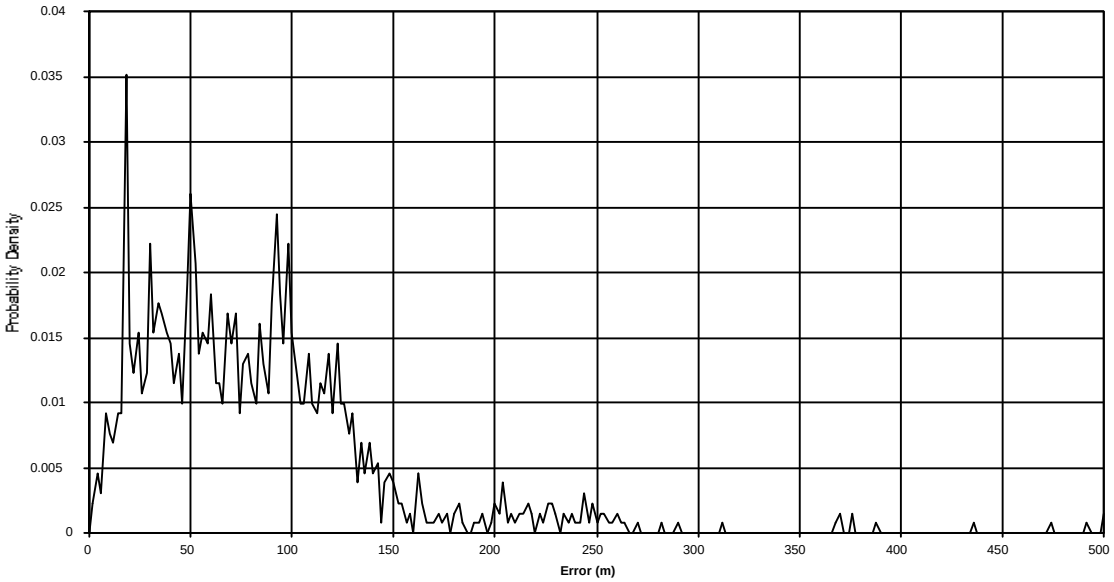

FIGURE 3.5: PROBABILITY DENSITY FUNCTION (PROFILE 3)

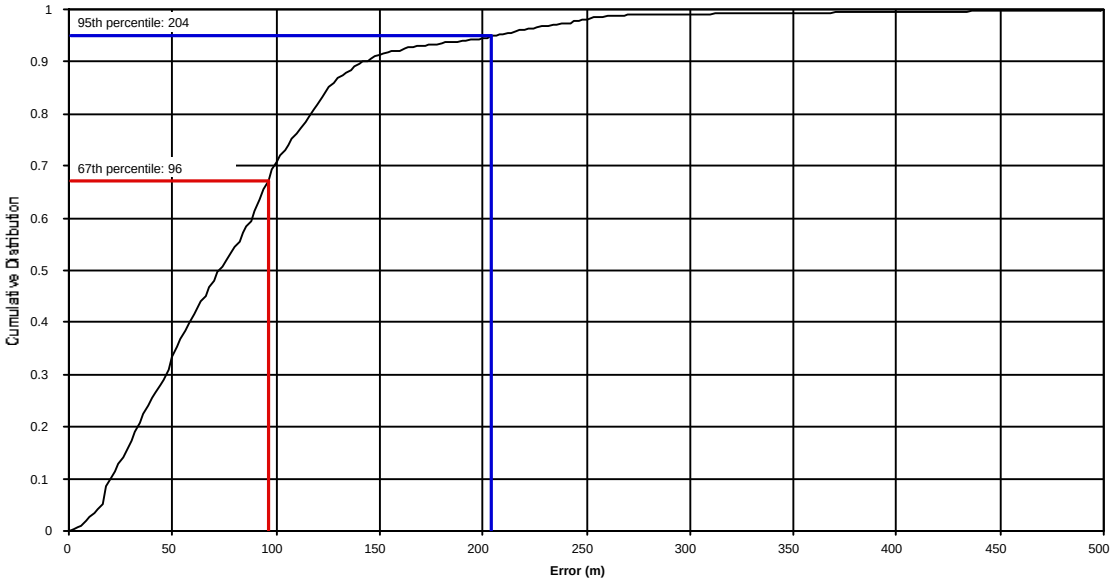

FIGURE 3.6: CUMULATIVE DISTRIBUTION FUNCTION (PROFILE 3)

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.

Verizon Technology Organization

TruePosition Trial/Delaware Bay

April 30–May 4, 2001

Iftekhar Rahman
David Freeman
Nabil Hinnawi

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Executive Summary

At the request of Verizon Wireless, the Verizon Technology Organization (VTO) conducted a rigorous trial of the TruePosition geo-location system in the states of New Jersey and Delaware, around and within Delaware Bay.

The purpose of the trial was to assess compliance with the FCC requirement for Phase II E911 that a network-based geolocation system shall provide the location of a wireless 911 call with an accuracy of 100 meters 67% of the time and 300 meters 95% of the time. The focus of the trial was to assess the accuracy for water and highway water scenarios. In the trial area the average distance between cell sites was 8 miles.

The CDMA Development Group (CDG) Test Plan was used as a basis for most of the tests. Seven water scenarios from the CDG Test Plan were tested, including on water as well as waterfront tests. Two highway scenarios from the CDG Test Plan were also tested, while moving at maximum highway speeds and while moving at 30 mph. In addition to the CDG scenarios, stationary highway tests were also performed, outdoors or from inside a car, near a cell site or far away from cell sites.

Analysis of water testing results revealed that the tested version of the TruePosition system yielded 25 meters accuracy 67% of the time and 52 meters accuracy 95% of the time. In fact, the system performed better than expected for water scenarios, and well within the FCC requirements. As far as the tested highway scenarios, the accuracy of TruePosition system was 54 meters for the 67th percentile, well within the FCC requirements for the 67th percentile. It performed well and was accurate within 150 meters for 90% of the highway measurements. However, the 95th percentile for the highway cases was over 500 meters, and was not compliant with the FCC requirements.

The VTO trial stressed the TruePosition system in an area where cell sites were 8 miles apart. In such cases, the ability to reliably detect signals from a mobile at non-serving cell sites is more challenging, which makes accurate location determination difficult. On the other hand, VTO expects that such cases are representative of significant sections of the Verizon Wireless national footprint. As a result of VTO testing TruePosition adjusted their algorithm to handle the assignment of weights to signals detected at cell sites with low signal to noise ratio, and based on cell site spacing. TruePosition independently re-tested their modified algorithm and informed VTO that such a scheme will significantly improve the accuracy of their algorithm.

VTO recommends an independent re-test of the TruePosition system in the Delaware Bay area to verify improvements in the accuracy of the modified algorithm. VTO also recommends limited re-testing of the TruePosition system in Manhattan to verify that the changes to the algorithm will not adversely affect accuracy in urban environments.

1. Introduction

This report summarizes the results of the Delaware Bay Location Accuracy Trial conducted by Verizon Technology Organization (VTO, *i.e.*, Verizon Laboratories and BBN-T) of the network-based, geo-location system from TruePosition, Inc. The purpose of the trial was to assess compliance with the FCC requirement for Phase II E911 that a network-based system shall provide the location of a wireless 911 call with an accuracy to within 100 meters 67% of the time and to within 300 meters 95% of the time.

The trial was conducted in the states of New Jersey and Delaware, in an area around and within Delaware Bay. The focus of the trial was to test the location determination accuracy of the TruePosition system for water and highway scenarios, as well as for scenarios where 911 callers are either near or are far away from cell sites. The average distance between cell sites in the tested area was 8 miles.

The highway scenarios were tested on the major highways and state routes on both sides of Delaware Bay. On the State of Delaware side, the highways, tested, ran from south of Christiana, near Newark, to Lewes. On the State of New Jersey side, the highways tested, ran from south of Wilmington all the way to Cape May. The water scenarios were tested on a portion of Delaware Bay, starting from its mouth to about 15 miles inland. It should be mentioned that this area was considered to be most representative of the water scenario environment as envisioned in the CDG Test Plan. About 42 cell sites in the trial area were populated with TruePosition wireless location sensors.

The CDG Test Plan was used as a basis for the trial. All seven water scenarios from the CDG Test Plan were tested. This included scenarios on the water as well as on the waterfront. Two of the four highway scenarios from the CDG Test Plan were also tested. This included tests while moving at maximum highway speeds and while moving at 30 mph. Four additional highway scenarios were also defined and tested. These were all stationary scenarios. Two of these scenarios were located near base stations and two were far away from base stations. At each location, scenarios were enacted from both outside and inside the car.

The following table outlines the scenarios tested. CDMA test calls were made for each scenario. Each CDG scenario was tested in three different locations. Typically, between 95 and 99 independent fixes were obtained for each scenario using CDMA test calls, i.e., over 30 CDMA fixes per location. For the additional scenarios, each location was in turn comprised of three separate sub-locations, so that in effect each such scenario was tested in 9 different locations. For these scenarios about 11 fixes were obtained per location. Also between 96 and 99 fixes were obtained for selected scenarios using AMPS test calls.

Scenarios Tested

Scenario	**In CDG Test Plan?**	**No of Locations**	**No of fixes**
H2: Highway, Inside car, 30 - 40 MPH	Yes	3	97 CDMA
H3: Highway, Inside car, Maximum speed	Yes	3	94 CDMA
H5: Highway, near base station, inside car	No	9	99 CDMA 98 AMPS
H6: Highway, outdoor, stationary, near base station	No	9	99 CDMA
H7: Highway, Inside car, stationary, away from base station	No	9	99 CDMA 96 AMPS
H8: Highway, outdoor, stationary, away from base station	No	9	98 CDMA
W1: Boat within 2 miles of shore, stationary	Yes	3	95 CDMA
W2: Boat within 2 miles of shore, 5 - 20 knots	Yes	3	95 CDMA
W3: Waterfront building, exterior room, Indoor stationary	Yes	3	99 CDMA
W4: Waterfront building, interior room, Indoor stationary	Yes	3	97 CDMA
W5: Waterfront, Inside car, 20 - 40 MPH	Yes	3	99 CDMA
W6: Waterfront, Outdoor, stationary	Yes	3	99 CDMA 99 AMPS
W7: Waterfront, Inside car stationary	Yes	3	96 CDMA

Highway scenario fixes were obtained when the handset was in both stationary and driving modes. Stationary highway fixes were obtained for locations close to cell sites, far away from cell sites, inside a car or outdoors. Fixes for on the water scenarios were obtained when making calls from a boat both when the boat was moving and when it was stationary. The other water scenario fixes were obtained when making calls from selected waterfront locations while driving, while outdoors and stationary, or, while indoors.

The accuracy was analyzed by comparing the location fixes estimated by the geo-location system to the corresponding ground truth locations. Differential GPS was used to determine ground truth for most scenarios. For indoors scenarios, where a GPS reading could not be obtained, the ground truth was derived from the co-ordinates of a nearby outdoor location along with angle and distance measurements from that outdoor location to the indoor location from which test calls were generated.

The location accuracy of the TruePosition system was analyzed for the scenarios that were tested. The details of the analysis are given in Section 2. For each scenario, the following are included:

1) Addresses of the test points at which the scenarios were tested,
2) the 67th percentile of the location estimation error,
3) the 95th percentile of the location estimation error,
4) the number of fixes that were obtained for that scenario, and,
5) photographs capturing the scenario,

Section 3 provides an analysis of the overall (aggregate) location accuracy for the water scenarios and for the highway scenarios, as separate classes. For this the results of the tested scenarios in a class are combined using appropriate weighting factors. A rationale for the weighting factors is also included. The performance results include estimates of the probability density function and the cumulative distribution function of the location errors. Section 4 provides a conclusion and recommends next steps for further evaluation.

Appendix A gives comments on the test by TruePosition and descriptions of modifications made to the location algorithm so as to improve performance.

2. Test Scenarios with Summary Performance Results

In this section, we give the test scenarios used for E911 location performance testing, providing both verbal descriptions of the test locations and representative photographs of the test sites.

For each scenario, we give estimates of the 67th percentile and the 95th percentile of the locations errors. These estimates are the 67th percentile and the 95th percentile, respectively, of the test samples. The confidence of these joint estimates is computed, using the formula provided in Appendix A of OET BULLETIN No. 71.[1] We observe that all of these joint estimates have a 30% confidence, within 2%.

Scenario H2—highway—inside car, 30-40 mph (CDMA Summary)

Location 1	35–40 mph on NJ Highway 40 west from NJ Highway 55
Location 2	35–40 mph on NJ Highway 55 west from exit 20 off Garden State Parkway
Location 3	35–40 mph on DE Route 1 south from near Christiana, DE to about 10 miles north of Dover, DE, then from Milford, DE south towards Rehoboth Beach, DE
Fixes	97
67% error	31 m
95% error	1479 m

Scenario H3—highway—inside car, maximum speed (CDMA Summary)

Location 1	55 mph on NJ Highway 55 north from NJ Highway 49 to NJ Highway 40
Location 2	55 mph on Garden State Parkway from Cape May, NJ north towards NJ Highway 50
Location 3	55 mph on DE Route 1 south from Christiana, DE mall towards Dover, DE
Fixes	94
67% error	41 m
95% error	2338 m

Figure 1: 55 mph on Garden State Parkway from Cape May, NJ north towards NJ Highway 50

[1] OET BULLETIN No. 71: *Guidelines for Testing and Verifying the Accuracy of Wireless E911 Location Systems*, April 12, 2000; APPENDIX A: A Statistical Approach for Demonstrating Compliance for Empirical Testing.

Figure 2: 55 mph on NJ Highway 55 north from NJ Highway 49 to NJ Highway 40

Scenario H5—highway, near base station—inside car, stationary
(CDMA Summary)

Location 1	1. NJ Highway 40 (East Lake St.) near cell site 673 2. NJ Highway 40 near cell site 667 3. NJ Highway 50 about ½ mile from cell site 677
Location 2	1. NJ Highway 9 near cell site 674 2. NJ Highway 9 about 300 feet from cell site 682 3. NJ Highway 9 about ½ mile from cell site 633
Location 3	1. DE Route 1 between Milford, DE and Lewes, DE, going north and stopped near cell site 8102 2. DE Route 15 near cell site 887 3. DE Route 13 near cell site 881
Fixes	99
67% error	665 m
95% error	3241 m

(AMPS Summary)

Fixes	98
67% error	134 m
95% error	509 m

Figure 3: DE Route 1 between Milford, DE and Lewes, DE, going north and stopped near cell site 8102

Figure 4: DE Route 1 between Milford, DE and Lewes, DE, going north and stopped near cell site 8102

Figure 5: NJ Highway 40 (East Lake St.) near cell site 673

Figure 6: NJ Highway 40 (East Lake St.) near cell site 673

Figure 7: NJ Highway 40 near cell site 667

Figure 8: NJ Highway 9 near cell site 674

Figure 9: NJ Highway 9 near cell site 674

Figure 10: NJ Highway 9 about 300 feet from cell site 682

Figure 11: NJ Highway 9 about ½ mile from cell site 633

Figure 12: NJ Highway 9 about ½ mile from cell site 633

Scenario H6—highway, near base station—outdoor, stationary (CDMA Summary)

Location 1	1. NJ Highway 40 (East Lake St.) near cell site 673 2. NJ Highway 40 near cell site 667 3. NJ Highway 50 about ½ mile from cell site 677
Location 2	1. NJ Highway 9 near cell site 674 2. NJ Highway 9 about 300 feet from cell site 682 3. NJ Highway 9 about ½ mile from cell site 633
Location 3	1. DE Route 1 between Milford, DE and Lewes, DE, going north and stopped near cell site 8102 2. DE Route 15 near cell site 887 3. DE Route 13 near cell site 881
Fixes	99
67% error	492 m
95% error	22533 m

Figure 13: DE Route 1 between Milford, DE and Lewes, DE, going north and stopped near cell site 8102

Figure 14: DE Route 1 between Milford, DE and Lewes, DE, going north and stopped near cell site 8102

Figure 15: DE Route 1 between Milford, DE and Lewes, DE, going north and stopped near cell site 8102

Figure 16: NJ Highway 40 (East Lake St.) near cell site 673

Figure 17: NJ Highway 40 near cell site 667

Figure 18: NJ Highway 9 near cell site 674

Figure 19: NJ Highway 9 near cell site 674

Figure 20: NJ Highway 9 about 300 feet from cell site 682

Figure 21: NJ Highway 9 about ½ mile from cell site 633

Scenario H7—highway, away from base station—inside car, stationary
(CDMA Summary)

Location 1	1. NJ Highway 40 between cell sites 637 and 667 2. NJ Highway 55 between cell sites 667 and 666 3. NJ Highway 50 between cell sites 677 and 665
Location 2	1. NJ Highway 9 about 2 miles north of cell site 633, between cell sites 633 and 682 2. NJ Highway 9 between cell sites 682 and 633 3. NJ Highway 9 between cell sites 633 and 665
Location 3	1. DE Route 1 near Argos Corner, DE between cell sites 8102 and 887 2. DE Route 15 between cell sites 887 and 881 3. DE Route 13 between cell sites 881 and 828
Fixes	99
67% error	78 m
95% error	2330 m

(AMPS Summary)

Fixes	96
67% error	159 m
95% error	355 m

Figure 22: NJ Highway 55 between cell sites 667 and 666

Scenario H8—highway, away from base station—outdoor, stationary
(CDMA Summary)

Location 1	1. NJ Highway 40 between cell sites 637 and 667 2. NJ Highway 55 between cell sites 667 and 666 3. NJ Highway 50 between cell sites 677 and 665
Location 2	1. NJ Highway 9 about 2 miles north of cell site 633, between cell sites 633 and 682 2. NJ Highway 9 between cell sites 682 and 633 3. NJ Highway 9 between cell sites 633 and 665
Location 3	1. DE Route 1 near Argos Corner, DE between cell sites 8102 and 887 2. DE Route 15 between cell sites 887 and 881 3. DE Route 13 between cell sites 881 and 828
Fixes	98
67% error	62 m
95% error	156 m

Figure 23: NJ Highway 55 between cell sites 667 and 666

Figure 24: NJ Highway 9 between cell sites 633 and 665

Figure 25: NJ Highway 50 between cell sites 677 and 665

Scenario W1—boat within 2 miles of shore—outdoor, stationary (CDMA Summary)

Location 1 Location 2 Location 3	2–3 miles east of Slaughter Beach, DE 2 miles from shore near tip of peninsular land mass, south of Lewes Ferry Wharf, DE 1.7–2 miles from shore, just southwest of N. Cape May, NJ
Fixes	95
67% error 95% error	13 m 25 m

Figure 26: 2–3 miles east of Slaughter Beach, DE

Figure 27: 2 miles from shore near tip of peninsular land mass, south of Lewes Ferry Wharf, DE

Figure 28: 1.7–2 miles from shore, just southwest of N. Cape May, NJ

Scenario W2—boat within 2 miles of shore—outdoor, 5-20 kts (CDMA Summary)

Location 1	starting about 2 miles north of Slaughter Beach, DE and moving south toward Lewes, DE at about 15 knots, staying about 2–3 miles from shore
Location 2	starting from near Lewes Ferry Wharf, DE and moving north towards Slaughter Beach, DE at 15 knots, staying about 2 miles from shore
Location 3	starting southwest of N. Cape May, NJ and moving northeast at 15 knots, staying about 2 miles from shore
Fixes	95
67% error	16 m
95% error	63 m

Figure 29: starting about 2 miles north of Slaughter Beach, DE and moving south toward Lewes, DE at about 15 knots, staying about 2–3 miles from shore

Figure 30: starting from near Lewes Ferry Wharf, DE and moving north towards Slaughter Beach, DE at 15 knots, staying about 2 miles from shore

Figure 31: starting southwest of N. Cape May, NJ and moving northeast at 15 knots, staying about 2 miles from shore

Scenario W3—waterfront building, exterior room—indoor, stationary (CDMA Summary)

Location 1 Location 2 Location 3	new wooden house off Broadkill Beach Drive, DE new wooden house under construction, off Beach Avenue, Cape May, NJ Lewes Ferry Wharf Building, DE
Fixes	99
67% error 95% error	34 m 60 m

Figure 32: new wooden house under construction, off Beach Avenue, Cape May, NJ

Figure 33: new wooden house under construction, off Beach Avenue, Cape May, NJ

Scenario W4—waterfront building, interior room—indoor, stationary (CDMA Summary)

Location 1 Location 2 Location 3	new wooden house off Broadkill Beach Drive, DE new wooden house under construction, off Beach Avenue, Cape May, NJ Lewes Ferry Wharf Building, DE
Fixes	97
67% error 95% error	36 m 72 m

Figure 34: Lewes Ferry Wharf Building, DE

Figure 35: new wooden house off Broadkill Beach Drive, DE

Figure 36: new wooden house under construction, off Beach Avenue, Cape May, NJ

Figure 37: new wooden house under construction, off Beach Avenue, Cape May, NJ

Scenario W5—waterfront—outdoor, stationary (CDMA Summary)

Location 1 Location 2 Location 3	off Beach Drive, Slaughter Beach, DE next to sidewalk off 1041 Beach Avenue, Cape May, NJ off Bay Street, Lewes Beach, DE
Fixes	99
67% error 95% error	25 m 47 m

Figure 38: off Beach Drive, Slaughter Beach, DE

Figure 39: off Bay Street, Lewes Beach, DE

Figure 40: next to sidewalk off 1041 Beach Avenue, Cape May, NJ

Scenario W6—waterfront—inside car, stationary
(CDMA Summary)

Location 1 Location 2 Location 3	off Beach Drive, Slaughter Beach, DE next to sidewalk off 1041 Beach Avenue, Cape May, NJ off Bay Street, Lewes Beach, DE
Fixes	99
67% error 95% error	26 m 43 m

(AMPS Summary)

Fixes	99
67% error 95% error	84 m 189 m

Figure 41: off Beach Drive, Slaughter Beach, DE

Figure 42: off Bay Street, Lewes Beach, DE

Figure 43: next to sidewalk off 1041 Beach Avenue, Cape May, NJ

Scenario W7—waterfront—inside car, 20-40 mph (CDMA Summary)

Location 1 Location 2 Location 3	along Beach Drive at 20–30 mph, Slaughter Beach, DE along Beach Avenue at 20–30 mph, Cape May, NJ along beach drive at 20–30 mph, Lewes Ferry Wharf, DE and going west along beach
Fixes	96
67% error 95% error	24 m 73 m

Figure 44: along Beach Avenue at 20–30 mph, Cape May, NJ

3. Aggregated Performance Results

In this section, we aggregate the test results. In each instance, we show the estimated probability density function and cumulative distribution function, and provide estimates of the estimates of the 67th percentile and the 95th percentile.

Some of the aggregation is achieved simply by merging test data. This is done for sufficiently similar scenarios, and corresponds to giving both scenarios equal weight. In such cases, we are able to provide two estimates of the percentiles, with 30% and 90% confidence, respectively. The methodology is given above.

In other cases, the aggregation is performed by giving different weights to the constituents, in order to match more closely a realistic distribution of use of the wireless system. Here, the aggregation is performed by forming weighted averages of the two probability functions. In this case, the approach for estimating the confidence of the estimates is no longer available. The percentile estimates are read directly from the cumulative distribution function. Although the confidence of the joint estimates can no longer be calculated, we expect that it is still 30%, given that this is the confidence of the analogous estimates for all constituents. No 90% confidence estimates are available.

3.1 CDMA performance

We begin by aggregating the CDMA test data into four classes, as indicated in the following table. The table also provides the associated percentile estimates.

CDMA Test Data Classes

Aggregate Class	**Constituent Scenarios**	67% error	95% error
Water	W1, W2, W3, W4, W5, W6, W7	25 m	52 m
Highway moving	H2, H3	36 m	1479 m
Highway stationary, near cell site	H5, H6	549 m	4645 m
Highway stationary, not near cell site	H7, H8	69 m	512 m

These classes are in turn combined hierarchically. The two stationary CDMA classes are combined so as to give a 2.25% weight to the near cell site data, and 97.75% weight to the other data. These weights are intended to represent the relative areas near cell sites and the rest of coverage. For the region being tested, a given cell provides primary coverage for a radius of 4 miles, on the average. A test point, for purposes of the defined scenarios, was near to a cell site if it was within 1000 m. This is 15% of the average cell radius, and so the near-cell-site area is 2.25% of the total coverage.

Next, the moving CDMA class is combined with the stationary aggregate just defined to define a highway aggregate. The two are given equal weight, on the grounds that moving and stationary calls are approximately equally likely.

The following table summarizes the hierarchical aggregation of CDMA data, and provides associated percentile estimates. We will see from the figures below that these correspond to values read directly from the combined cumulative distribution functions. Because of the way in which the cumulative distribution functions were estimated, no percentile estimates larger than 500 m could be obtained. That is, an estimate of 500 m should be read as an estimate of at least 500 m.

Hierarchical Aggregation Of CDMA Highway Data

Aggregate Class	**Constituents**		67% error	95% error
Highway stationary	2.25% 97.75%	H5 & H6 H7 & H8	74 m	500 m
Highway, stationary and moving	50% 50%	H2 & H3 Stationary	54 m	500 m

We now give the estimated probability functions for all of these aggregates.

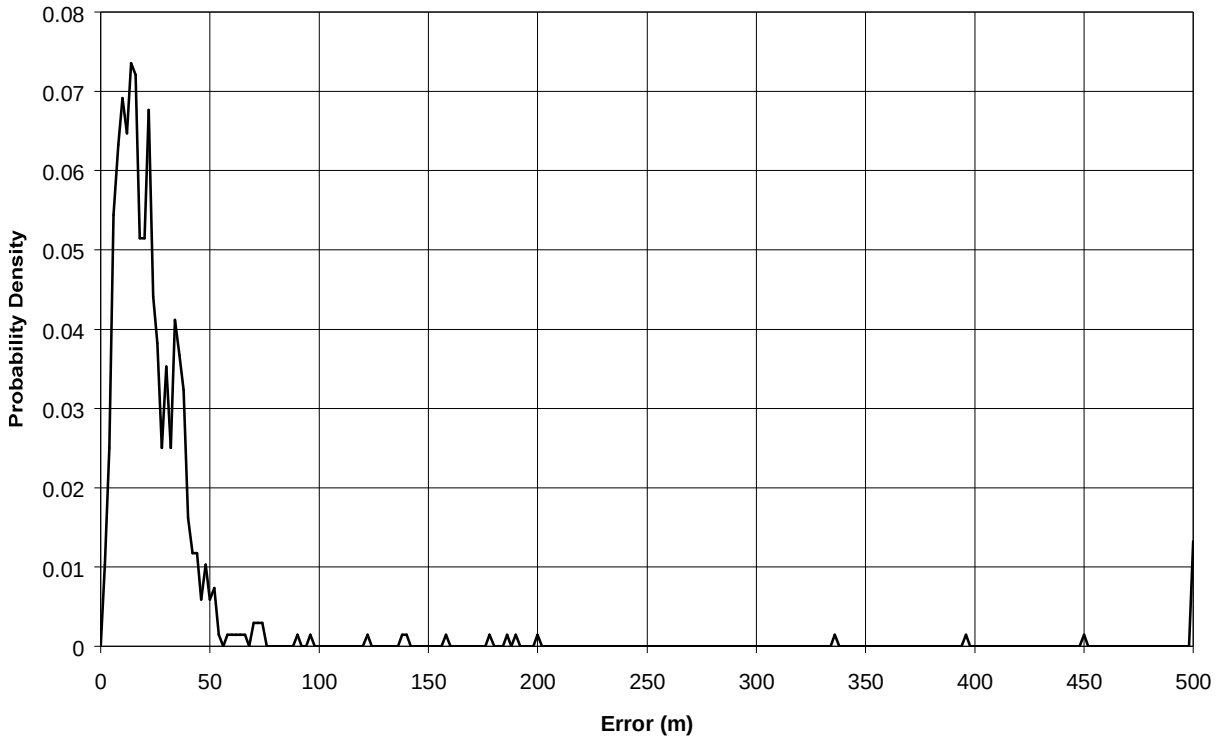

Figure 45: Probability Density Function for Location Error—CDMA Water

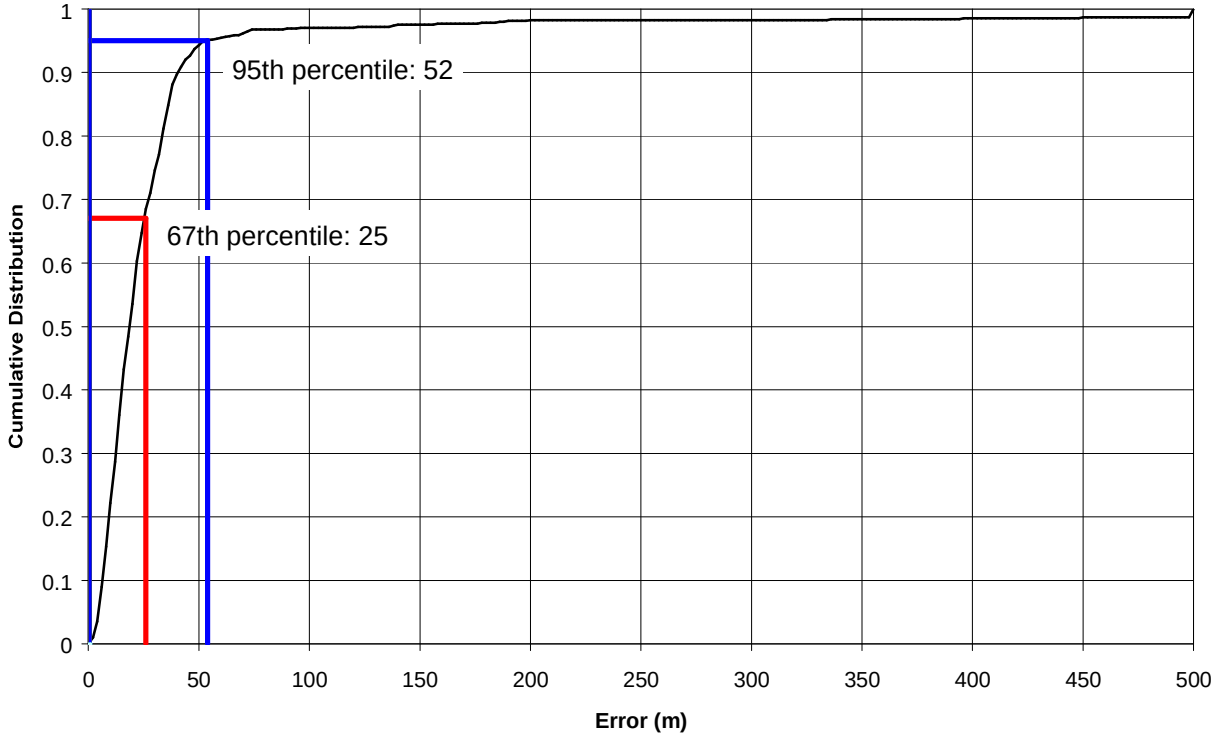

Figure 46: Cumulative Distribution Function for Location Error—CDMA Water

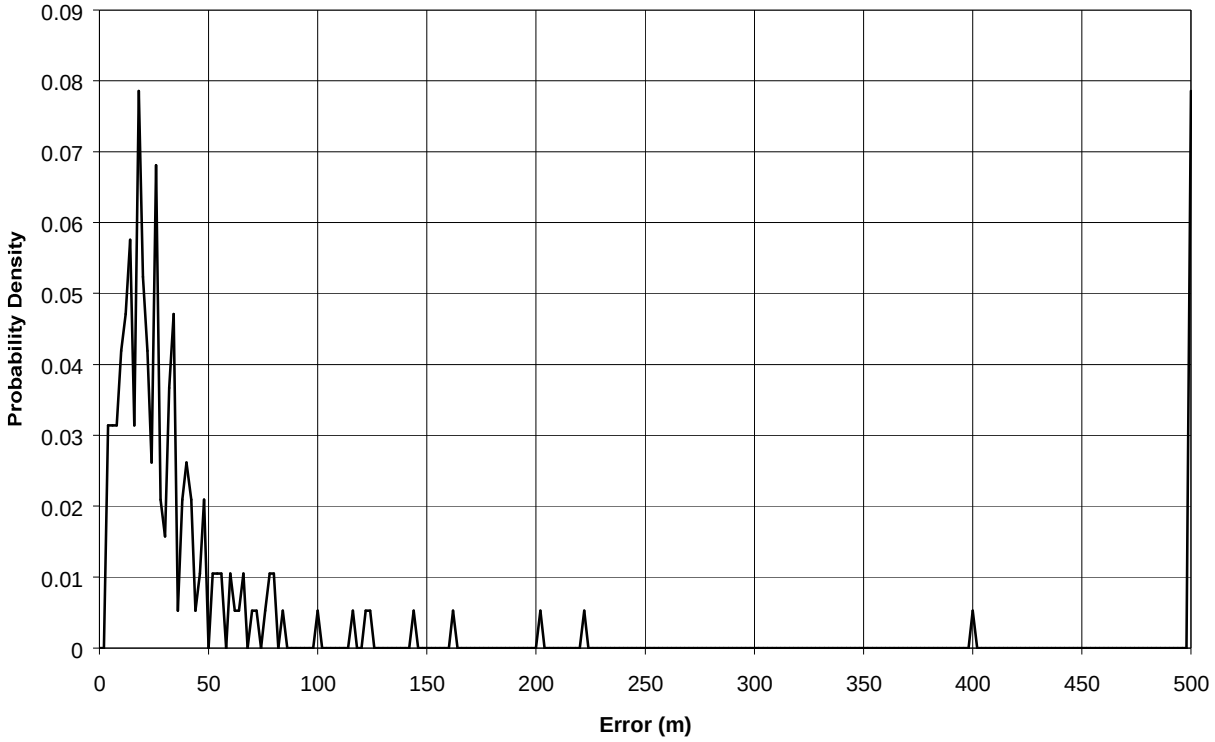

Figure 47: Probability Density Function for Location Error—CDMA Highway Moving

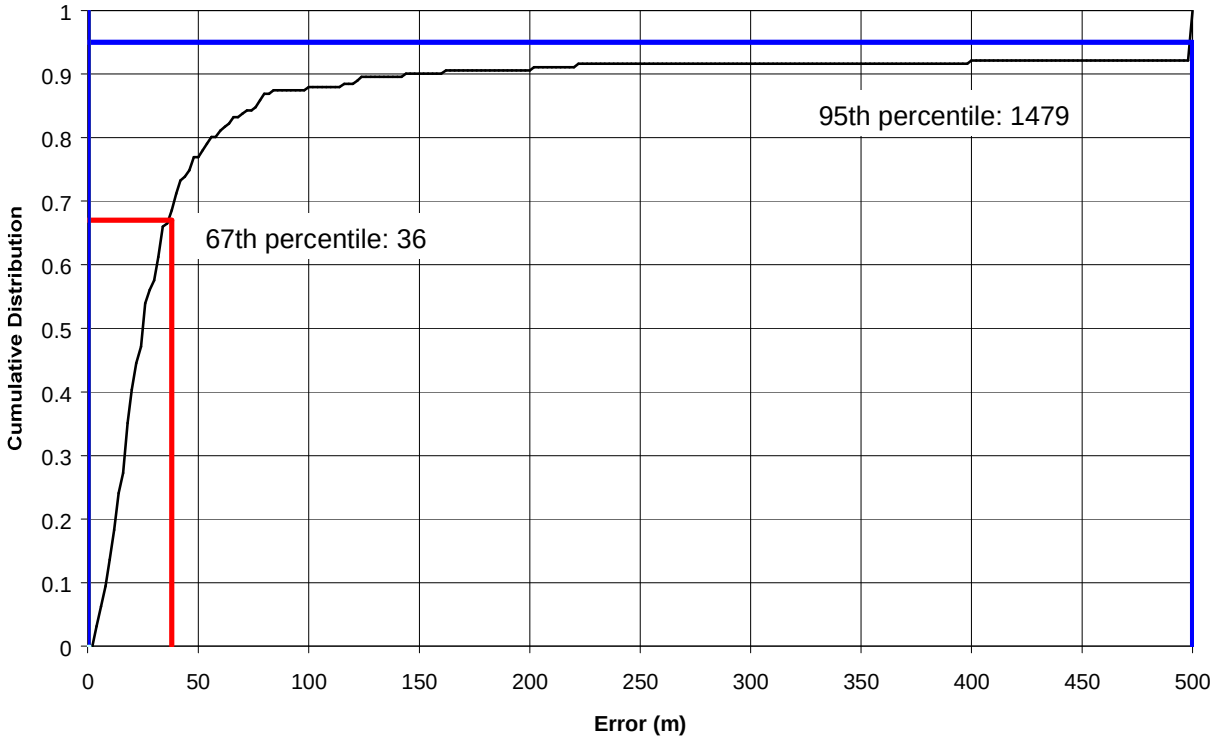

Figure 48: Cumulative Distribution Function for Location Error—CDMA Highway Moving

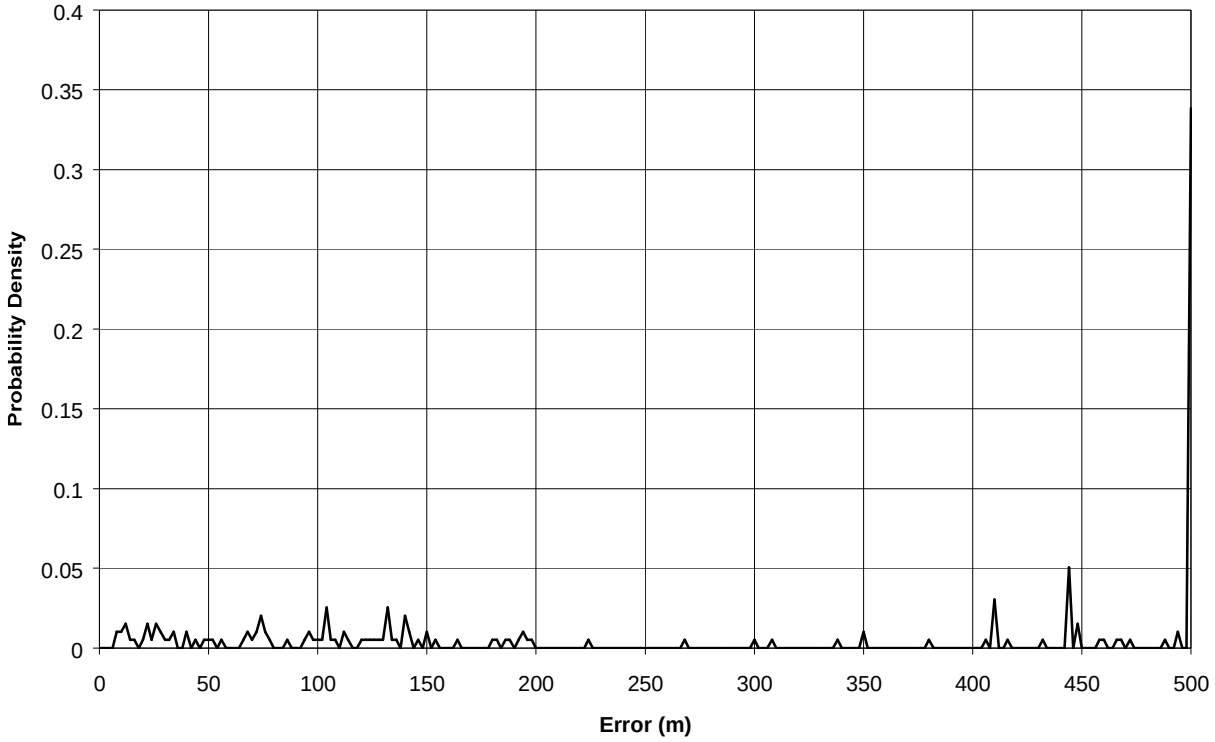

Figure 49: Probability Density Function for Location Error—CDMA Highway Stationary Near Cell Site

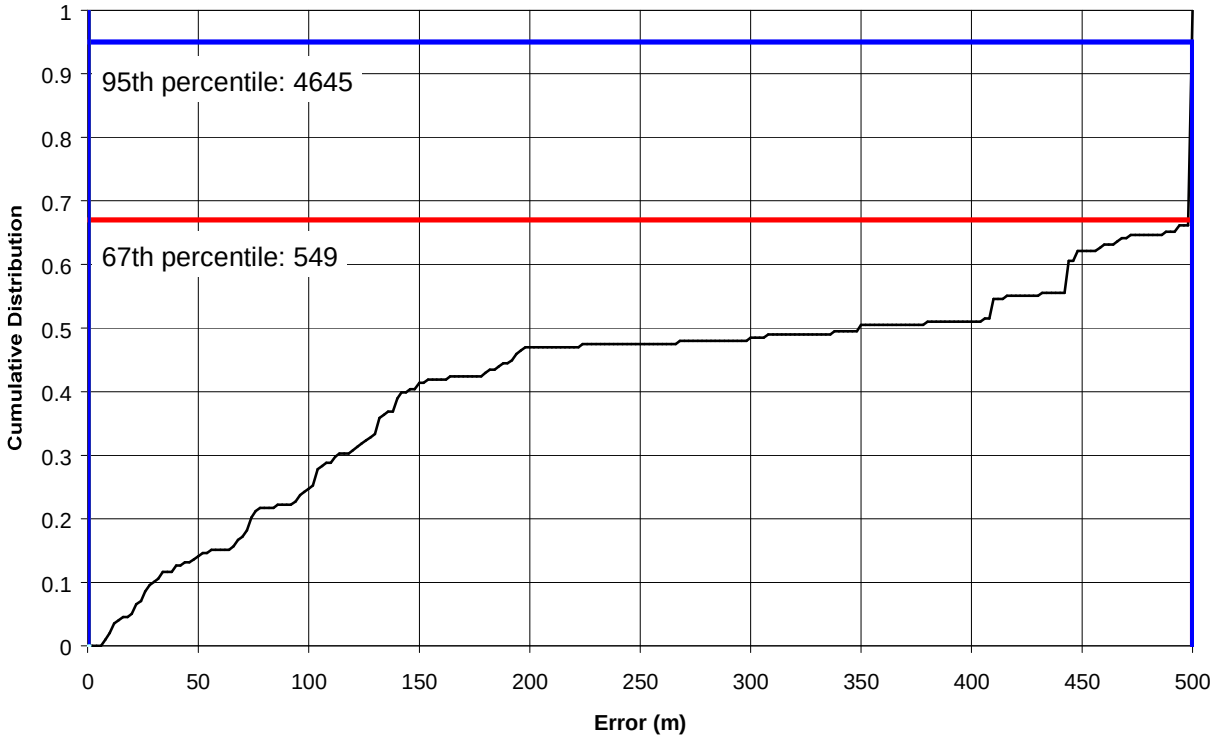

Figure 50: Cumulative Distribution Function for Location Error—CDMA Highway Stationary Near Cell Site

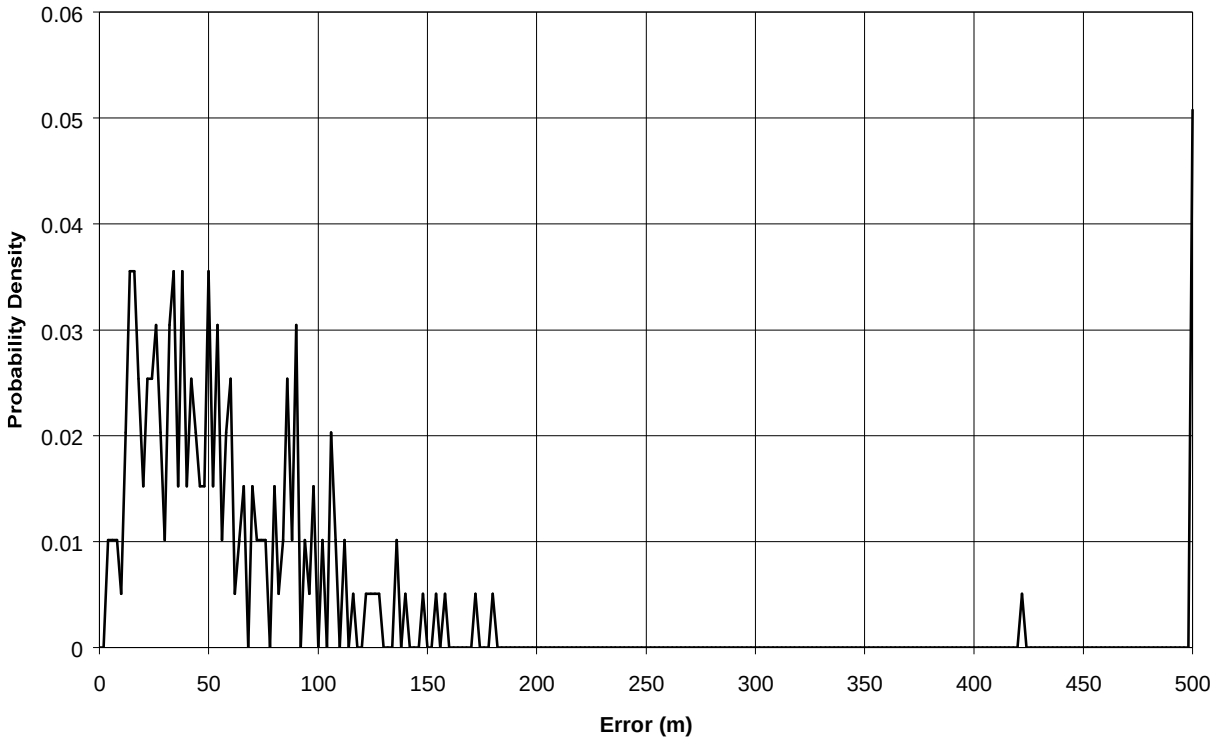

Figure 51: Probability Density Function for Location Error—CDMA Highway Stationary Far from Cell Site

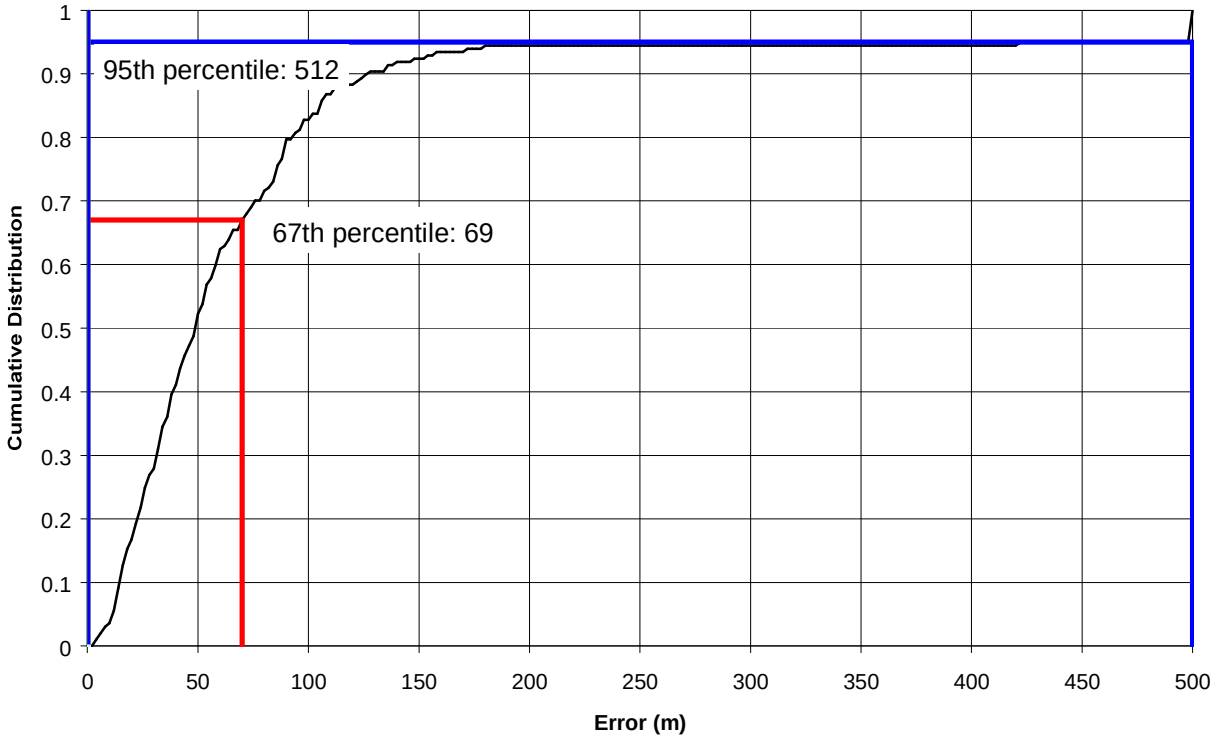

Figure 52: Cumulative Distribution Function for Location Error—CDMA Highway Stationary Far from Cell Site

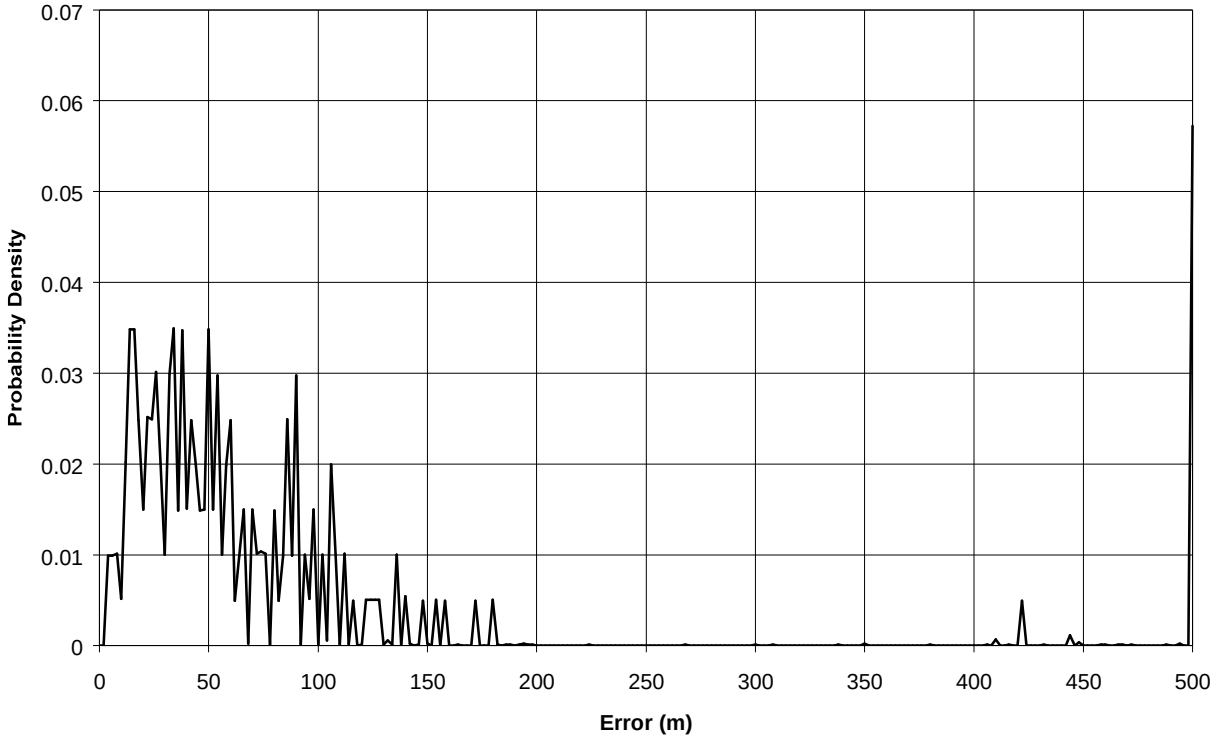

Figure 53: Probability Density Function for Location Error—CDMA Highway Stationary

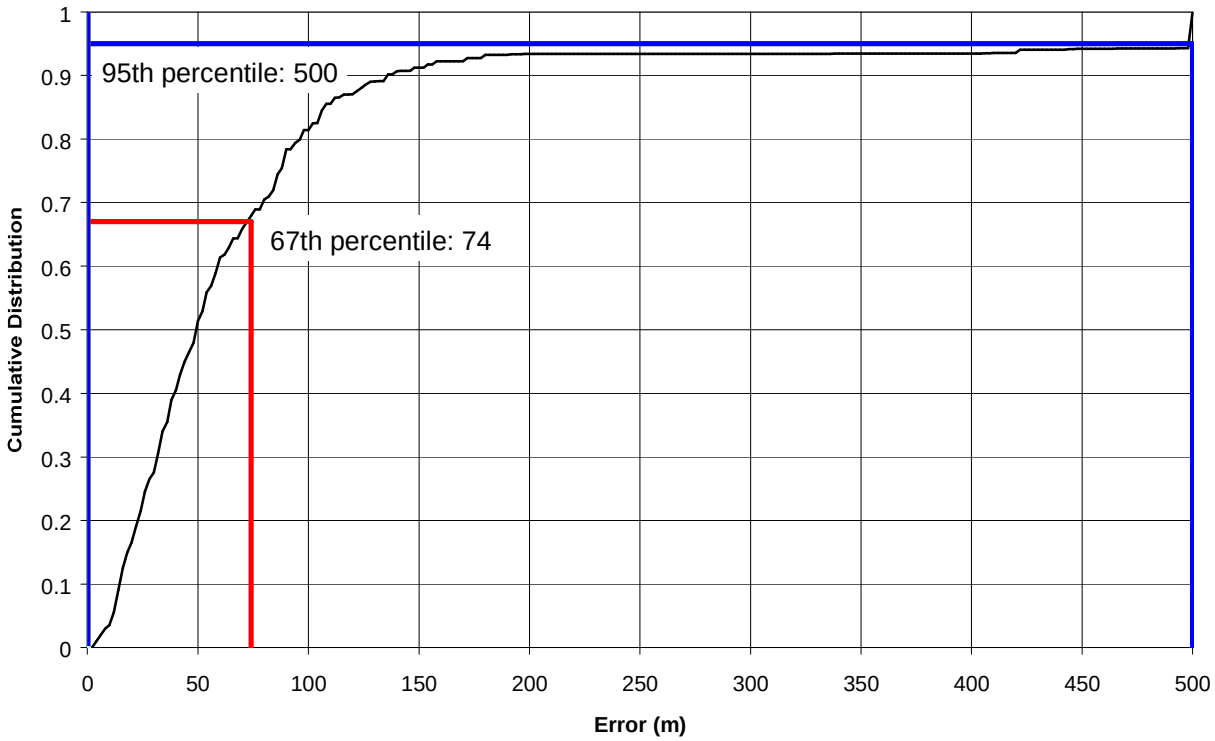

Figure 54: Cumulative Distribution Function for Location Error—CDMA Highway Stationary

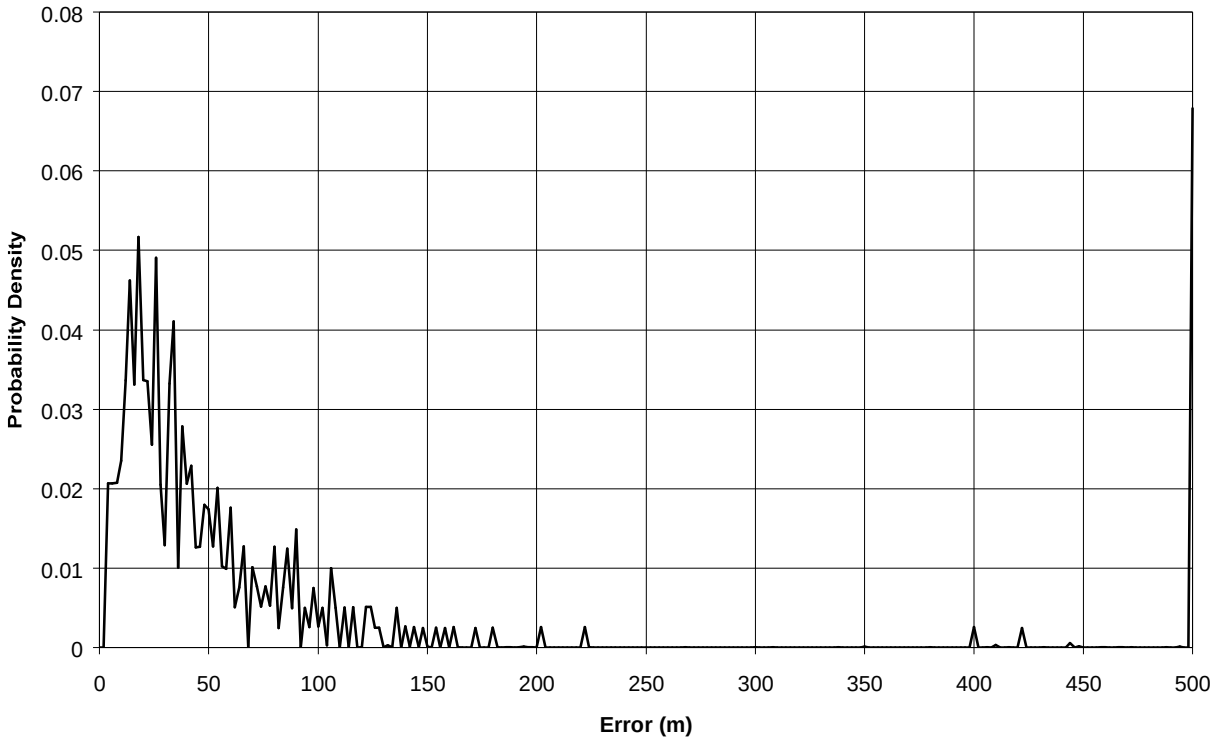

Figure 55: Probability Density Function for Location Error—CDMA Highway Stationary and Moving

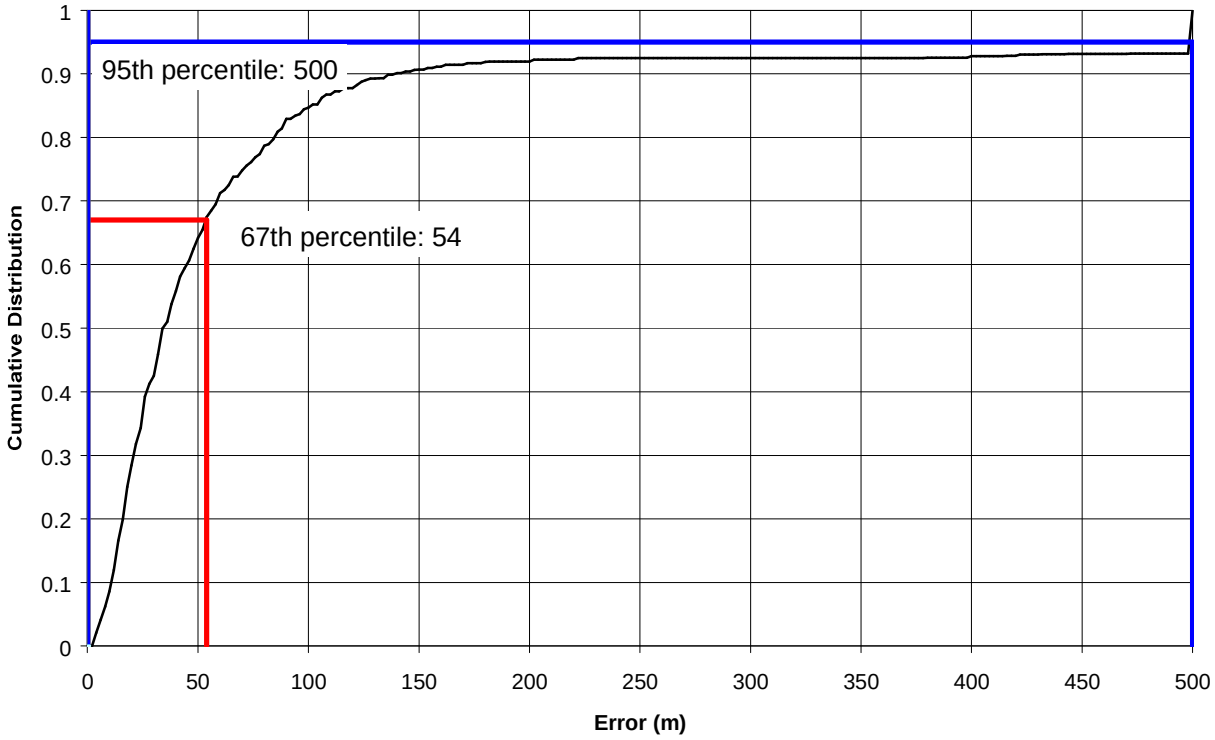

Figure 56: Cumulative Distribution Function for Location Error—CDMA Highway Stationary and Moving

3.2 Combined AMPS and CDMA performance

For three of the scenarios, AMPS test data was collected along with the CDMA data. This data was combined, by scenario, giving a 20% weight to the AMPS data and an 80% weight to the CDMA data. These weights are intended to reflect the approximate ratio of usage of the two technologies. The following table shows the summary performance. It is followed by the probability functions for each in turn.

Combined AMPS and CDMA Data

Scenario	67% error	95% error
H5	444 m	500 m
H7	88 m	500 m
W6	70 m	186 m

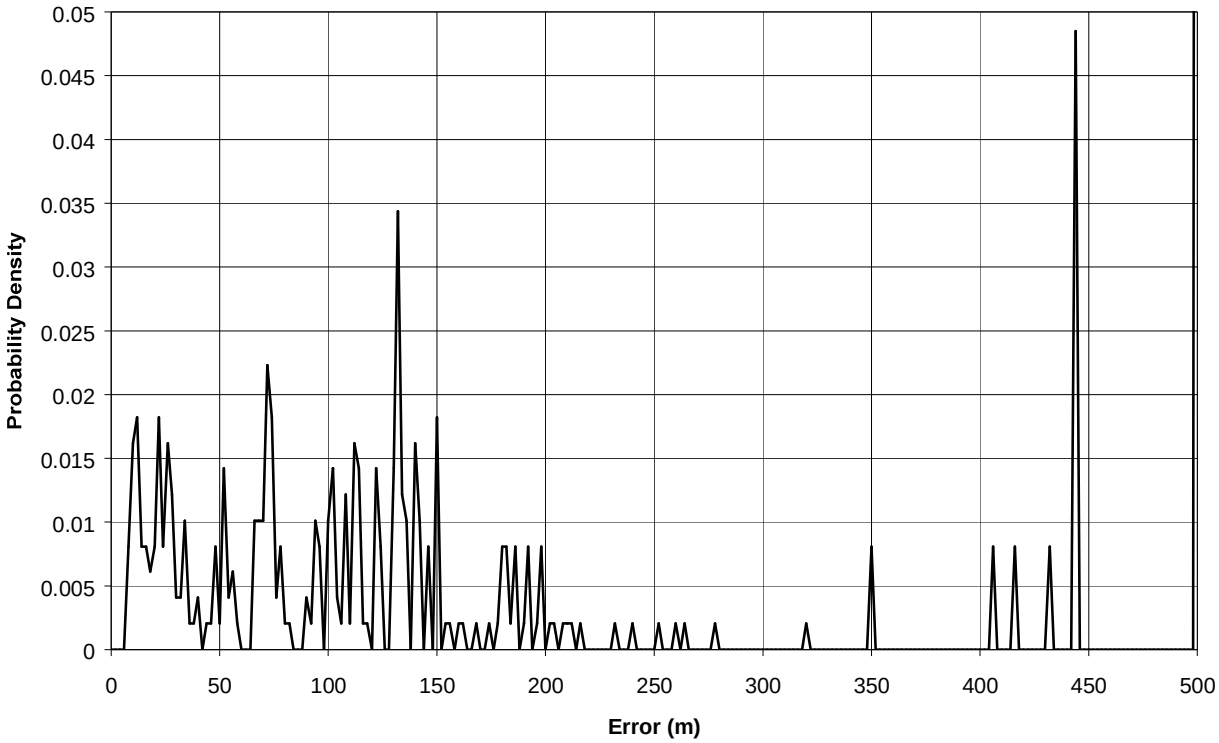

Figure 57: Probability Density Function for Location Error—AMPS & CDMA H5

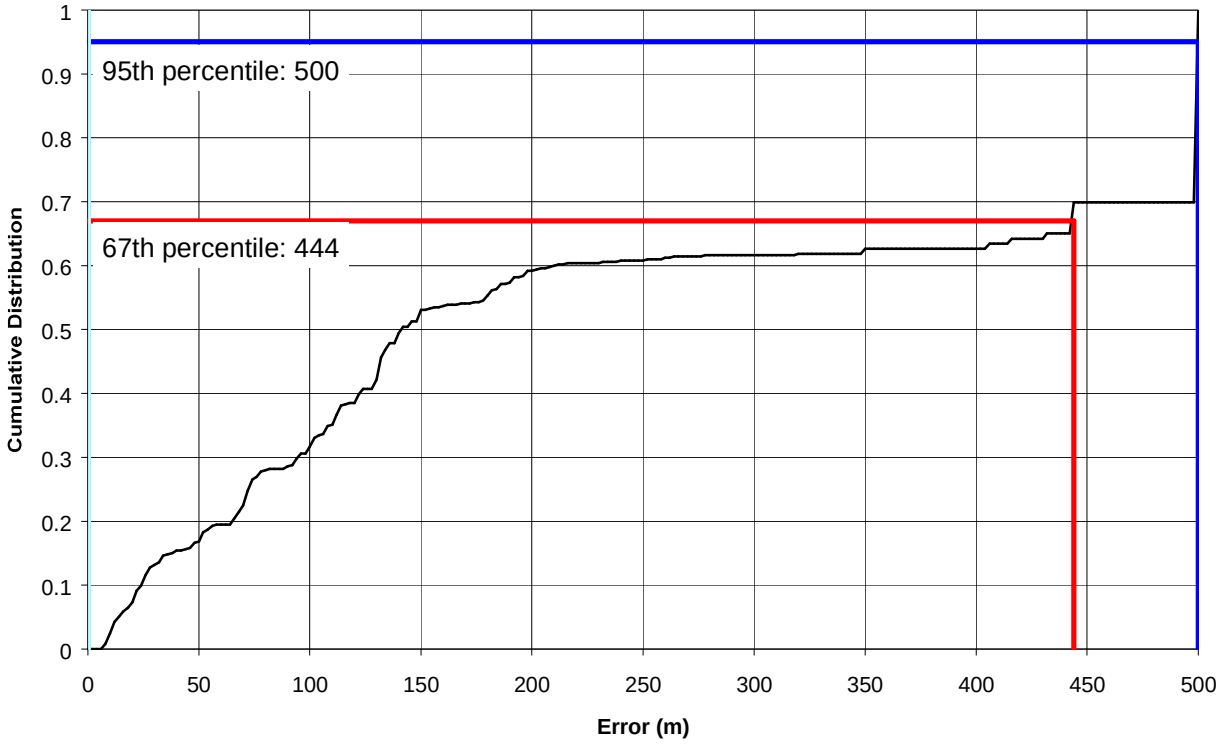

Figure 58: Cumulative Distribution Function for Location Error—AMPS & CDMA H5

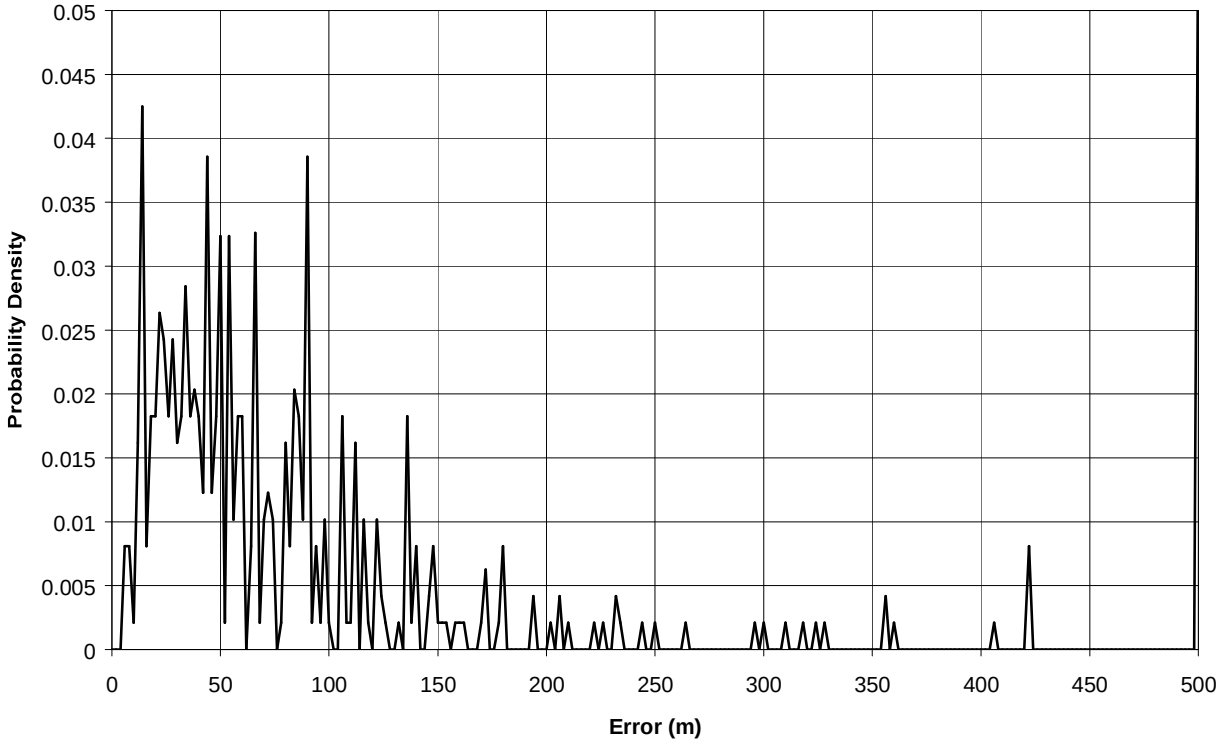

Figure 59: Probability Density Function for Location Error—AMPS & CDMA H7

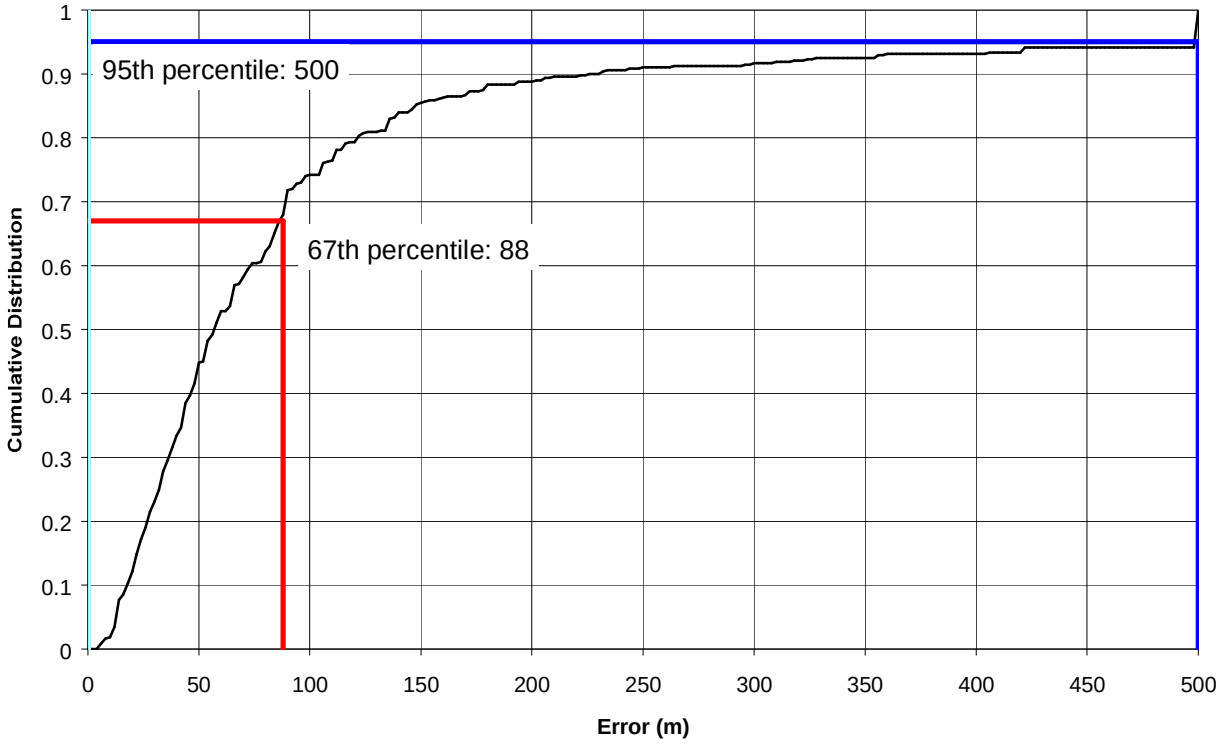

Figure 60: Cumulative Distribution Function for Location Error—AMPS & CDMA H7

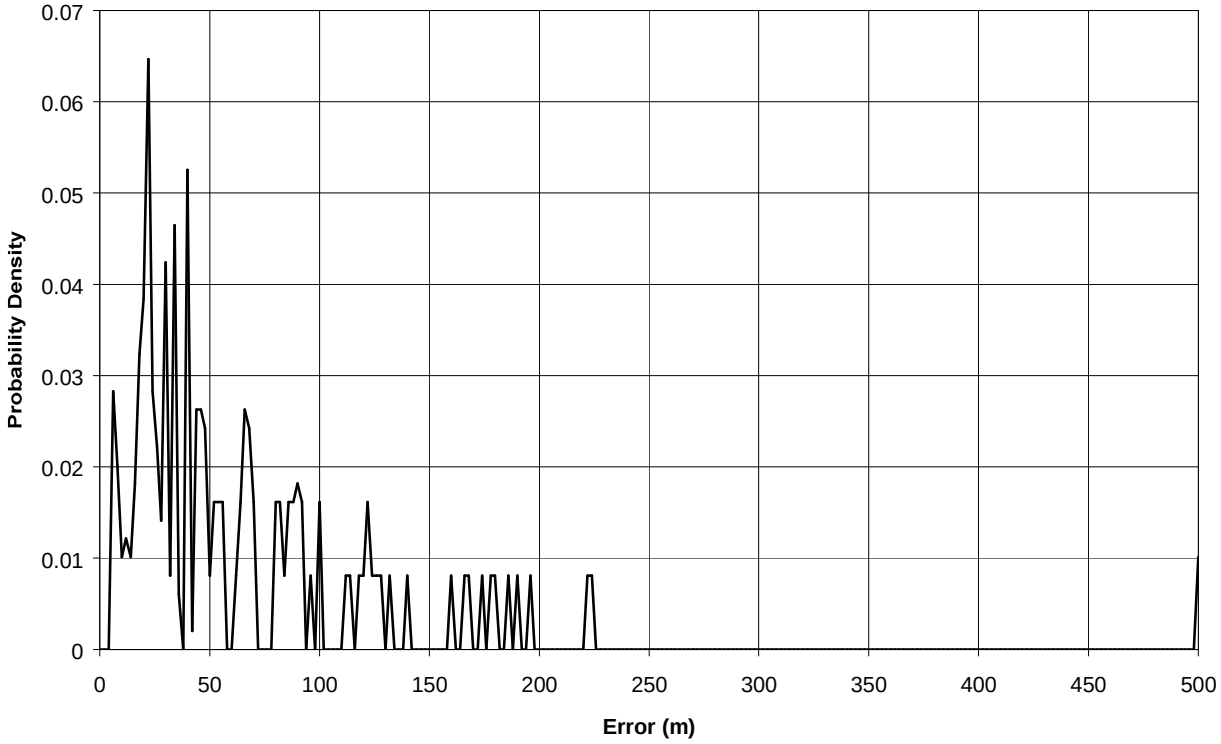

Figure 61: Probability Density Function for Location Error—AMPS & CDMA W6

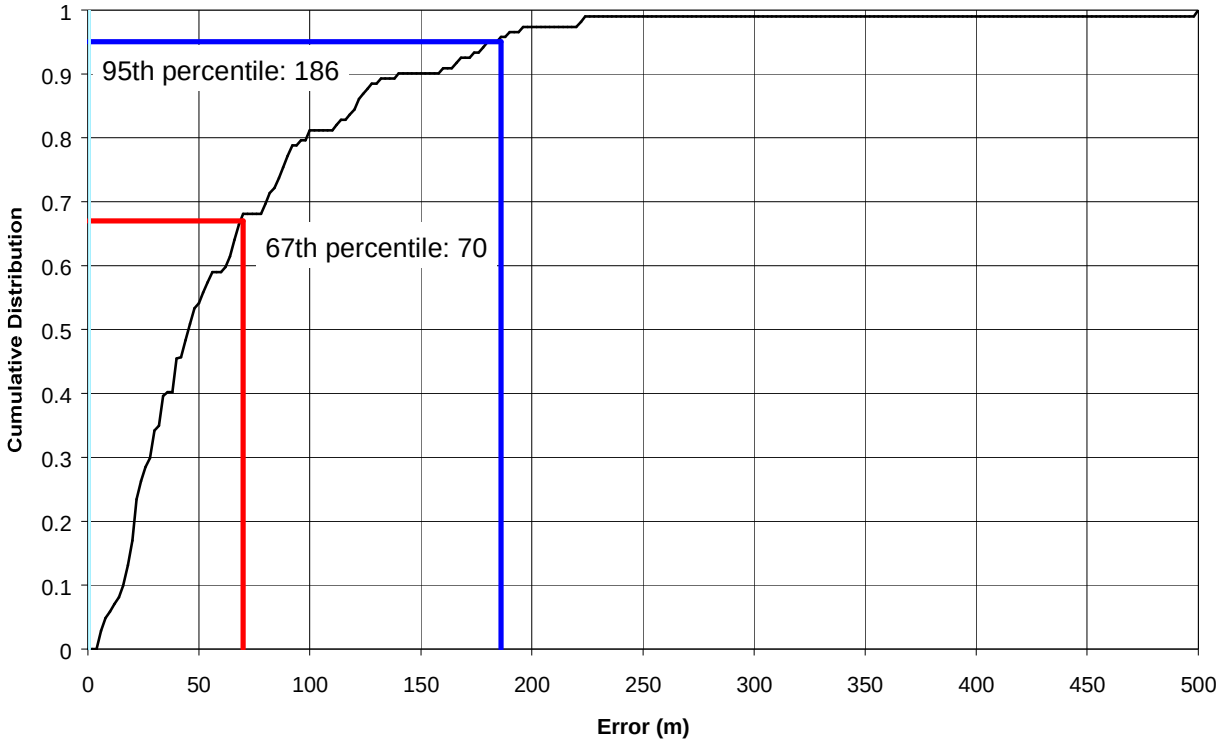

Figure 62: Cumulative Distribution Function for Location Error—AMPS & CDMA W6

4. Conclusion

At the request of Verizon Wireless, the Verizon Technology Organization (VTO) conducted a rigorous trial of the TruePosition geo-location system in the states of New Jersey and Delaware, around and within Delaware Bay.

The purpose of the trial was to assess compliance with the FCC requirement for Phase II E911 that a network-based geolocation system shall provide the location of a wireless 911 call with an accuracy of 100 meters 67% of the time and 300 meters 95% of the time. The focus of the trial was on water and highway scenarios. In the trial area the average distance between cell sites was 8 miles.

The CDMA Development Group (CDG) Test Plan was used as a basis for most of the tests. Seven water scenarios from the CDG Test Plan were tested, including on water as well as waterfront tests. Two highway scenarios from the CDG Test Plan were also tested, while moving at maximum highway speeds and while moving at 30 mph. In addition to the CDG scenarios, stationary highway tests were also performed, outdoors or from inside a car, near a cell site or far away from cell sites.

CDMA test calls were made for all the tested scenarios. AMPS test calls were also made for selected waterfront and highway scenarios in stationary mode. Analysis of the test results revealed the following:

- The TruePosition system responded very rapidly, even in very difficult situations where voice calls were problematic. This suggests that the OET Bulletin 71 guideline for getting a fix within 30 seconds of placing the call will not be an issue for this system.
- The overall location determination accuracy of the TruePosition System for the tested water scenarios for CDMA test calls was 25 meters for 67% of the time and 52 meters for 95% of the time, if no corresponding analysis on the statistical confidence is done. Even if one goes by the more strict guidelines of the OET Bulletin No. 71, which require a statistical confidence of 90% for the accuracy estimates, it was found that the accuracy is only slightly worse, but still well within the FCC mandate. Hence, the accuracy for the overall water class of scenarios is far better than expected, no matter whether we go by the broad interpretation of the FCC mandate or by the OET Bulletin 71 guidelines.
- The overall accuracy for the highway scenarios in CDMA mode was 54 meters for 67% of the time and over 500 meters for 95% of the time. This includes stationary and in-motion highway tests. It also includes tests near and far away of cell sites. As expected, the highest location errors occurred while testing near to cell sites. Thus, while the overall accuracy for the highway scenarios meets the FCC mandate for the 67th percentile, it does not meet the 95th percentile requirement.
- Analysis of the limited AMPS test cases also revealed compliance in locating AMPS calls for water tests and non-compliance for highway tests.

The VTO trial stressed the TruePosition system in an area where cell sites were 8 miles apart. In such cases, the ability to reliably detect signals from a mobile at non-serving cell sites is more challenging which makes accurate location determination difficult. It should be pointed out that for about 90% of the highway calls the accuracy was within 150 meters even though the 95th percentile was greater than 500 meters. This suggests that in such cases the statistics may improve if one performs the tests using a larger sample, both in the number of locations per scenario and in the number of calls.

On the other hand, we expect that such environments are not atypical, but rather representative of significant sections of the Verizon Wireless national footprint. As a result of VTO testing, TruePosition adjusted their algorithm to handle the assignment of weights to signals detected at cell sites with low SNR, and based on cell site spacing. Based on re-testing of their modifications subsequent to the VTO Trial, TruePosition informed VTO that such a scheme would improve the accuracy of their algorithm. This, combined with larger samples, is expected to significantly improve the 95th percentile performance.

VTO recommends an independent re-test of the TruePosition system in the same test area to verify improvements in the accuracy of the new algorithm. VTO also recommends limited testing of the TruePosition system in Manhattan to verify that the changes to the algorithm will not adversely affect urban accuracy.

Appendix A: TruePosition Comments

While testing the TruePosition geo-location system in the rural areas around the Delaware Bay VTO noted that the 95th percentile accuracy performance in the highway scenarios was not meeting the FCC's requirement of 300 meters. TruePosition was surprised by this result because extensive testing of the entire Phase 1 coverage area performed previously by TruePosition had indicated both the 67th percentile and 95th percentile accuracy performance were well within the FCC's requirements. After further analysis TruePosition determined the problem with the 95th percentile accuracy performance in the rural highway scenarios noted by VTO are caused by the following:

- The function used to establish the weighting of individual TDOA measurements used within a single location estimate was not adequately optimized to mitigate the negative effects of false detections on the 95th percentile accuracy performance.
- The algorithm used to factor power measurement data into the final location estimate was not conditioned to exclude the power measurements from sites where TDOA measurements had been down weighted.
- Several thresholds within the geo-location algorithms had been configured to optimize the accuracy performance in urban and suburban coverage areas.

As soon as these problems were identified TruePosition made changes to the geo-location algorithms to correct these problems. TruePosition then retested the same areas that had been tested by VTO. Significant improvements were realized in the 95th percentile accuracy performance in all of the cases but the moving scenarios (H2 and H3). These results are provided in the two tables below.

Table A1: CDMA Test Data Classes

Aggregate Class	Constituent Scenarios	Before Algorithm Improvements		After Algorithm Improvements	
		67% error	95% error	67% error	95% error
Water	W1, W2, W3, W4, W5, W6, W7	25 m	52 m	Not Retested	Not Retested
Highway moving	H2, H3	36 m	1479 m	**52 m**	**1664 m**
Highway stationary, near cell site	H5, H6	549 m	4645 m	**363 m**	**955 m**
Highway stationary, not near cell site	H7, H8	69 m	512 m	**72 m**	**156 m**

Table A2: Hierachical Aggregation Of CDMA Highway Data

Aggregate Class	Constituent Scenarios	Before Algorithm Improvements		After Algorithm Improvements	
		67% error	95% error	67% error	95% error
Highway stationary	2.25% H5 & H6 97.75% H7 & H8	74 m	500 m	**73 m**	**190 m**
Highway, stationary and moving	50% H2 & H3 50% Stationary	54 m	500 m	**62 m**	**540 m**

After further analysis of the moving scenarios, TruePosition has determined that the problem with the 95th percentile accuracy performance is caused by the same weighting function mentioned above not being optimized to mitigate the effects of fading in cases where the CDMA mobile being located is moving. TruePosition is in the process of making further improvements to the geo-location algorithms to address this problem. TruePosition will retest these same moving scenarios with the improved geo-location algorithms and will provide the results to VTO.

TruePosition believes the modifications described above will address the problem with the 95th percentile accuracy performance in the rural highway scenarios identified by VTO, and will result in the TruePosition system meeting the FCC's location accuracy requirements. In addition, TruePosition believes that the relatively small set of test points and test calls placed during VTO's testing may be inadequate to establish compliance with the FCC's 95th percentile accuracy requirement. During more extensive testing TruePosition has seen a significant variance in the 95th percentile accuracy performance in data sets

containing fewer than 75 independent test points and fewer than 2000 test calls. TruePosition suggests that VTO retest the rural highway scenario as soon as possible to independently verify these results and conclusion.

Although several optimizations have been made to address the problem with the 95th percentile accuracy performance in the rural highway scenarios, these optimizations have been implemented in a way as to be compatible with all types of scenarios. This has been accomplished by making the configuration of the weighting functions, thresholds and other heuristics within the geo-location algorithms a function of several criteria that can be determined dynamically on a location-by-location basis. In order to demonstrate this, data collected from testing previously performed in urban Manhattan, suburban King of Prussia, and rural New Jersey and Delaware were processed using the modified algorithms. These results are provided in the table below.

Table A3: Effect of Algorithm Improvements in Urban and Suburban Environments

Test Area	**Number of Calls**	**Before Algorithm Improvements**		**After Algorithm Improvements**	
		67% error	95% error	67% error	95% error
Phase 1 without Wilmington	4842	48 m	286 m	**48 m**	**184 m**
Manhattan	8095	82 m	232 m	**82 m**	**176 m**
King of Prussia	4701	64 m	230 m	**66 m**	**209 m**