TruePosition Indoor Test Report
Wilmington, DE

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Prepared By:

TechnoCom

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Executive Summary

TruePosition commissioned TechnoCom to perform indoor testing of its UTDOA and Hybrid AGPS/UTDOA location technology solutions in a manner analogous to the tests performed 18 months ago by TechnoCom for CSRIC III in the Bay Area. The indoor test campaign was performed in May 2014, in the Wilmington, Delaware area, where TruePosition has an existing deployment of its UTDOA network-based technology. The tests were very similar in their environment and settings to testing TechnoCom had performed for TruePosition in February/March 2013 and reported on to the FCC on March 28, 2013. The current campaign was broader in scope, including more buildings and test points, and tested the latest, improved technology from TruePosition.

The current tests focused on solutions for 3G technologies therefore some changes were made to the UTDOA technology as compared to the 2013 testing. In particular, the signals from the mobile handsets were located during High Speed Uplink Packet Access ("HSUPA") transmissions. These HSUPA signals result in a "powered-up" transmission from the handset, analogous to what is done in emergency voice calls on the GSM network. This entails a minor modification to the existing UMTS networks using features already in the standard. More specifically, features that already allow power control of the mobile for various reasons would need to be invoked to power-up the mobile for a brief period during 911 voice calls on 3G networks. The handsets used in the testing were regular off-the-shelf handsets. The AGPS capability was provided by a Samsung Galaxy S3 handset that supports AGPS and GLONASS operating normally through the AT&T E911 network but with the test calls routed to AT&T's PSAP simulator. The Hybrid computation was performed at TruePosition and the result was provided to TechnoCom in near real time. The Hybrid algorithm used the reported individual uncertainties of UTDOA and AGPS as an input to the hybrid location computation.

The testing comprised indoor testing in both the urban and suburban environments in Wilmington, DE and its surroundings. The methodology and procedures established during the CSRIC III testing were followed closely. Eight buildings of varying sizes, construction materials and use were selected by TechnoCom in each morphology. In total 62 test points were selected among the 16 buildings. All but one small suburban building had four test points in different parts of the building and at different depths from the outside world. 7 of the 16 buildings had been used in the 2013 testing by TechnoCom but only 10 of the 62 test points were used before. In all cases, the test buildings and test points remained anonymous to TruePosition until the conclusion of the testing and delivery of all results to TechnoCom.

The test configuration adopted in this testing had a yield of 100% by design. The Time to First Fix (TTFF) was driven by the delay to transfer the high data rate HSUPA signals over limited bandwidth backhaul lines and to process those signals was essentially fixed at 26 +/- 1 sec. for all calls. Both of these parameters were specific to the test setup and therefore did not enter into the evaluation presented in this report. Location accuracy and secondarily reported uncertainty are the focus of this report.

The improvement in location accuracy observed in the current testing compared to the March 2013 test results is quite evident for both UTDOA and Hybrid AGPS/UTDOA. Reductions in the 67th and 90th percentile location errors approximately in the 40 to 60 percent range are obtained under very similar morphology and test point conditions. The outcome is a current overall performance that readily meets the FCC's proposed location performance threshold for indoor wireless E911 at the 67th percentile. The demonstrated performance even comes very close to meeting the 50 meter threshold at 80%, which is intended for 5 years from adoption of the proposed rules.

Notably, a significant improvement in the indoor performance of the UTDOA component of the hybrid is demonstrated. The higher bandwidth waveform of WCDMA UMTS coupled with the powered-up HSUPA data session (emulating a powered-up emergency call from the handset) make possible the significant indoor UTDOA performance improvement. A relative improvement in the AGPS performance, albeit less significant, is also observed relative to the prior testing in Wilmington. This resulted in better availability of AGPS fixes in challenging deep indoor locations. Support of GLONASS by the Samsung Galaxy S3 handset likely contributed to better deep indoor availability. However, in

such deep indoor situations the UTDOA fix was very frequently superior in quality; i.e., lower in uncertainty and actual measured error, than the AGPS fix, and was the main location source used by the selection performed in the hybrid algorithm used by TruePosition.

The reported uncertainty of UTDOA at times did not provide an accurate reflection of the actual quality of the location fix, often underestimating the quality of the fix in challenging buildings. This, however, did not appear to have had material impact on the workings of the hybrid algorithm.

The results and findings of this Wilmington test report are provided to the FCC so it can consider them, along with the other sources of data, in formulating its plan of action on the pending Third FNPRM.

1 Introduction

1.1 Background

The FCC commissioned its third Communication, Security, Reliability and Interoperability Council (CSRIC III), specifically its Working Group 3 (WG3), to advise it on critical and timely issues related to wireless E911, including indoor wireless location accuracy for E911. Based on the CSRIC III findings and recommendations[1], the indoor E911 location accuracy standards recently proposed by the FCC in its Third Further Notice of Proposed Rule Making (FNPRM)[2] would require the wireless carriers to locate indoor wireless callers within 50 meters 67 percent of the time within two years and 80 percent of the time within five years of the effective date of adoption of its rules.

Fully cognizant of the importance of indoor location performance in support of E911, and to provide the FCC with timely information on the achievability of the proposed standards, TruePosition once again decided to independently carry out an indoor testing campaign that is as similar and equivalent as possible to the indoor testing that was performed by CSRIC III in the Bay Area.

This report presents a summary of this indoor testing effort in Wilmington and the associated indoor location performance results of TruePosition's Hybrid AGPS/UTDOA technology, which is a combination of two well established, widely deployed technologies.

1.2 Similarity to CSRIC III Indoor Testing

To obtain location performance results that are analogous to those obtained for the technologies tested in the CRSIC III test bed, which is currently viewed to represent the consensus standard testing approach and benchmark, a very similar test process was followed.

One of the key principles of the CSRIC test bed was to provide the FCC with objectively derived, independently collected test results. Two fundamental aspects to ensure this were attained by: (1) using a credible, independent, and neutral test house to perform the testing, and (2) maintaining test point anonymity, where the technology participants do not have an influence on where specifically or under what indoor conditions the tests are performed.

These basic principles were fully adopted by TruePosition in both the testing campaigns performed in March 2013 as well as currently. Moreover, to insure the maximum adherence to the details of the testing processes followed for CSRIC III, the same independent test house used by CSRIC III was retained to perform the tests in Wilmington on both occasions. Furthermore, the same test methodology in representative morphologies was adopted, including the detailed aspects of testing, which mirrored the test process employed in the Bay Area in late 2012. To the extent possible, the test environments chosen in the Wilmington area attempted to duplicate the indoor environments examined in the Bay Area. The test point selection followed similarly rigorous and demanding selection criteria mirroring the criteria used in the CSRIC indoor test bed.

1.3 Independent Test House

Since its inception in 1995, TechnoCom has been providing its engineering expertise to a host of location technology companies and wireless carriers evaluating and subsequently deploying some of those technologies. Throughout its history, TechnoCom has opted to take a location technology vendor independent approach to its E911 quality of service assurance and testing business.

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[1] CSRIC III Working Group 3: "Indoor Location Test Bed Report," March 14, 2013.

[2] FCC Third Further Notice of Proposed Rule Making, Adopted February 20, 2014, published in Federal Register Vol. 79, No. 60, March 28, 2014

Over the last decade, TechnoCom has also been a key player in the development and adoption of industry standard E911 testing methodologies. Notably, TechnoCom was a lead contributor in the development of the indoor testing methodology within ATIS's ESIF (embodied in ATIS-0500013), which is the methodology that was adopted by CSRIC III WG3 as the basis for indoor testing within its Bay Area test bed, and more recently recommended as the preferred test methodology by CSRIC IV WG1, as well as proposed by the FCC as a possible basis for accuracy compliance testing of indoor E911 location.

TechnoCom brought to the current Wilmington indoor tests its highly detailed experience performing the indoor testing and reporting for CSRIC III WG3 as well as multiple subsequent indoor location technology evaluation campaigns using the same methodology, including for TruePosition in Wilmington, DE in March 2013. Throughout the testing, TechnoCom has strived to duplicate, to the extent possible, the environments and test scenarios encountered and selected during the Bay Area CSRIC III testing.

1.4 Scope of Report

This report contains the results of the indoor testing performed by TechnoCom on behalf of TruePosition in the Wilmington area in May 2014. To cast the results in the proper context and highlight the similarity with the CSRIC III test bed in the San Francisco Bay Area, sections that concisely describe the methodology, scope of testing, test criteria, and test execution are provided. These are followed by descriptions of the representative environments (morphologies) in which the testing took place along with the specific buildings selected for inclusion in the Wilmington testing. This provides a reference framework to interpret the results which are subsequently presented. For the reader's convenience, the various results are provided in summary tabular and graphic forms. The results are first aggregated for the entire test area, followed by morphology, and then presented aggregated per building within each morphology. This sheds light on the performance differences between distinct types of buildings within each broadly defined environment. For the interested reader, more detailed results for each of the 62 test points are provided in two appendixes attached to this document, one for UTDOA performance and the other of Hybrid AGPS/UTDOA performance. Concise observations and conclusions based on the various results are also included in this report to aid the reader in interpreting the results.

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2 Test Approach

2.1 Representative Morphologies (Use Environments)

As mentioned in the Introduction, the Wilmington indoor testing for TruePosition followed the same methodology used for CSRIC III in the San Francisco Bay Area. This included the same morphology to test point logical flow down as shown in Figure 2.1-1.

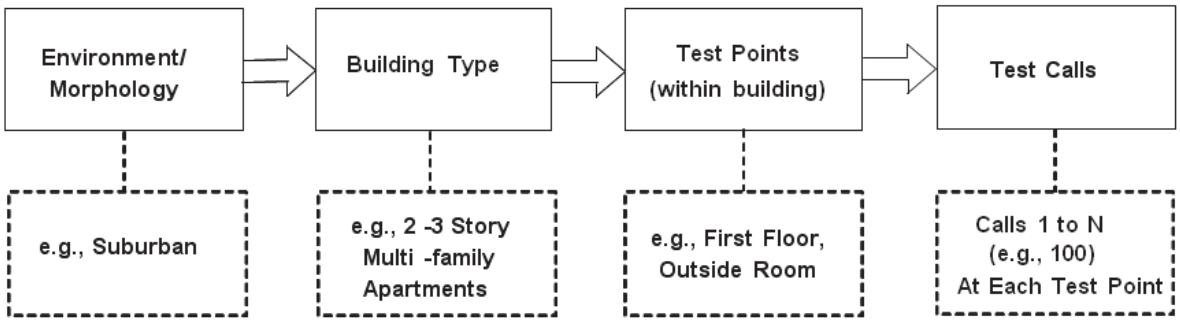

Figure 2.1-1. Morphology, Building and Test Point Flow Down

In each morphology (i.e., broad wireless use environment) a number of buildings of different sizes and types common in that morphology were identified. Within each building different test points were selected to represent the range of conditions encountered within that building.

In contrast to the greater Bay Area where representative polygons were identified for all four basic morphologies, namely, dense urban, urban, suburban, and rural, only urban and suburban polygons were suitable for identification in the Wilmington area. This will be described further below in Section 5 presenting the detailed test environments

In aggregate, 16 buildings equally spanning the two distinct morphologies (urban and suburban) were attained with a good spectrum of building types, construction materials, and settings. 8 buildings per morphology is actually more than what was used in the Bay Area, and resulted in a solid characterization of the technology under test sampled throughout the Wilmington area. This number of buildings was complemented by a sizeable number of test points (62) over a wide range of indoor test scenarios inside those buildings. The result is a broadly representative sample of indoor performance in the urban and suburban environments.

All buildings except for one small suburban building had 4 test points, and those were distributed in different parts of the building and with different degrees of depth from the outside world including the sky. At each test point a statistically significant number of independent test calls (75 in the current testing as discussed in Section 2.3) was placed from the test handsets

2.2 Anonymous Test Buildings and Test Points

TechnoCom independently performed the tasks of test building identification and test point selection. At no time until the delivery of the report did TruePosition know the test buildings, the indoor test scenarios chosen or the specific test points. TruePosition, however, did have access to daily logs of location system obtained fixes, which it forwarded to TechnoCom on a daily basis. This is a process identical to that adopted in the CSRIC indoor testing in the Bay Area.

2.3 Statistically Significant Samples

Indoor location performance can suffer from rapid changes in signal conditions and can experience significant performance variation from call to call even within a short period of time. It is therefore necessary to use a large enough sample of independent calls at each test point to arrive at reliable (statistically significant) performance statistics. The consensus adopted by WG3 for the CSRIC III testing was a minimum sample size of 100 test calls per technology per test point. The same was used in the prior testing in Wilmington in 2013.

The TruePosition system under test for UMTS required the use of high data rate HSUPA wireless data sessions to emulate the power-up condition that would be expected in a commercial E911 voice implementation (e.g., as widely used in commercial 2G). Although the CSRIC III testing used a sample of 100 test calls per test point (which was not always attained), the real time wireless data network loading in Wilmington caused varying delays in establishing the required high data rate HSUPA sessions (see Section 4.4). These network induced delays necessitated a small reduction in the sample size from 100 to 75 test calls per point to ensure that the vast majority of test buildings were completed within a single day of testing. It was decided that a slightly smaller number of calls would be a better option than a fewer number of test points (than 4) per building or a fewer number of buildings overall. As the results in subsequent sections will bear, no compromise in the statistical stability of the results was observed with the TruePosition technology under test[3].

2.4 Accurate, Reliable Indoor Ground Truths

To match the high ground truth accuracy adopted in the CSRIC III test bed as a benchmark, a professional survey company was retained by TechnoCom in this test campaign. A local certified land surveying vendor from the Wilmington Area was contracted to perform precise ground truth surveys for the test point selected by TechnoCom's senior engineers. This ensured the highest quality and reliability in comparing the test call results to the actual ground truths of the selected test points.

The survey information provided by the vendor included latitude, longitude and height. The certified accuracy is +/-5 cm in the horizontal or vertical directions, which is much better than the minimum needed for indoor wireless E911 applications. The survey method and equipment are described in Section 4.2, along with a sample survey ground truth output measurement.

2.5 Performance Attributes Analyzed

2.5.1 Location Accuracy

The error in estimating the location of the TruePosition device under test was computed by comparing its reported horizontal position (provided to TechnoCom) to the surveyed ground truth position of the test location (determined through the precise survey). Each test call was assumed to be independent from prior calls and accuracy was based on the computed location coordinates, whether UTDOA or hybrid AGPS/UTDOA, delivered by the TruePosition system in logs to TechnoCom in near real time.

The accuracy results are presented in Section 6 where an overall summary is presented first, followed by the results summarized by building and aggregated by morphology. In Section 7 more detailed results are presented for each building within the two morphologies. The accuracy statistics are provided for both UTDOA and hybrid AGPS/UTDOA. The former fix would normally be available within a few seconds from call setup and be used for call routing to the proper PSAP; the latter would be available within the 30 second window and be available to the PSAP upon a rebid.

[3] This statement about the stability of the statistical sample cannot be generalized for any arbitrary indoor location technology under test.

The accuracy results provided in tabular form include the 67th, 80th and 90th percentiles of horizontal accuracy, the standard deviation of error, and minimum and maximum errors, all in meters. In addition, the error CDF is also provided for each technology aggregated by morphology in Section 6 and for each building in Section 7. More detailed accuracy results for each of the 62 test points are provided in the two appendixes, one for UTDOA and one for Hybrid.

2.5.2 Latency (TTFF)

The Time to First Fix (TTFF) or the time to obtain the first computed caller location is reported only in summary fashion, since by the design of the test it is centered around 26 seconds +/- 1 second, driven by the time necessary to transport over the backhaul and process the HSUPA data stream emulating the powered-up voice call.

2.5.3 Yield

Yield is not presented in tabular form because it is by the necessity for the design of the test 100%. If no valid high data rate HSUPA session is possible, the corresponding (time matched) AGPS fix is discarded. On the other hand, for all UTDOA fixes there are AGPS fixes from the AT&T network, which could well be RTT fallback fixes if not a pure GPS (or GNSS) fix is possible. Likewise, TruePosition's UTDOA solution always returns an estimated position even if there are insufficient number of LMU measurements to generate a complete multilateration fix. Hence in all cases the yield is 100% by design.

2.5.4 Reported Uncertainty

The uncertainty reported by the location system for both the UTDOA and Hybrid AGPS/UTDOA is also presented. The uncertainty plays an important role in the hybrid algorithm and its reliability as a measure of location fidelity is therefore important. The reported uncertainty at each test point (corresponding to a nominal 90% confidence) is compared to the fraction of calls for which the resulting (empirically measured) location falls inside the uncertainty circle. The ideal number would be 90% of the calls have an actual error that causes the reported locations to fall inside the reported uncertainty circle. In general, the quality of the uncertainty measure reflects how well a location system is operating. The uncertainty results are also aggregated by building and morphology.

2.5.5 Location Scatter

To provide the reader with added insight into the qualitative indoor performance of the UTDOA and Hybrid location technology tested in the different environments, to aid in discerning possible effects of specific structural features at certain test points, to place observed error distances in the proper indoor perspective, and finally to provide a qualitative means for historical comparison, scatter diagrams have been prepared and provided for each building in Section 7. The location scatter results are overlaid on the building landscape, e.g., from Google Earth imagery, and the resulting fix clusters for all the test points in a given building are shown in the scatter diagram for that building.

3 TruePosition's Location Technologies Tested

The hybrid technology solution tested from TruePosition contained two components: Uplink Time Difference of Arrival (UTDOA) and AGPS[4]. The Hybrid solution was based on a selection of the better of the two solutions (UTDOA and GPS [GNSS more broadly]), based on their respective uncertainties. To ensure that the system under test closely modeled the behavior of the final 3G E911 system, TruePosition devised a method that utilizes High-Speed Uplink Packet Access (HSUPA) sessions to establish a higher handset transmit power, emulating the transmit power of a powered-up voice call placing a 911 call. In this test system, the UTDOA location is utilized as the response for the initial location bid (e.g., for PSAP call routing) followed by the Hybrid location which would be provided when a PSAP requests a rebid. The Hybrid algorithm time matches the locations generated from the UTDOA and AGPS and selects the best one to produce a hybrid location based on the latitude, longitude, uncertainty, and confidence level reported by each method.

3.1 UTDOA

U-TDOA is the widely deployed network-based multilateration solution from TruePosition. UTDOA determines location based on the time it takes a signal to travel from a mobile phone to a number of sensitive, well calibrated receivers called Location Measurement Units (LMUs). The LMUs are often placed at cell sites for logistical and engineering convenience. With existing 2G networks, the transmit power utilized during the first few seconds of a 911 call is at the maximum allowed power. A similar technique can be implemented by 3G network providers.

The UTDOA portion of the test setup uses a standard handset running a script that sets up a concurrent voice call to an HSUPA session by dialing a test number and uploading a file to an FTP server in parallel. HSUPA sessions in 3G networks allocate additional bandwidth to the mobile by using smaller spreading factors, which in turn require higher received power to be properly demodulated. Performing UTDOA locations on these higher power HSUPA sessions simulates the accuracy performance that would be achieved with power-up of the mobile during 911 voice calls on 3G networks, similar to what is currently done in 2G networks.

A network monitoring probe detects the initiation of the HSUPA session and triggers a UTDOA location to be performed for that session. The computed location is then sent to a server to be combined with the location received for the other location technology, AGPS.

3.2 AGPS

The AGPS portion of the setup uses, a standard smartphone handset equipped with a specially configured SIM card on ATT's 3G network. A script on the handset periodically dials a series of 911 calls. This triggers standards-based control-plane AGPS location transactions as would normally occur for real 911 calls on the 3G network. Accordingly, the AGPS fixes on successive test calls are in a warm fix mode where previous location fix information is not utilized in the current fix. Both the call and the associated location are directed to a PSAP Simulator rather than a live PSAP based on the specially configured SIM card.

3.3 Devices Tested

Two off-the-shelf and unmodified handsets were used in testing the TruePosition Hybrid solution:

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[4] In this report AGPS is used as a common shorthand notation to indicate assisted GPS + GLONASS

1. Samsung Galaxy S3

   This handset supported the AGPS portion of the setup. The Samsung Galaxy S3, uses a Qualcomm MSM8960 chipset which supports both GPS and GLONASS. This standard, off-the-shelf handset is equipped with a specially configured SIM card on ATT's 3G network. This SIM ensures that both the E911 test calls (placed via a NEMO Handy script) and their associated locations are directed to a PSAP Simulator rather than to a live PSAP.

2. Sony Ericsson Xperia

   The UTDOA device is a Sony Ericsson Xperia running the TEMS Pocket with voice and FTP capability. TEMS Pocket is Ascom Network Testing's handheld network performance measurement tool that is used to qualify the HSUPA connection and its power level.

One handset of each type was included in the test fixture.

Sony Ericsson Xperia

Samsung Galaxy S3

Figure 3.2-1. Handsets Used in the TruePosition Indoor Testing

3.4 Test Configuration and Architecture

The diagram shown in Figure 3.3.1 shows the test setup used for the purposes of this accuracy testing protocol. There are two separate portions that generate the AGPS and UTDOA results. A final process combines the results from the individual components into the resulting Hybrid location estimate.

The AGPS portion of the test system is the standard AGPS E-911solution being used by AT&T today. Using the special SIM card designed to route 911 calls to a PSAP simulator, this portion allows periodic 911 calls that are established at a rate of one call per minute. The resulting location information is gathered at the PSAP simulator and relayed to TruePosition via email.

The UTDOA portion uses HSPUA sessions that are established to simulate the high power voice calls that are desired with all E911 voice calls. Upon establishment of such connection, the TruePosition LMUs are utilized in the trilateration process used in locating the device under test.

The TruePosition system compares the quality of the resulting UTDOA location to that of the AGPS locate for the same time period, and the higher quality result (e.g., lower uncertainty) is presented as the hybrid solution.

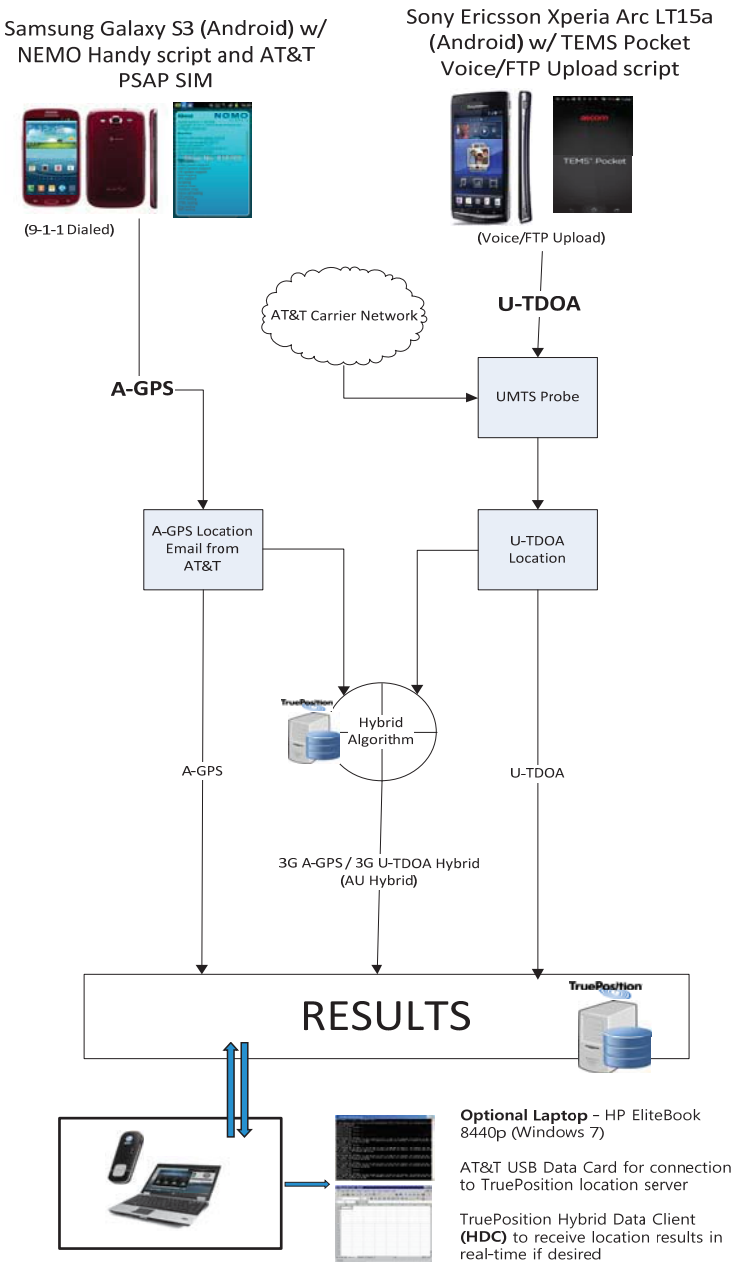

Figure 3.3-1. TruePosition's Test Architecture for the Hybrid Solution

4 Test Execution

4.1 Test Point Selection

TechnoCom's principal engineers/location experts evaluated possible candidate building selections and contacted their management. A letter of support from local public safety assisted in facilitating the communication with the building management. The evaluation of the possible buildings was in the context of the requirements of a test plan that mirrored the test plan that was adopted for the CSRIC III testing. Buildings were evaluated for their fit into the criteria of selection for each morphology, including their location, their type of construction, their broad RF characteristics, their distinction from other buildings previously selected, and their physical and logistical access.

Upon granting of permission for access/testing, TechnoCom's principal engineer performed a walkthrough of each of the identified buildings to determine the appropriate test points. The test points were selected to meet the general requirements of the test plan with adequate diversity in their RF environment (including adequate cellular signal coverage), placement of the point in the building, and non-intrusive test performance. The test points were then documented and pictures taken to ensure that the ground truth survey team surveyed the specific points intended. At some buildings, access restrictions implied that the walkthrough, the formal survey, and the actual testing were all coordinated and performed on the same day.

In all, 62 points were selected broken down as shown in Table 4.1-1. Slightly more test points were selected in the urban area since its buildings were on average larger than some of the suburban buildings.

Table 4.1-1 Summary of Test Point Distribution

Morphology	Number of Test Buildings	Number of Test Points
Urban	8	32
Suburban	8	30
Total	16	62

The identities and specific locations of all the test buildings and test points were maintained strictly anonymous to TruePosition until the delivery of this report.

TechnoCom leveraged its knowledge of the Wilmington area from the previous indoor testing it performed for TruePosition in March 2013, the results of which were submitted to the FCC[5,6]. Among the 16 buildings used in the current campaign, 7 were previously used in 2013. Those were mostly large buildings. The majority of the test points in those buildings were new test points, with a variety of test scenario and locations. Of the total of 62 test points in the current testing only 10 were used in the indoor testing of 2013. Maintaining a small common set in this manner helps for performance comparison purposes and in sanity checking the results during testing.

4.2 Ground Truth Determination

A professional land survey company with experience in indoor surveying and local knowledge was selected by TechnoCom to perform the precise ground truth surveys. The surveyor used established land

[5] TechnoCom Ex parte filing on behalf of TruePosition dated March 28, 2013.

[6] TechnoCom's 2013 test report is also included in TruePosition's Comments on the 3rd FNPRM dated May 12, 2014, as Attachment One

survey techniques using modern technology. The equipment used of the survey inside the buildings is shown in Figure 4.2-1. The following is a quote from one of the 10 formal survey reports prepared by the land surveyor.

"Surveyed positions were established using Leica GS15 SmartRover utilizing the Leica SmartNet CORS Network. These positions were established on Delaware State Plane Coordinate System in the NAD83 (NA2011) Reference Frame, Epoch 2010.0000 and converted to WGS84 Latitude and Longitude. Elevations were established in NAVD88 datum with the Geoid 09 Model. GPS control points were established outside the building with a horizontal and vertical positional tolerance of +/- 2 cm and traversing into the building was accomplished with a Leica TS15 Total Station resulting in a positional tolerance of +/- 5 cm in the horizontal and vertical."

Figure 4.2-1. Setup Used by Professional Surveyor for Ground Truth Determination

A sample surveyed location took the form:

Building X. Test Point: 1

Description: First Floor, interior office

Latitude: N39°43'XX.85581"

Longitude: W75°40'XX.84057"

Elevation: 91.96ft (28.03m) (NAVD 88)

WGS84 Ellipsoid Height: -16.06ft (-4.90m)

Although the test points were surveyed with exceptional accuracy and precision, a practical accuracy in test device placement relative to surveyed location was better than half a meter. The contribution of such placement tolerance to overall location error is completely negligible.

4.3 Test Fixture

For ease of transportation the test devices were mounted on a portable platform. As shown in Figure 4.3-1 the platform carried the two test handsets plus one that TruePosition used for their internal testing, placed each in a cradle atop a 12-inch arm. The test devices were separated by approximately 18 inches.

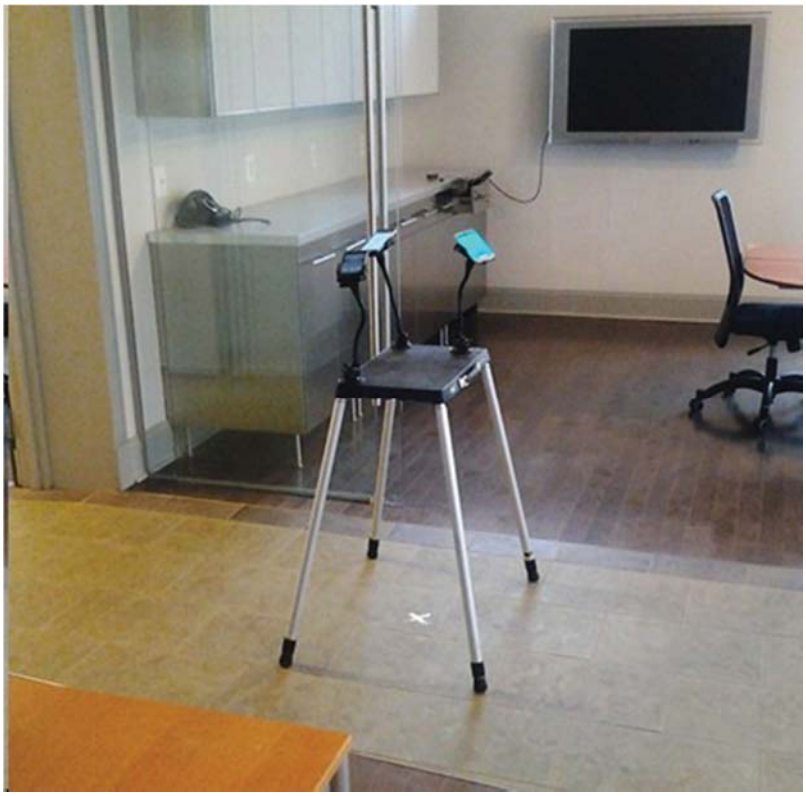

Figure 4.3-1. Test Fixture Used During the Indoor Testing in Wilmington

4.4 Placement, Timing, and Alignment of Test Calls

The Samsung S3 AGPS phone was programmed to place one call every 60 seconds. As mentioned above, these calls received emergency call location treatment but did not get routed to an actual PSAP because of the special SIMs used. Each such test call was up to 30 seconds long. If the test configuration were AGPS alone, then within the desirable logistical target of 75 minutes per test point, 75 test calls would have been placed. Real world wireless data traffic conditions on the AT&T wireless network in Wilmington, however, often necessitated a longer duration at each test point to accommodate variations in traffic and ensure that an equivalent minimum number of high data rate HSUPA sessions (emulating power-up conditions) were successfully placed.

Not all attempts to setup an HSUPA data session were usable for the purpose of this testing. Three scenarios were identified and at each such occurrence the corresponding AGPS locate was discarded as being inapplicable to the test. By design, this led to a 100% yield for the test calls. The HSUPA scenarios were:

- No data session was setup at all – No UTDOA location was attempted.

- Data session used a configuration utilizing a 2ms TTI (Transmit Time Interval). This configuration is only used for some data sessions, and is never used for circuit switched voice calls. To keep this test as close to voice call processing as possible, any calls with this 2ms TTI configuration were discarded – No UTDOA location was attempted.
- An HSUPA data session was setup, but the data rate was low. Since the goal of this testing is to evaluate the accuracy under power-up conditions, a filter was applied to only consider sessions with a minimum data rate. The setting used was 30kbps. All UTDOA locations performed on sessions with a lower data rate along with their corresponding AGPS locates were therefore discarded.

Because of the data channel traffic conditions, which varied during each day, and with the 75 test calls per point baseline, the overall duration of the test call placement averaged roughly an hour and 45 minutes per test point. Accordingly, the maximum practical number of test points per building for planning purposes was 4 test points. On three occasions during almost 3 weeks of field testing, extensive delays in establishing the required high rate HSUPA sessions were experienced; at those test points sample sizes over 50 calls were gathered. Again, no deleterious statistical effect on the results was observed with the TruePosition technology at those specific points due to those smaller call samples[7].

Additionally, it should be noted that because of the slow nature of collecting and processing the HSUPA signals in this test, which is primarily due to the bandwidth of the backhaul lines, a nominal 26 seconds were required to complete the UTDOA location processing. In a true power-up emergency voice call implementation, the typical UTDOA voice call processing time is typically under 7 seconds[8].

The AGPS results collected using the Samsung Galaxy S3 and run concurrently with the HSUPA from the Sony Ericsson Xperia were delivered to the test server via email from the AT&T PSAP Simulator. They were subsequently time stamp matched to the corresponding UTDOA location fix to generate the hybrid UTDOA/AGPS location fix. AGPS fixes that did not correspond to a valid HSUPA UTDOA data collection session were discarded from the outset.

[7] Had the preliminary performance observed at those 3 test points indicated large variability, a revisit to those test points would have been necessary to complete the sample. Had considerable variation in the results been observed across many points, a larger sample of 100 calls, or even more, per test point would have been necessary. This would have resulted in a fewer number of test points per building and overall in this time-limited campaign.

[8] TruePosition's Comments on the 3rd FNPRM dated May 12, 2014, page 11.

5 Detailed Test Environments

5.1 Overall Test Area and Environment

TruePosition provided to TechnoCom geographical information on the area in which its 3G test infrastructure is deployed. The area encompasses the City of Wilmington, DE and a wide swath of suburban areas extending towards its northeast and southwest. The general area is shown in Figure 5.1-1.

The boundary of the suburban test area is shown in the figure with purple-colored boundary. Excluded from it are the blue polygon in the center of the City of Wilmington, which is the urban environment of this testing, and shown in red is the boundary of the Christiana Mall which excluded from coverage. AT&T recently installed a new DAS in the mall and its support by TruePosition was not feasible within the time frame of this time-constrained test campaign. It is also worth noting that the rectangular area excluded from the purple polygon that is just to the southwest of the blue urban polygon is due to the recent deployment by AT&T of a UMTS/LTE site for which TruePosition has not yet installed an LMU.

Finally, the area northwest of Wilmington appears as almost rural; however it has a cell site density that was not deemed sufficiently sparse by TechnoCom to consider that area as a truly rural morphology. Consequently, following a methodology similar to that used under CSRIC, the Wilmington test area was considered to comprise only two morphologies: urban and suburban.

In spite of the minor boundary adjustments relative to the indoor testing of 2G in Wilmington in 2013, the test area within the purple and blue polygons still represents an extensive sample of both the suburban and urban morphologies, with more than enough diversity and target buildings that span the spectrum of structure types prevalent in those two major and critical morphologies.

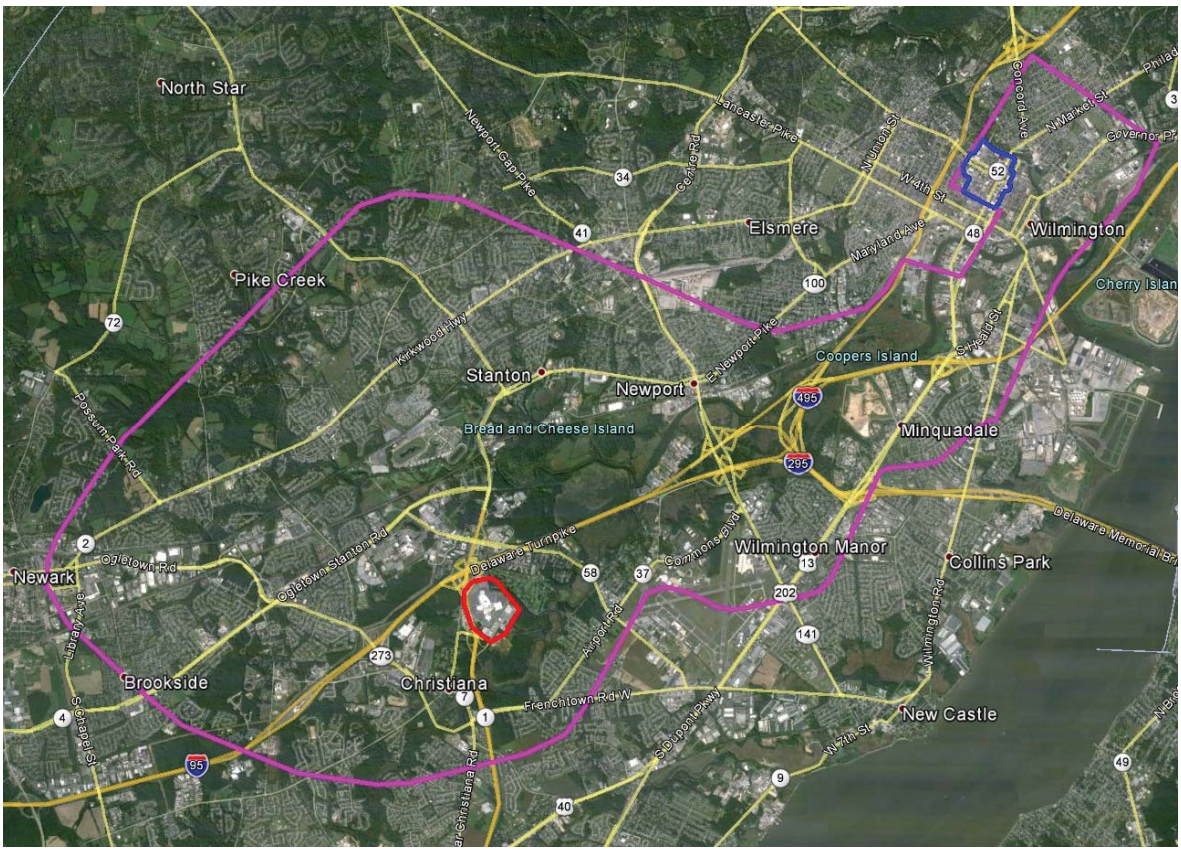

Figure 5.1-1. TruePosition's Wilmington Test Bed Area in May 2014

5.2 Urban Morphology

5.2.1 Urban Polygon

Within the large purple polygon of the test area, TechnoCom defined, using techniques similar to what it had used for CSRIC III in the Bay Area, the urban morphology polygon concentrated around downtown Wilmington. This polygon is shown in dark blue above and expanded in Figure 5.2-1 below. The blue-colored boundary follows similar definition and placement criteria (e.g., clutter type, building density, area layout) to what was used in the Bay Area, e.g., the polygon surrounding Downtown San Jose. The area of the urban polygon in Wilmington is approximately 0.3 square mile, slightly smaller than the size of the urban area that was used in San Jose during CSRIC III.

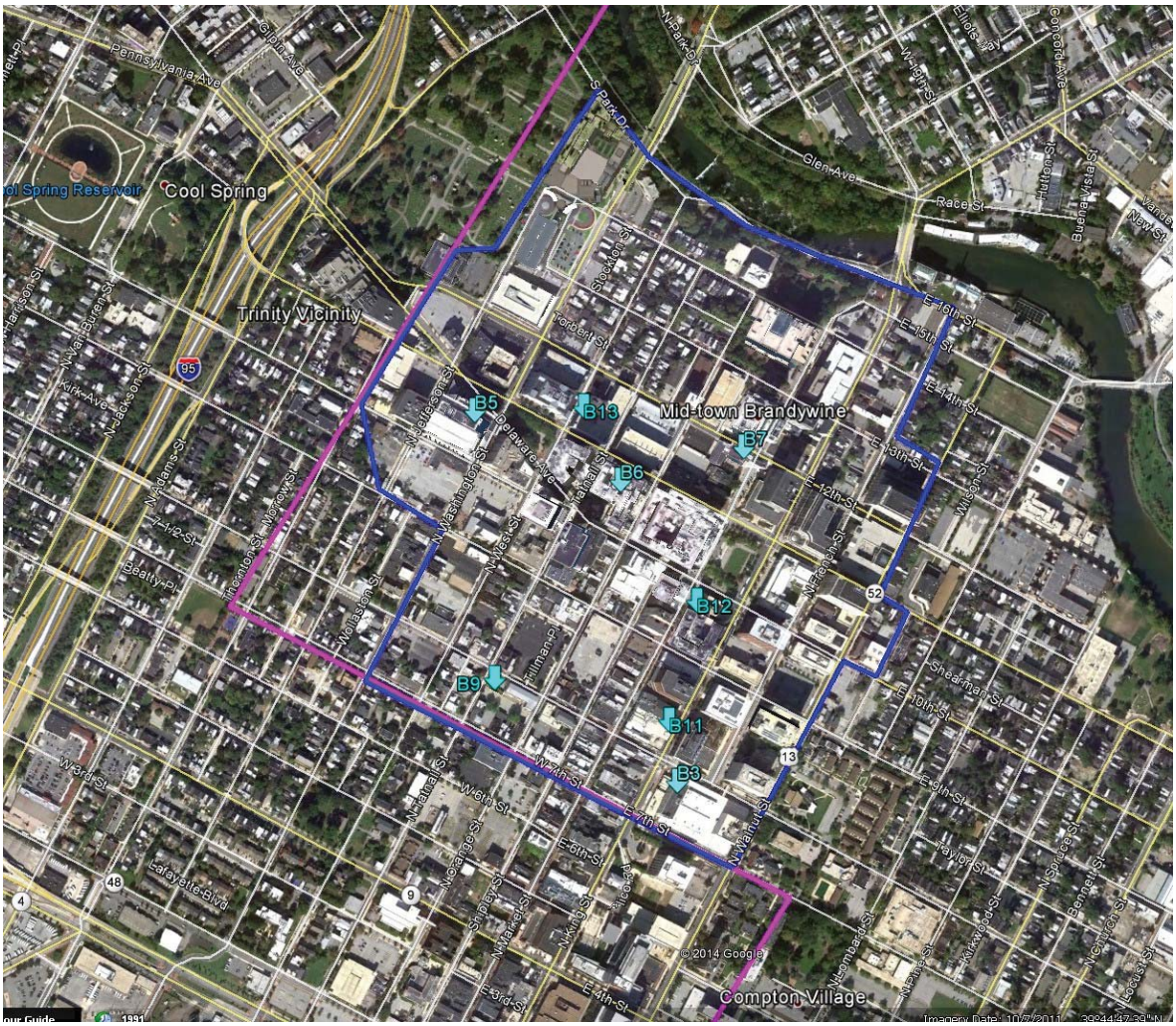

Figure 5.2-1. Urban Polygon and Relative Locations of the Urban Test Buildings

5.2.2 Urban Buildings Used

The urban buildings used for indoor testing in Wilmington in May 2014 are:

Bldg. 3: Double Tree Hotel, 700 N. King St., Wilmington, DE

Bldg. 5: 500 Delaware Ave., Wilmington, DE

Bldg. 6: Nemours Building, 1007 N. Orange St., Wilmington, DE

Bldg. 7: Wilmington Tower, 1105 N. Market St., Wilmington, DE

Bldg. 9: "Tatnall" Building, 716 North Tatnall Street, Wilmington, DE

Bldg. 11: Grand Opera House, 818 North Market Street, Wilmington, DE

Bldg. 12: Wilmington Library, 10 E 10th Street, Wilmington, DE

Bldg. 13: Courtyard by Marriott, 1102 N. West Street, Wilmington, DE

The geographic placement of the 8 urban test buildings is depicted in Figure 5.2-1. Both the denser area comprising central downtown Wilmington, with large and tall buildings, as well as the somewhat lighter urban part of the area, with buildings of varying heights, are included in the test sample. Different construction types are well represented, as can be clearly seen in the following figures, so are different propagation surroundings, e.g., differing surrounding building heights and the prevalence of dominant larger buildings to act as multipath reflectors.

In each of these 8 urban buildings 4 test points were selected. Among those 8 buildings, 4 buildings were used by TechnoCom in the prior testing of the TruePosition system in 2013. However, of the 16 test points in those 4 buildings only 5 test points were unchanged. All other test points were newly selected and surveyed. Hence, in summary, 5 anonymous test points in the urban environment were used before and the remaining 35 anonymous test points were newly selected.

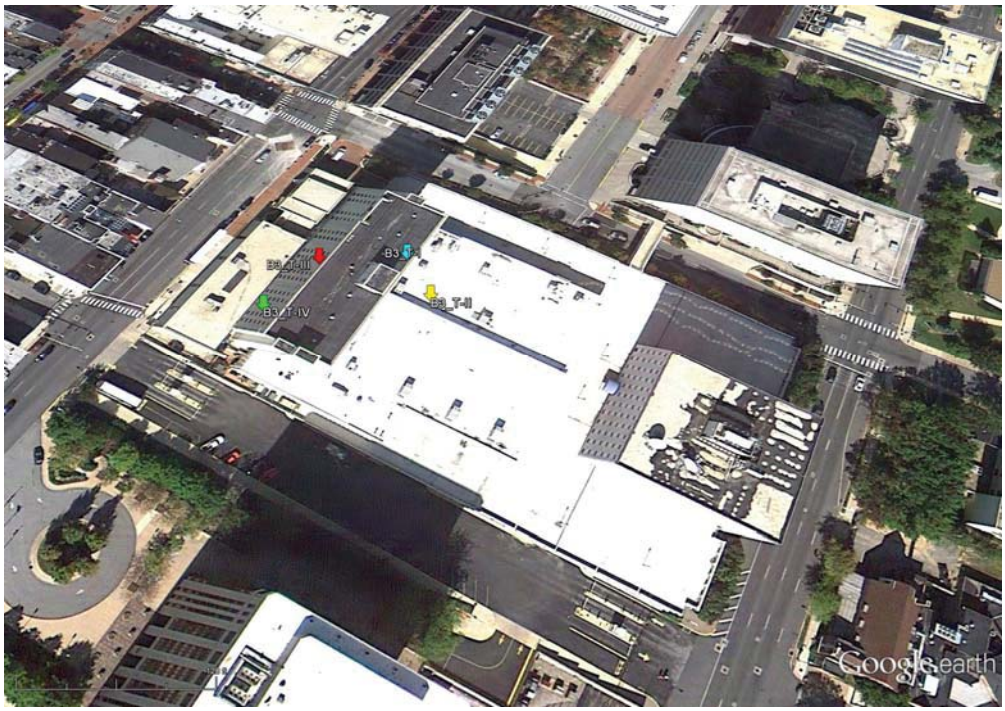

Figure 5.2-2. Bldg. 3: Double Tree Hotel

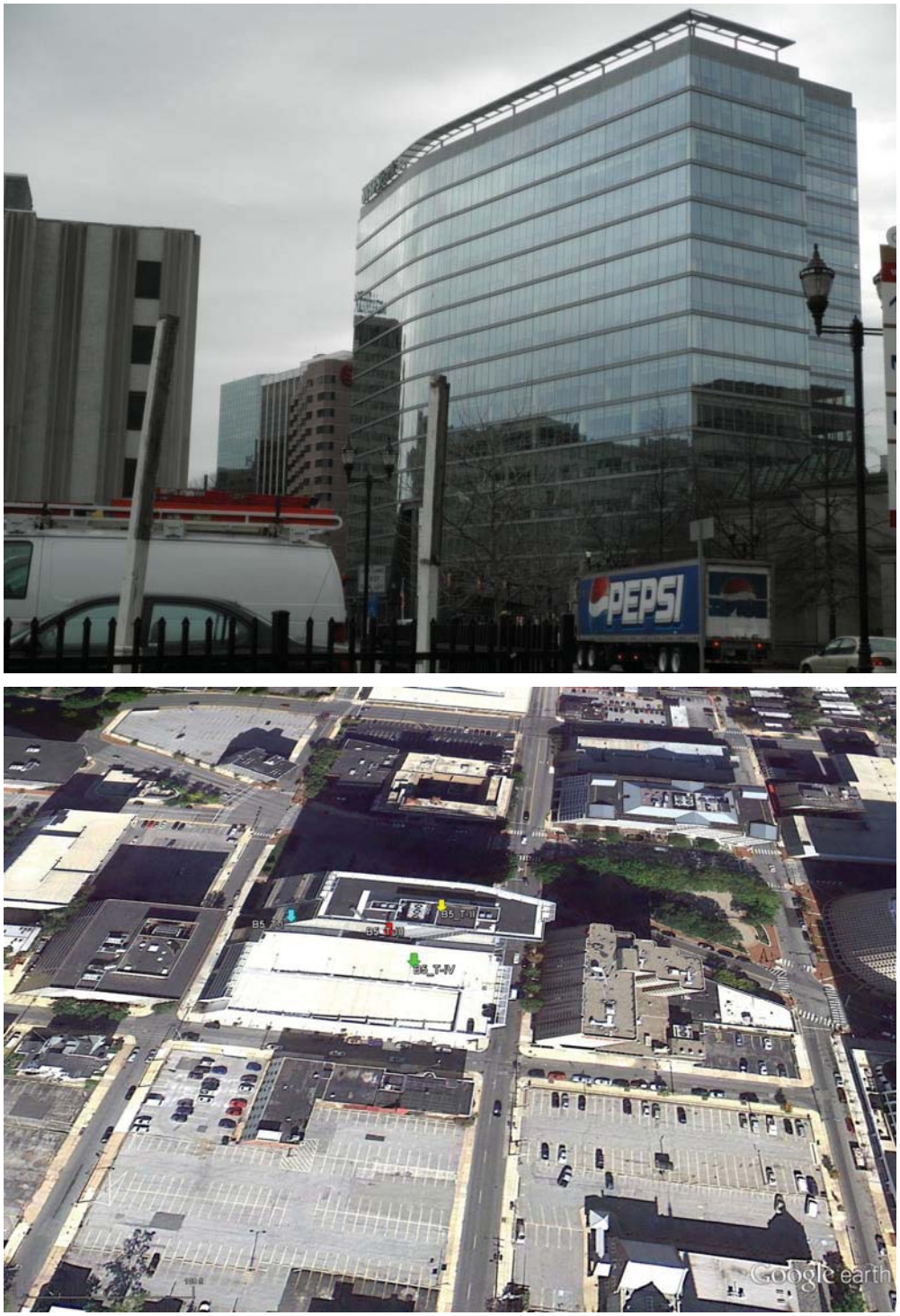

Figure 5.2-3. Bldg. 5: 500 Delaware

Figure 5.2-4. Bldg. 6: Nemours Building

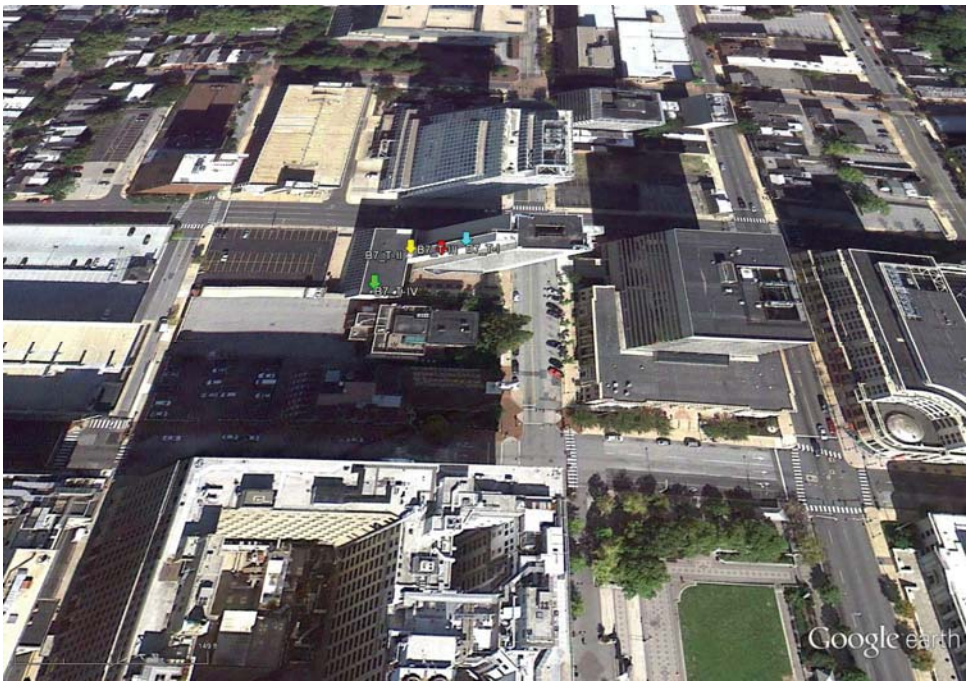

Figure 5.2-5. Bldg. 7: Wilmington Tower

Figure 5.2-6. Bldg. 9: "Tatnall" building

Figure 5.2-7. Bldg. 11: Grand Opera House

Figure 5.2-8. Bldg. 12: Wilmington Library

Figure 5.2-9. Bldg. 13: Courtyard by Marriott, Wilmington

5.3 Suburban Morphology

5.3.1 Suburban Polygon

The suburban polygon in the Wilmington area extends across a 12.5 mile swath, from northeast of downtown Wilmington to roughly 11 miles southwest of it. It encompasses an area containing a wide variety of suburban densities, clutter types, building sizes and construction techniques.

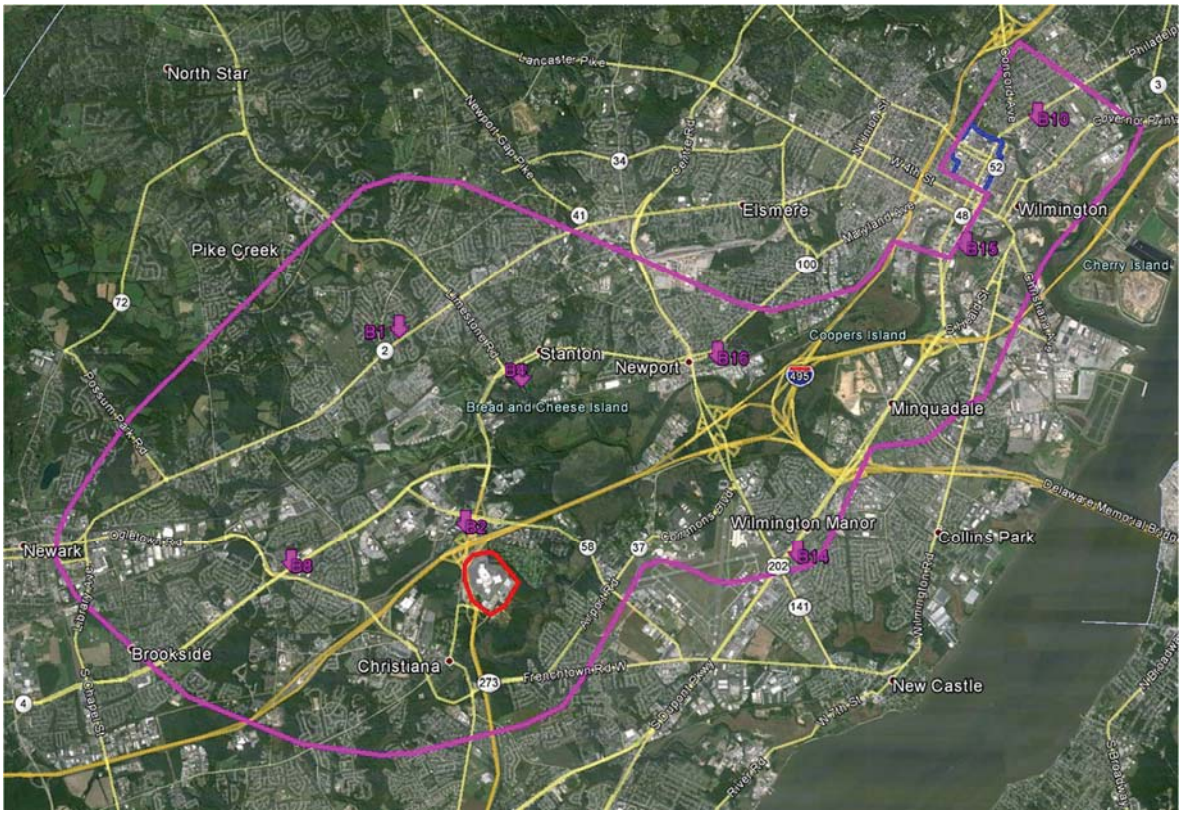

Figure 5.3-1. Suburban Polygon and Relative Locations of the Suburban Test Buildings

5.3.2 Suburban Buildings Used

Eight suburban buildings offered a wide spectrum of actual use environments in a diverse suburban area, ranging from a townhome, to a 3 story office building, to a hotel, to an apartment complex, a university building and a storage facility. Widely varying building sizes with distinct construction and different surrounding clutter were represented in this suburban building sample.

The Suburban buildings used for indoor testing in the Wilmington area were:

Bldg. 1: 2-Story Townhouse, 5215 W. Woodmill Drive, Wilmington, DE.

Bldg. 2: Hilton Hotel, 100 Continental Drive in Newark, DE

Bldg. 4: Arbor Point Apartment Complex, 4000 Dawnbrook Drive, Wilmington, DE

Bldg. 8: "Iron Hill" Office Building, 700 Prides Crossings, Newark, DE

Bldg. 10: Reybold Storage Building, 2523 LaMotte Street, Wilmington, DE

Bldg. 14: Wilmington University Admissions Center, 320 N. DuPont Highway, New Castle, DE.

Bldg. 15: Buccini Polin Headquarters Office Building, 322 A Street, Wilmington, DE

Bldg. 16: Larch Business Center Office Building, 102 Robino Court, Wilmington, DE

The locations of those 8 suburban buildings relative to the boundary of the test area are shown in Figure 5.3-1 above.

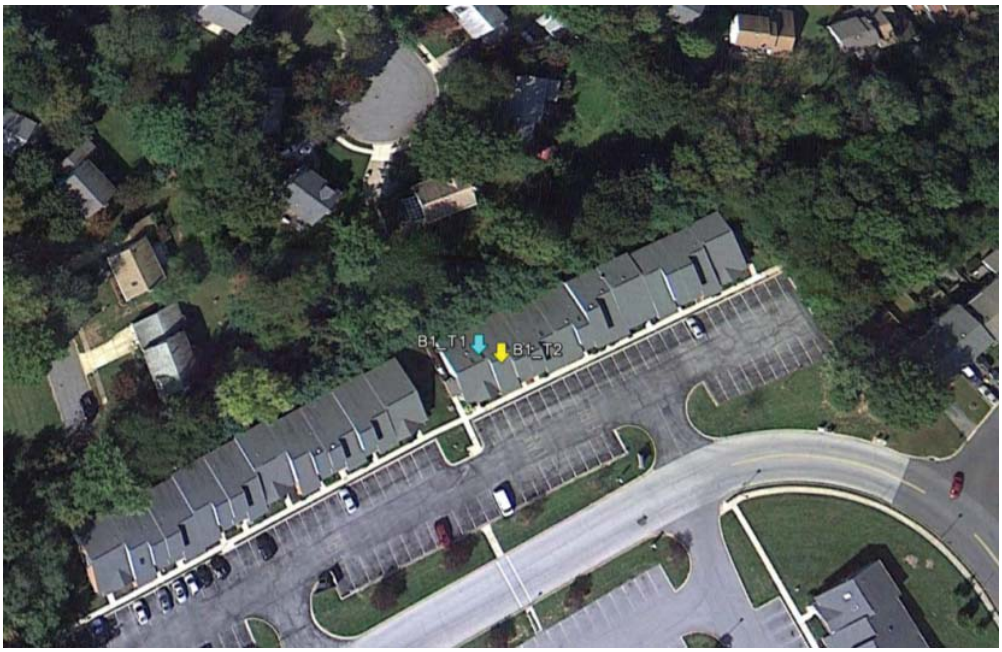

Figure 5.3-2. Bldg. 1: 2-Story Townhouse

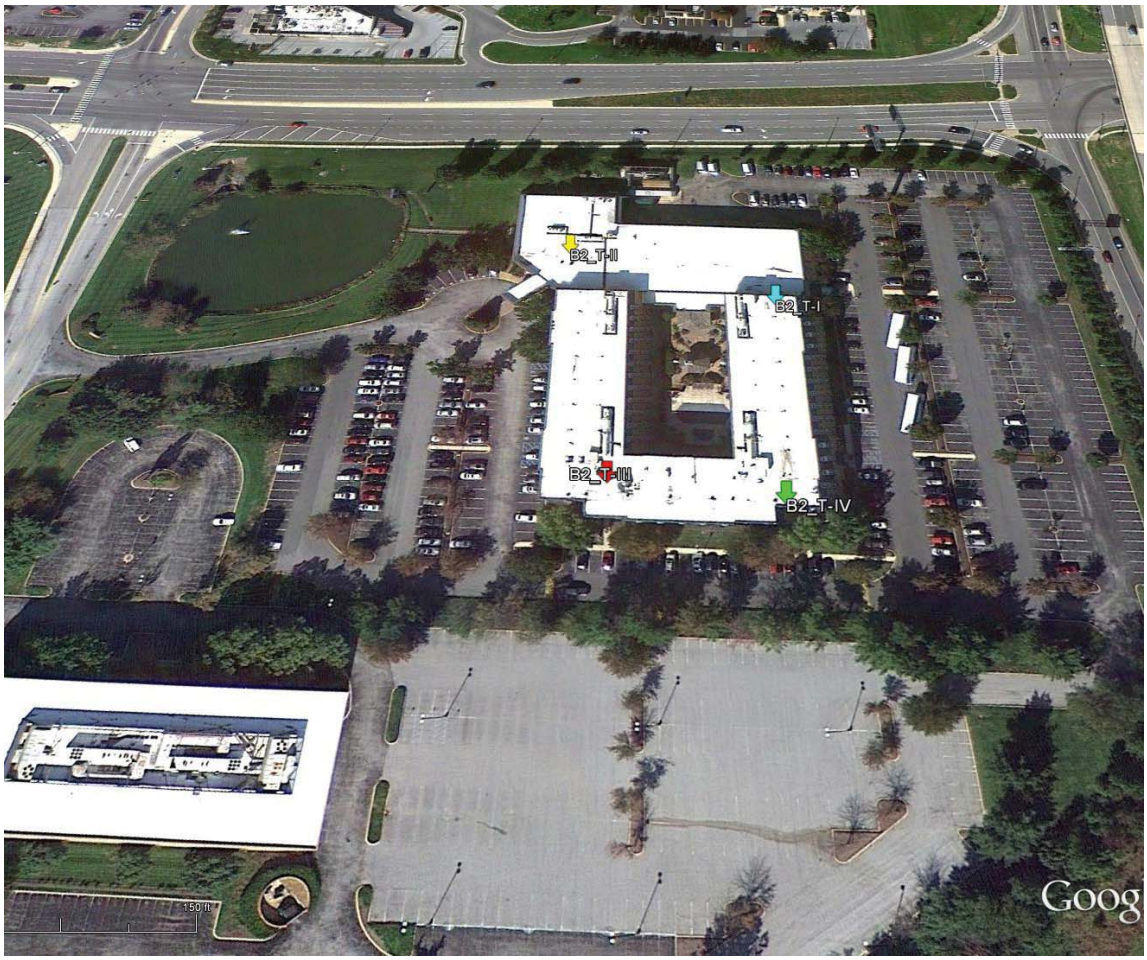

Figure 5.3-3. Bldg. 2: Hilton Hotel

Figure 5.3-4. Bldg. 4: Arbor Point Apartment Complex (Buildings and Clubhouse)

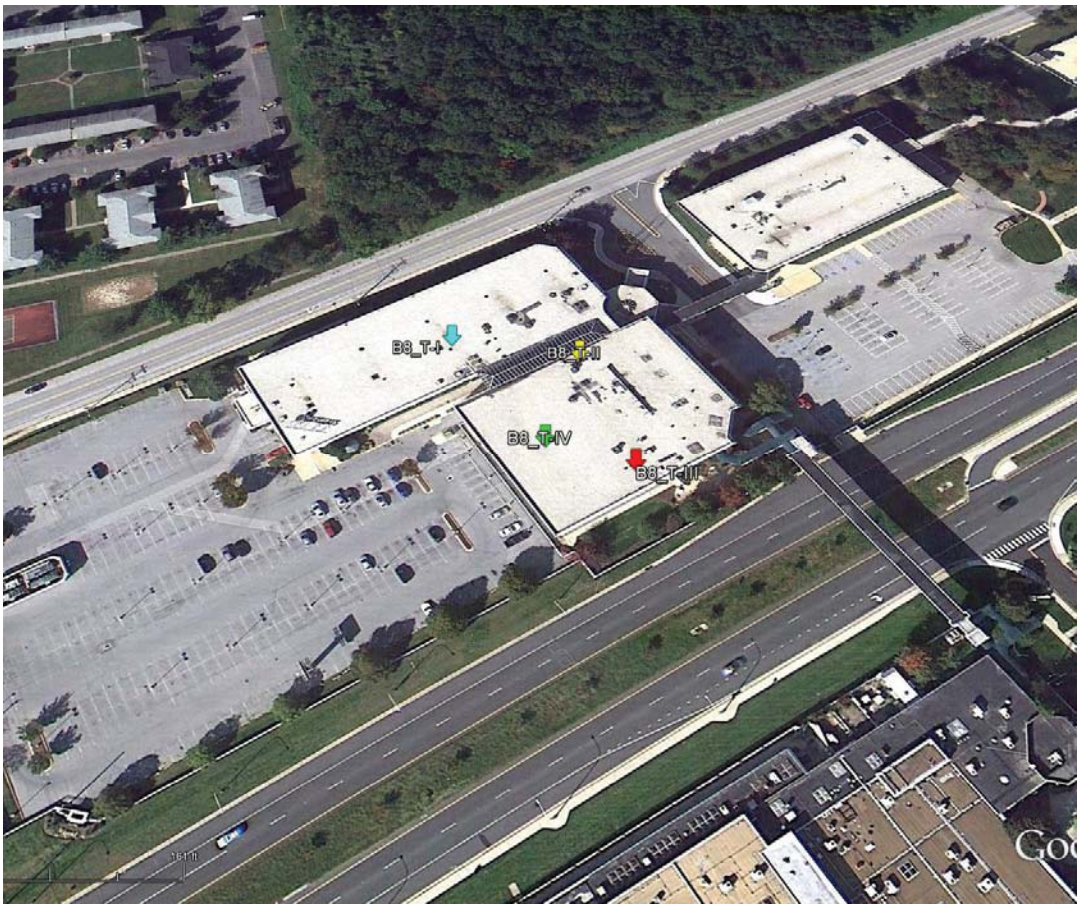

Figure 5.3-5. Bldg. 8: Iron Hill Office Building

Figure 5.3-6. Bldg. 10: Reybold Storage Building

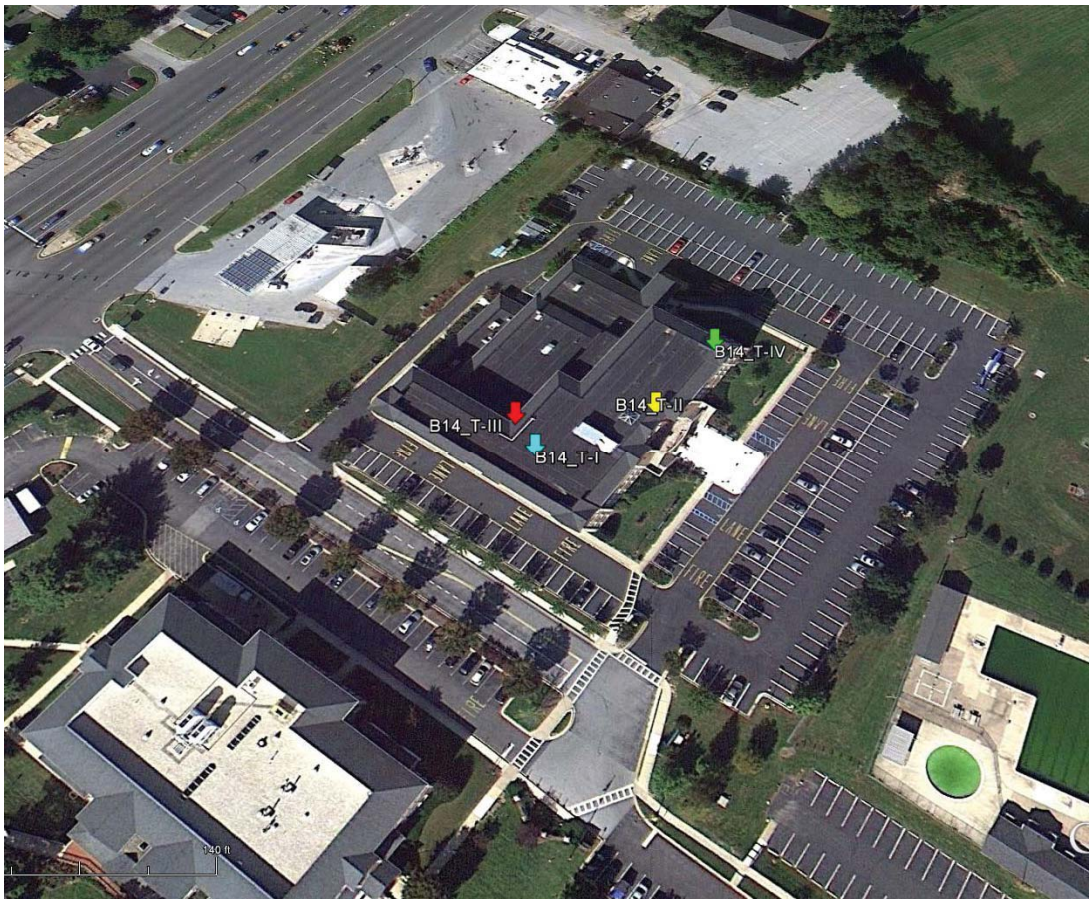

Figure 5.3-7. Bldg. 14: Wilmington University Admissions Center

Figure 5.3-8. Bldg. 15: Buccini Polin HQ Office Building

Figure 5.3-8. Bldg. 15: Larch Business Center Office Building

6 Summary Test Results

As mentioned above in Section 3, the yield of the Wilmington testing was by design 100%. The TTFF was driven by the time to transport and process the HSUPA data and was by design 26 +/- 1 sec for all test calls. The following sections will present the results of the key parameters investigated by the Wilmington testing, first and foremost the location accuracy, and secondarily the reported uncertainty delivered with the location results.

The results are presented for both UTDOA and Hybrid AGPS/UTDOA because UTDOA by itself can serve as a viable location determination system in support of both outdoor and indoor E911, or it could simply provide the low delay location fix to be used for emergency call routing and the Hybrid AGPS/UTDOA solution, which is subsequently available within the 30 second window, is delivered to the PSAP upon their rebid. This presentation also provides the reader with a clear view of the extent of improvement achieved by this hybrid relative to UTDOA by itself in the different settings tested.

6.1 Accuracy Statistics

6.1.1 Accuracy Performance Summary

The following summary tables and CDFs provide the indoor accuracy over the entire set of 16 buildings and 62 test points within them across both the urban and suburban environments (morphologies) in the Wilmington, DE test area.

Table 6.1-1. UTDOA Indoor Accuracy Statistics—Wilmington Aggregate

UTDOA Location Error Statistics (m)								
Test Point ID	Total Number of Calls	67th Percentile	80th Percentile	90th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_Combined	**4648**	**42.3**	**59.0**	**81.9**	**42.7**	**75.8**	**1966.1**	**0.38**

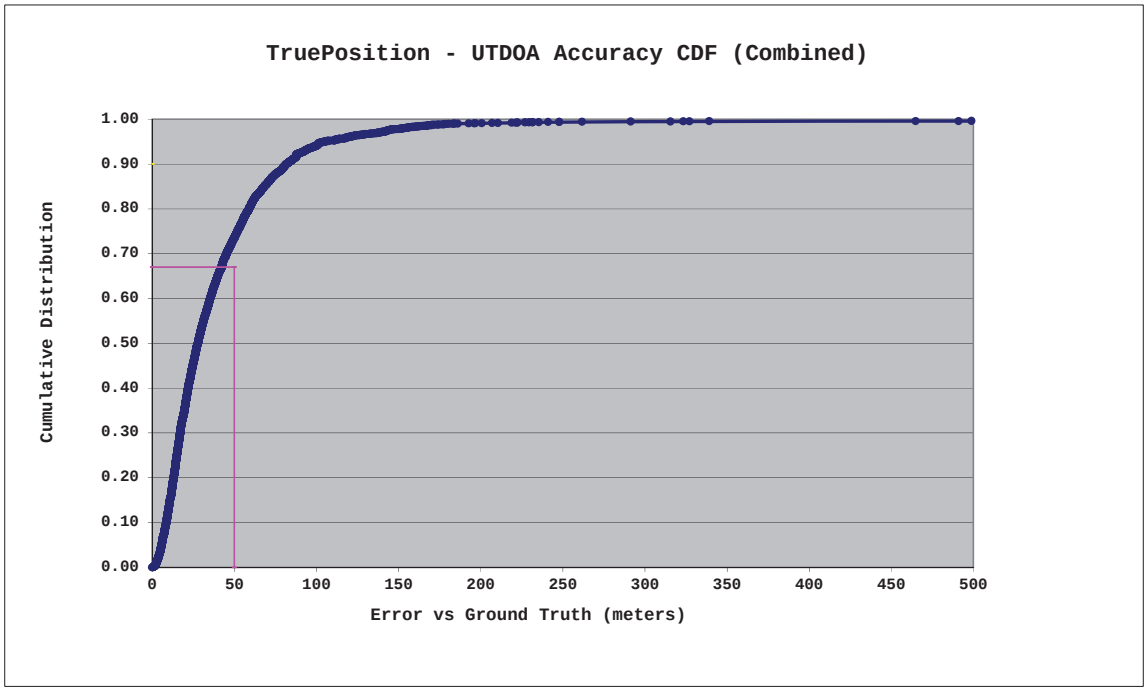

Figure 6.1-1 UTDOA Indoor Location Error Distribution—Wilmington Aggregate

Table 6.1-2. Hybrid AGPS/UTDOA Indoor Accuracy Statistics—Wilmington Aggregate

AGPS/UTDOA Hybrid - Location Error Statistics (m)								
Test Point ID	Total Number of Calls	67th Percentile	80th Percentile	90th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_Combined	**4648**	**35.1**	**51.9**	**76.9**	**35.9**	**65.0**	**1702.0**	**0.38**

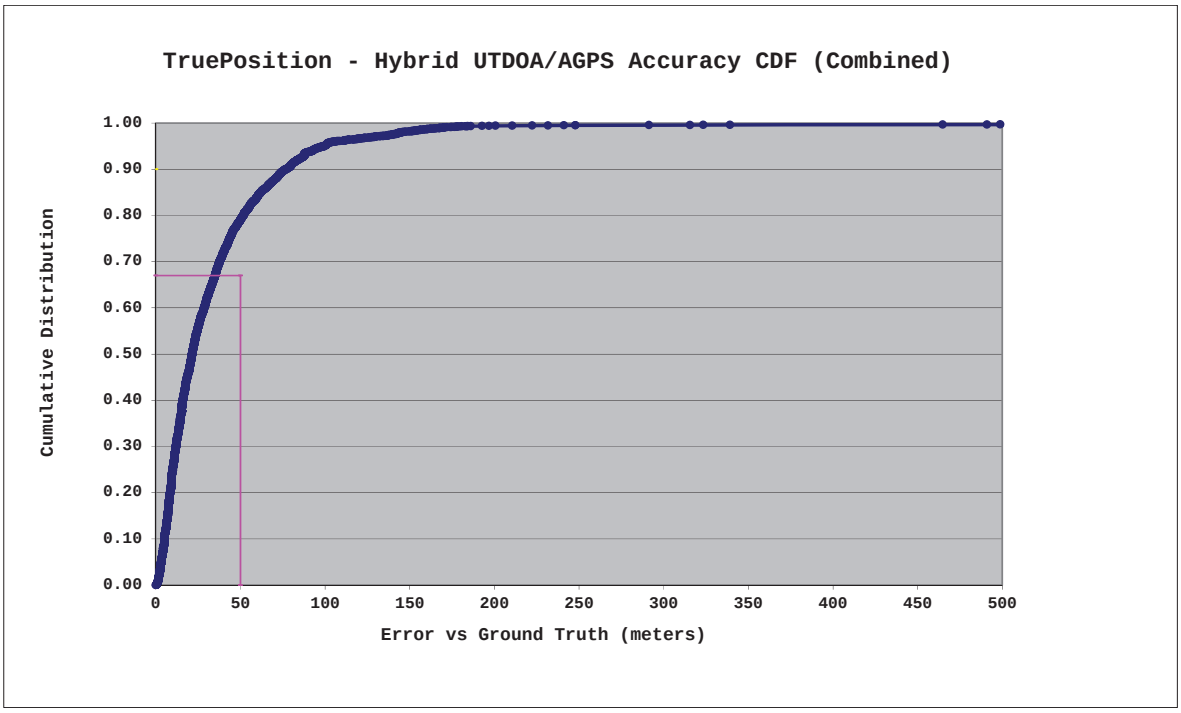

Figure 6.1-2 Hybrid AGPS/UTDOA Indoor Location Error Distribution—Wilmington Aggregate

The following bar chart provides at a glance a summary of the accuracy performance achieved in the Wilmington testing in May 2014. The expected relative improvement in accuracy from urban to suburban environment is seen for both the UTDOA and the Hybrid AGPS[9]/UTDOA solutions by observing the red and blue bars either on the left (UTDOA) or the right (Hybrid). The improvement achieved by the Hybrid AGPS/UTDOA over UTDOA by itself is also seen in comparing the cluster of bars on the left to that on the right.

It is seen that in aggregate across the Wilmington area both the UTDOA and Hybrid AGPS/UTDOA with the configuration tested, i.e., UMTS with emulated emergency voice call powered-up via a high data rate HSUPA session, meet the proposed 50 m 67% of the time threshold for indoor calls. Additionally, the hybrid AGPS/UTDOA solution meets that requirement for both the urban and suburban environments individually.

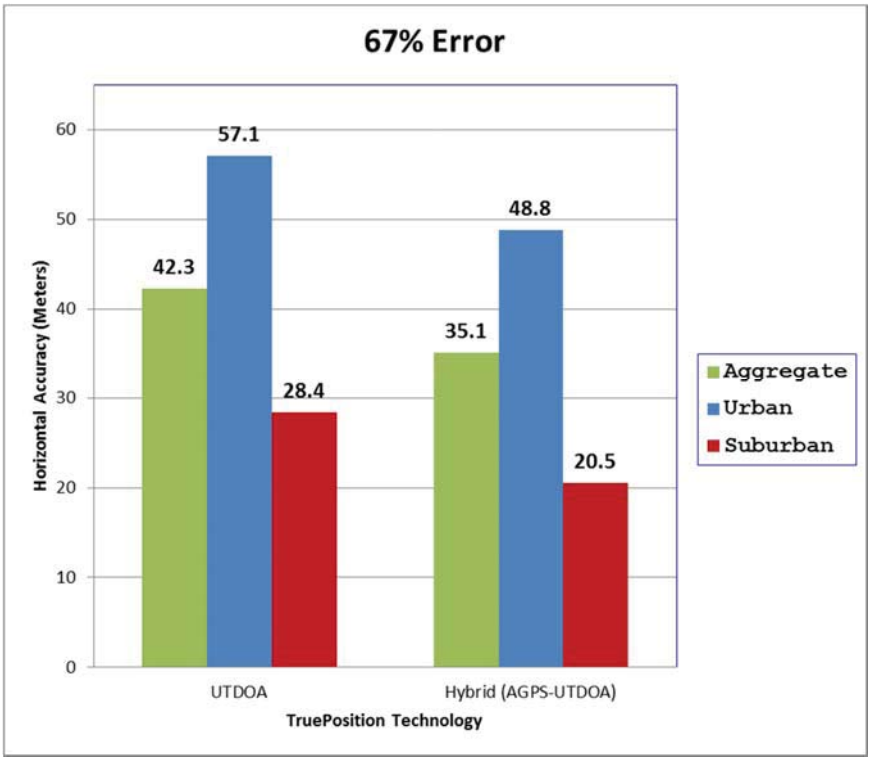

Figure 6.1-3 Indoor Accuracy Percentile Summary—Wilmington, DE

[9] With handset and network configuration tested "AGPS" in this report is used as shorthand notation to denote Assisted GPS plus GLONASS.

6.1.2 UTDOA Accuracy by Environment

For the reader's convenience, the location accuracy results in the following tables also include in each row a summary of the accuracy statistics per building in the given environment (morphology). This highlights the range of variation of statistics across the buildings in that morphology. More detailed results for each building, including the location error CDF and the location scatter diagram for each building, are provided in Section 7 below. For the reader interested in a considerably more detail, the error statistics and CDFs on a test point by test point basis are provided in the two appendices (one for UTDOA and one for hybrid AGPS/UTDOA).

Table 6.1-3. UTDOA Indoor Accuracy Statistics—Urban Environment

UTDOA Location Error Statistics (m)								
Test Point ID	Total Number of Calls	67th Percentile	80th Percentile	90th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_BD3	281	39.3	50.3	57.5	59.4	164.8	1354.3	0.60
TruePosition_BD5	269	48.7	61.3	82.6	43.2	28.4	162.6	0.38
TruePosition_BD6	303	53.0	72.2	83.1	49.4	33.0	339.2	3.60
TruePosition_BD7	305	47.1	57.0	75.6	47.5	67.0	682.4	2.67
TruePosition_BD9	311	48.3	57.8	70.5	43.4	59.7	913.6	2.58
TruePosition_BD11	305	25.8	49.4	63.9	29.1	38.6	567.5	1.67
TruePosition_BD12	304	132.4	148.4	167.1	102.4	65.6	736.9	0.94
TruePosition_BD13	301	84.7	92.0	101.2	71.8	58.9	695.2	0.97
TruePosition_Urban_Combined	2379	57.1	79.4	101.2	55.9	78.1	1354.3	0.38

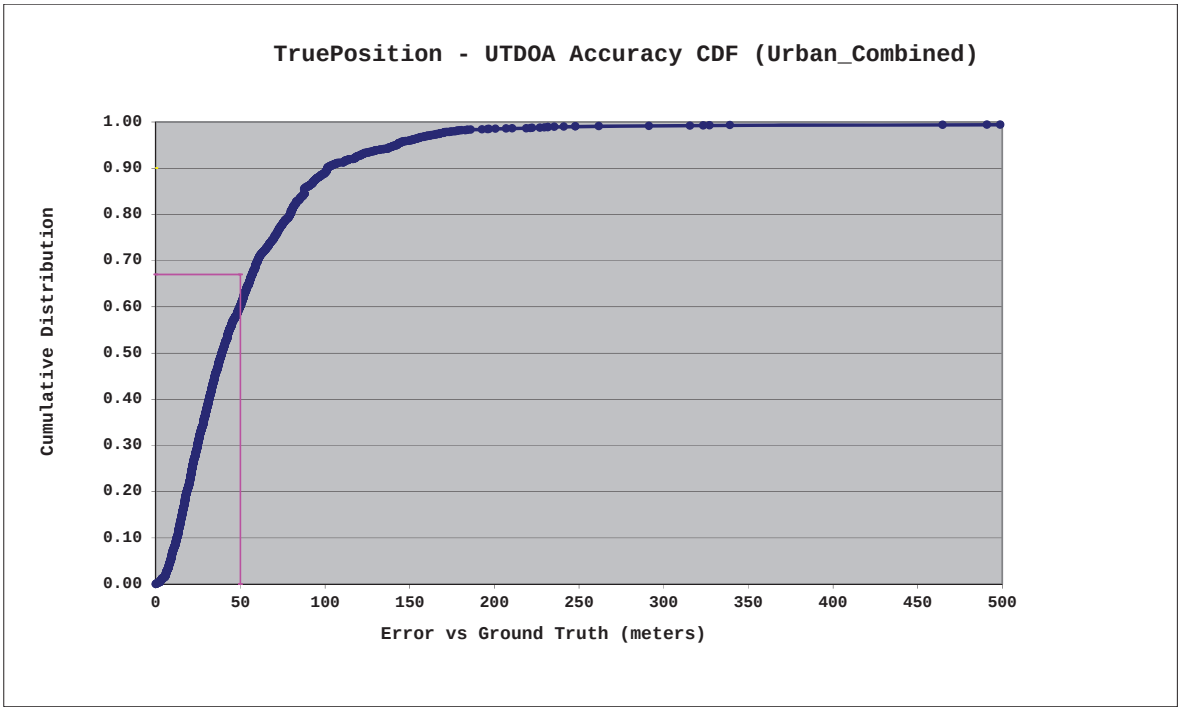

Figure 6.1-3 UTDOA Indoor Location Error Distribution—Urban Environment

Table 6.1-4. UTDOA Indoor Accuracy Statistics—Suburban Environment

UTDOA Location Error Statistics (m)								
Test Point ID	Total Number of Calls	67th Percentile	80th Percentile	90th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_BD1	151	16.7	21.5	27.6	15.3	10.9	73.8	1.87
TruePosition_BD2	305	21.8	27.3	35.6	19.4	12.0	91.5	1.18
TruePosition_BD4	303	31.5	39.5	53.1	28.0	19.2	143.1	2.84
TruePosition_BD8	300	46.1	53.7	65.5	58.2	186.2	1966.1	2.30
TruePosition_BD10	303	19.8	23.4	27.9	17.3	15.2	222.5	0.77
TruePosition_BD14	304	26.8	61.7	66.4	28.7	24.4	98.3	1.37
TruePosition_BD15	300	46.9	54.6	62.8	41.2	19.2	136.6	3.60
TruePosition_BD16	303	18.3	23.9	29.2	16.3	9.6	51.8	0.78
TruePosition_Suburban_Combined	2269	28.4	40.3	54.9	28.8	70.8	1966.1	0.77

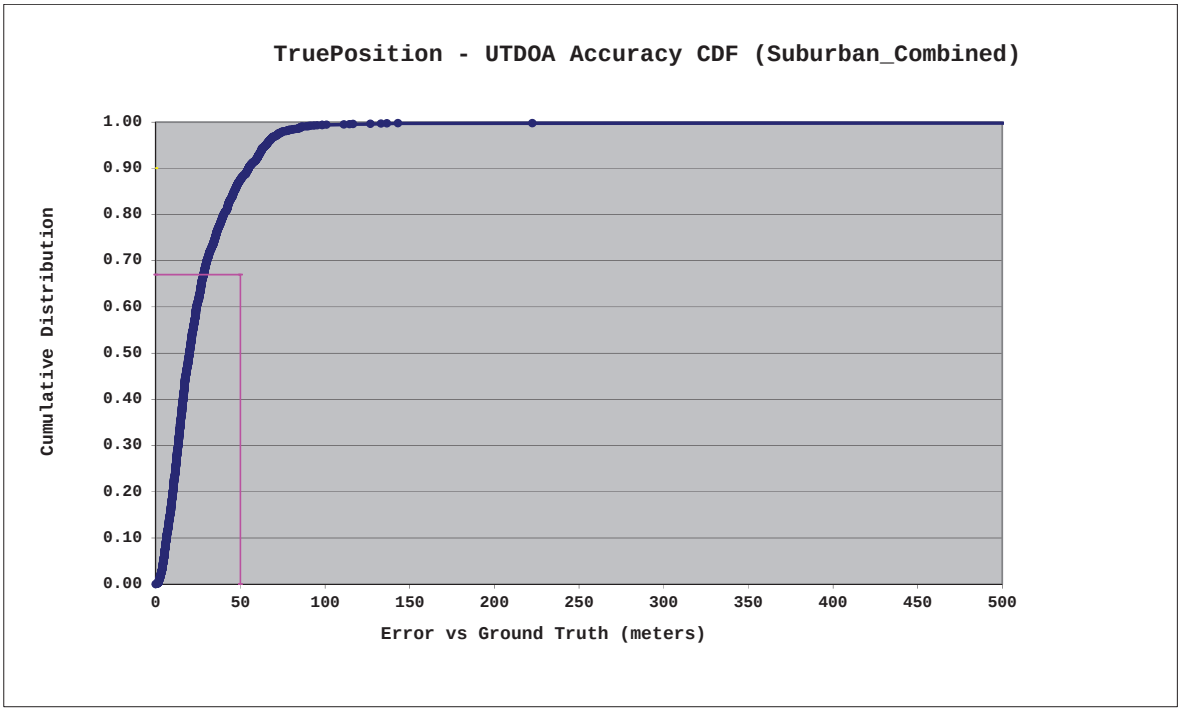

Figure 6.1-4 UTDOA Indoor Location Error Distribution—Suburban Environment

6.1.3 Hybrid AGPS/UTDOA Accuracy by Environment

Table 6.1-5. Hybrid AGPS/UTDOA Indoor Accuracy Statistics—Urban Environment

AGPS/UTDOA Hybrid - Location Error Statistics (m)								
Test Point ID	Total Number of Calls	67th Percentile	80th Percentile	90th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_BD3	281	39.3	50.3	57.5	59.4	164.8	1354.3	0.60
TruePosition_BD5	269	48.7	61.3	82.6	43.2	28.4	162.6	0.38
TruePosition_BD6	303	53.0	72.2	83.1	49.4	33.0	339.2	3.60
TruePosition_BD7	305	47.1	57.0	76.0	47.6	67.1	682.4	2.67
TruePosition_BD9	311	18.7	21.8	23.1	16.4	6.5	40.1	4.52
TruePosition_BD11	305	23.2	30.9	63.1	27.9	38.4	567.5	1.67
TruePosition_BD12	304	127.9	145.0	160.4	86.9	68.9	736.9	0.94
TruePosition_BD13	301	84.5	92.0	101.2	70.1	59.4	695.2	0.97
TruePosition_Urban_Combined	2379	48.8	73.5	97.4	50.0	75.5	1354.3	0.38

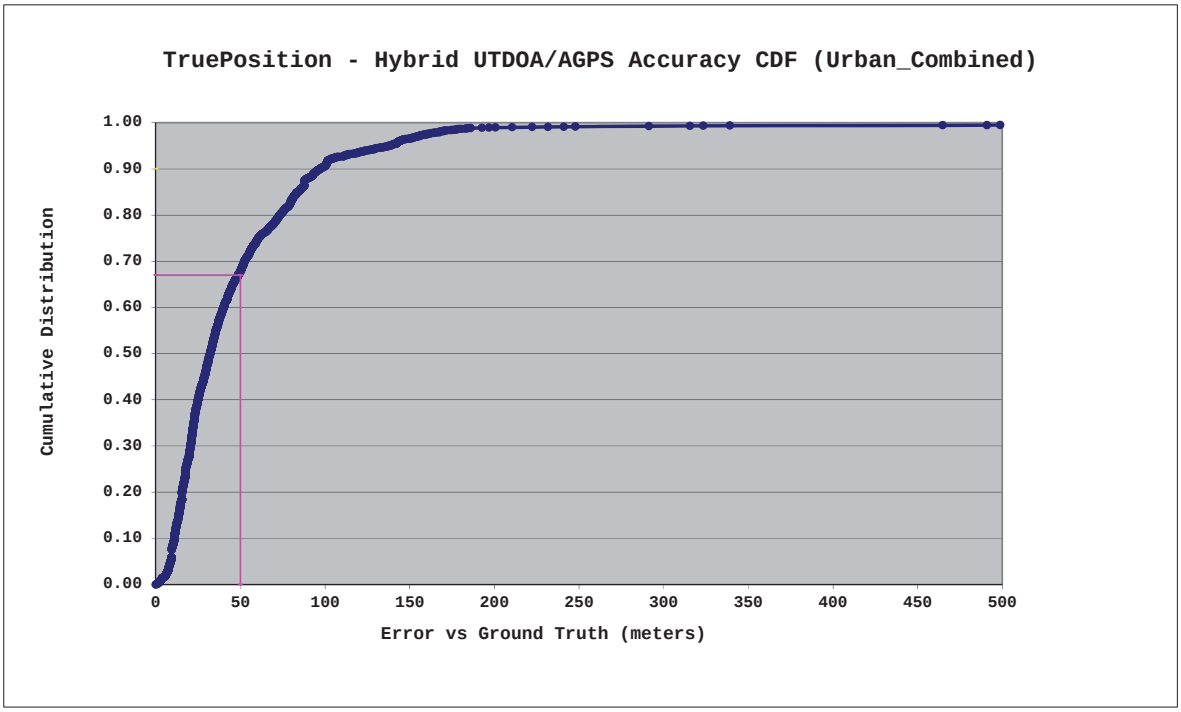

Figure 6.1-5 Hybrid AGPS/UTDOA Indoor Location Error Distribution—Urban Environment

Table 6.1-6. Hybrid AGPS/UTDOA Indoor Accuracy Statistics—Suburban Environment

AGPS/UTDOA Hybrid - Location Error Statistics (m)								
Test Point ID	Total Number of Calls	67th Percentile	80th Percentile	90th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_BD1	151	7.8	9.7	13.2	6.3	5.4	33.2	0.85
TruePosition_BD2	305	21.5	28.9	36.0	18.3	11.9	72.7	1.61
TruePosition_BD4	303	8.1	14.3	16.1	8.5	6.6	43.6	0.98
TruePosition_BD8	300	39.7	48.3	66.3	39.0	120.6	1702.0	0.95
TruePosition_BD10	303	16.2	21.8	27.9	14.9	10.6	62.1	0.77
TruePosition_BD14	304	14.9	52.7	64.3	22.0	23.2	80.5	3.82
TruePosition_BD15	300	46.3	54.6	62.8	41.1	19.2	136.6	3.60
TruePosition_BD16	303	13.0	17.7	25.5	11.6	9.9	55.7	0.61
TruePosition_Suburban_Combined	2269	20.5	34.6	48.2	21.1	47.3	1702.0	0.61

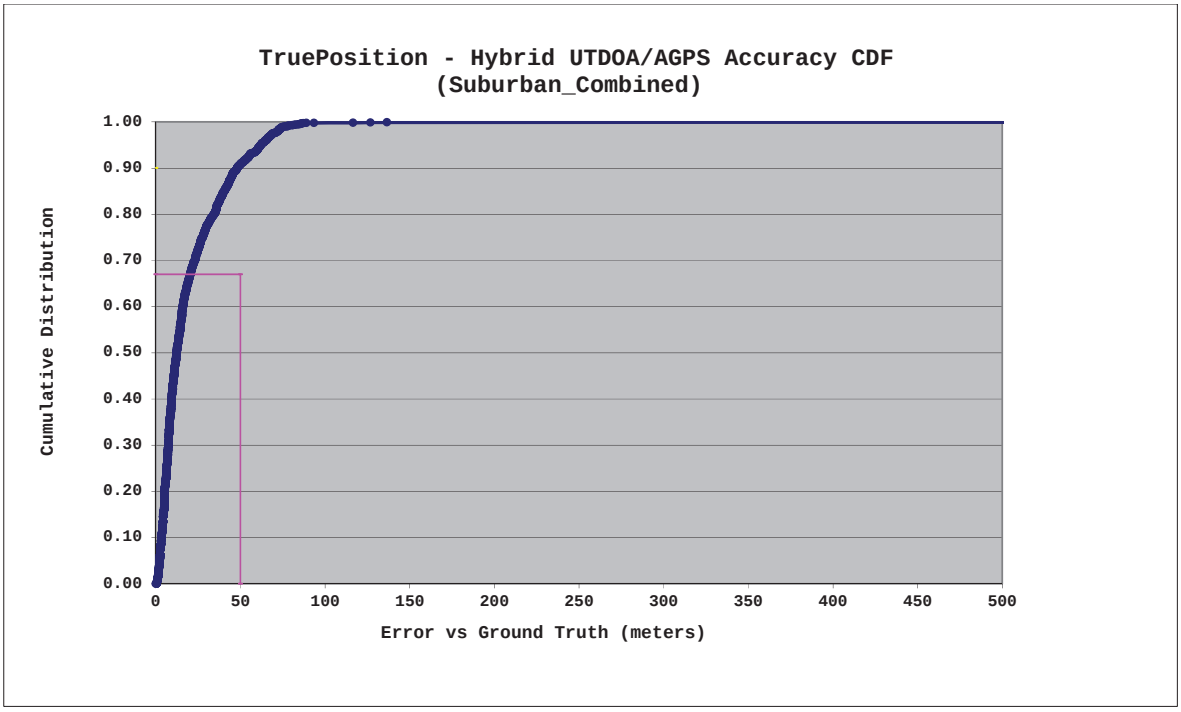

Figure 6.1-6 Hybrid AGPS/UTDOA Indoor Location Error Distribution—Suburban Environment

6.2 Reported Uncertainty

The reported uncertainty as a deliverable to the PSAP is an important auxiliary parameter that aids the dispatcher in assessing the quality of the delivered location result. Hence its reliability as a measure of the quality of the location performance is equally important. Furthermore, the uncertainty for each of the components of Hybrid AGPS/UTDOA plays an important role affecting the algorithm that selects between UTDOA and AGPS.

The uncertainty results in the tables are provided at the nominal 90% confidence level. The reported uncertainty per test point is compared to the fraction of calls for which the resulting (empirically measured) location falls inside the uncertainty circle. The ideal number would be 90% of the calls have an actual error that causes the reported locations to fall inside the reported uncertainty circle.

Like with accuracy results, the reported uncertainty results are first summarized aggregated for the test area as a whole. Then for each morphology, the results are shown aggregated per building (in each row in that table) and then aggregated for the whole morphology.

6.2.1 Summary Uncertainty Results

Table 6.2-1. Reported Uncertainty for UTDOA—Wilmington Aggregate

UTDOA Uncertainty			
Test Point ID	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_Combined	**4648**	**3597**	**77.39%**

Table 6.2-2. Reported Uncertainty for Hybrid AGPS/UTDOA—Wilmington Aggregate

AGPS/UTDOA Hybrid Uncertainty			
Test Point ID	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_Combined	**4648**	**4324**	**93.03%**

As can be seen from the two uncertainty tables above, the reported uncertainty is a more reliable reflection of actual accuracy for the Hybrid AGPS/UTDOA solution than for UTDOA by itself. This observation is explored further with the per-building results captured below.

6.2.2 UTDOA Uncertainty by Environment

Table 6.2-3. Reported Uncertainty for UTDOA—Urban Environment

UTDOA Uncertainty			
Test Point ID	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_BD3	281	217	77.22%
TruePosition_BD5	269	188	69.89%
TruePosition_BD6	303	171	56.44%
TruePosition_BD7	305	234	76.72%
TruePosition_BD9	311	271	87.14%
TruePosition_BD11	305	266	87.21%
TruePosition_BD12	304	199	65.46%
TruePosition_BD13	301	148	49.17%
TruePosition_Urban_Combined	2379	1694	71.21%

Table 6.2-4. Reported Uncertainty for UTDOA—Suburban Environment

UTDOA Uncertainty			
Test Point ID	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_BD1	151	144	95.36%
TruePosition_BD2	305	277	90.82%
TruePosition_BD4	303	270	89.11%
TruePosition_BD8	300	242	80.67%
TruePosition_BD10	303	274	90.43%
TruePosition_BD14	304	254	83.55%
TruePosition_BD15	300	175	58.33%
TruePosition_BD16	303	267	88.12%
TruePosition_Suburban_Combined	2269	1903	83.87%

As can be seen from the above two tables and a cross reference to the summary accuracy tables per building in Section 6, the UTDOA reported uncertainty generally follows the quality of the accuracy performance. However, the reliability of the UTDOA uncertainty figure of merit tends to degrade more rapidly than the actual accuracy in situations (here buildings) where the location determination is more challenging (e.g., Buildings 12 and 13 in the urban environment). This indicates that the uncertainty parameter for UTDOA is calibrated more aggressively (tighter circle) than it should be for those settings.

6.2.3 Hybrid AGPS/UTDOA Uncertainty by Environment

Table 6.2-5. Reported Uncertainty for Hybrid AGPS/UTDOA—Urban Environment

AGPS/UTDOA Hybrid Uncertainty			
Test Point ID	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_BD3	281	265	94.31%
TruePosition_BD5	269	246	91.45%
TruePosition_BD6	303	254	83.83%
TruePosition_BD7	305	289	94.75%
TruePosition_BD9	311	286	91.96%
TruePosition_BD11	305	295	96.72%
TruePosition_BD12	304	265	87.17%
TruePosition_BD13	301	258	85.71%
TruePosition_Urban_Combined	2379	2158	90.71%

Table 6.2-6. Reported Uncertainty for Hybrid AGPS/UTDOA—Suburban Environment

AGPS/UTDOA Hybrid Uncertainty			
Test Point ID	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_BD1	151	151	100.00%
TruePosition_BD2	305	299	98.03%
TruePosition_BD4	303	297	98.02%
TruePosition_BD8	300	256	85.33%
TruePosition_BD10	303	298	98.35%
TruePosition_BD14	304	297	97.70%
TruePosition_BD15	300	267	89.00%
TruePosition_BD16	303	301	99.34%
TruePosition_Suburban_Combined	2269	2166	95.46%

The above two tables indicate that the uncertainty reported with the hybrid AGPS/UTDOA solution is a reliable indicator of actual location fix quality. This holds true even though in many challenging urban and even suburban deep indoor test points the source of the eventual hybrid location is that from UTDOA (again as in buildings 12 and 13).

7 Performance per Building

This section provides more detailed performance of the UTDOA and Hybrid AGPS/UTDOA solutions presented on a per building basis. The buildings are grouped per morphology, first urban, followed by suburban buildings. For each building the cumulative CDF is presented together with the scatter diagram for that building first for UTDOA and subsequently for Hybrid AGPS/UTDOA. The error results reflected in the CDF of each building are aggregated from all the test points in that building. The scatter for each test point about the features pertaining to that building and its immediate surroundings can be seen in these illustrations. A further level of detailed per test point performance, including an individual CDF for each test point, is provided in the two appendixes, Appendix A for UTDOA results and Appendix B for Hybrid AGPS/UTDOA results.

7.1 Urban Buildings

7.1.1 Bldg. 3: Double Tree Hotel, Wilmington, DE

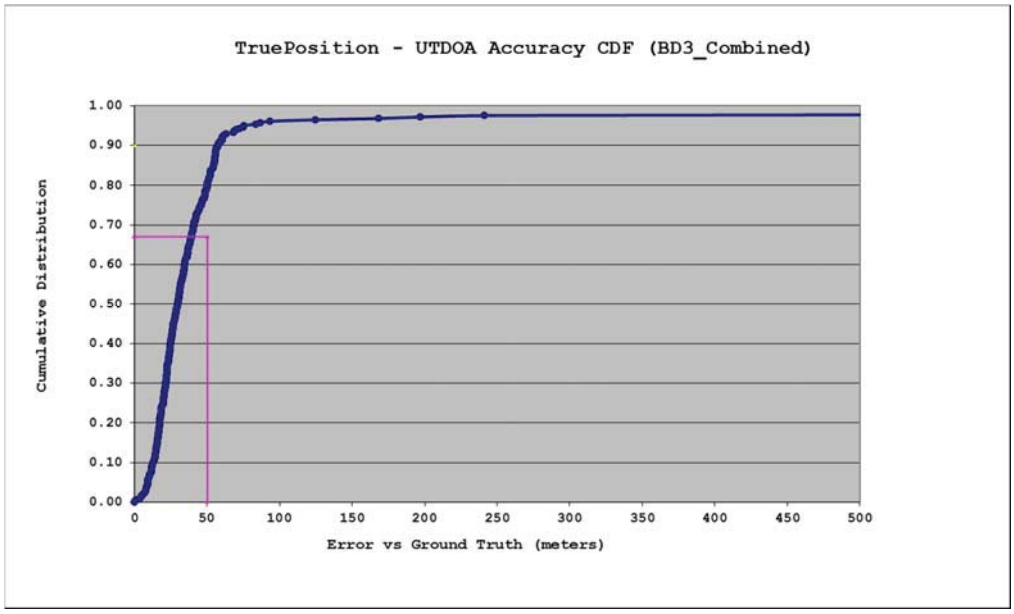

Figure 7.1-1. Bldg. 3 – UTDOA Location Error CDF

Figure 7.1-2. Bldg. 3 – UTDOA Location Scatter

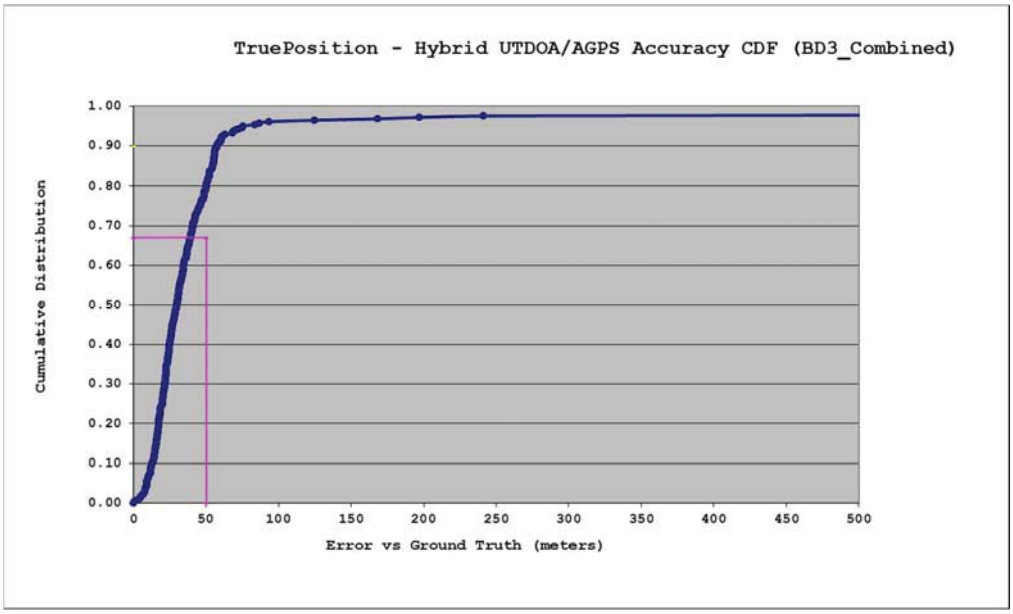

Figure 7.1-3. Bldg. 3 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.1-4. Bldg. 3 – Hybrid AGPS/UTDOA Location Scatter

7.1.2 Bldg. 5: 500 Delaware Ave., Wilmington, DE

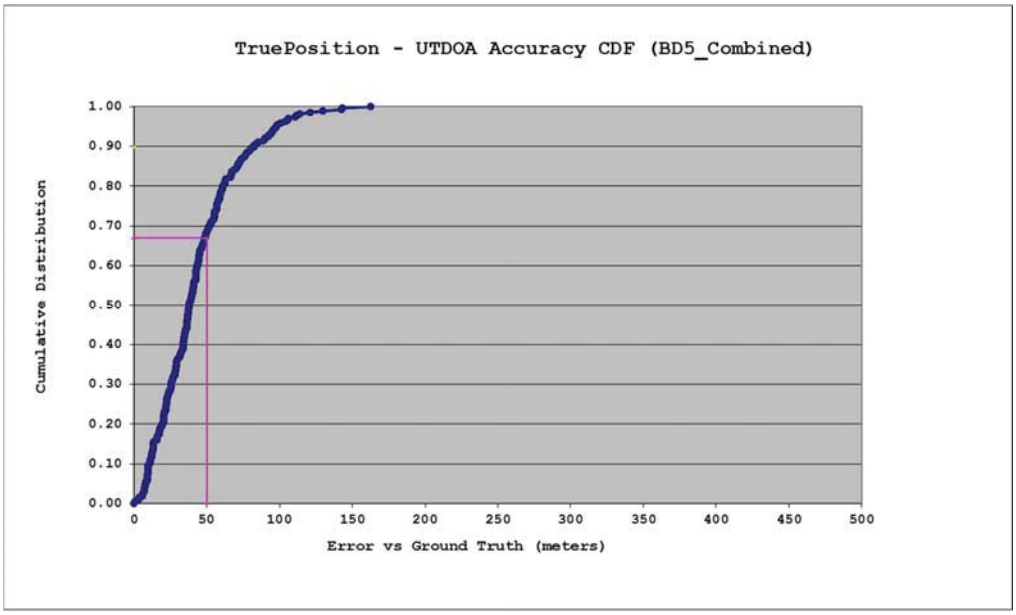

Figure 7.1-5. Bldg. 5 – UTDOA Location Error CDF

Figure 7.1-6. Bldg. 5 – UTDOA Location Scatter

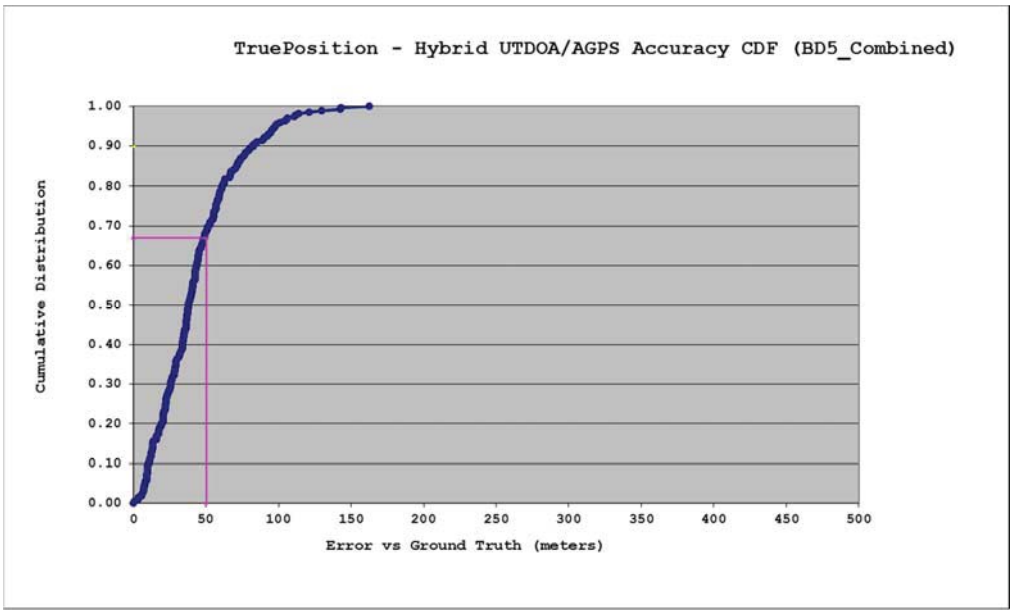

Figure 7.1-7. Bldg. 5 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.1-8. Bldg. 5 – Hybrid AGPS/UTDOA Location Scatter

7.1.3 Bldg. 6: Nemours Building, Wilmington, DE

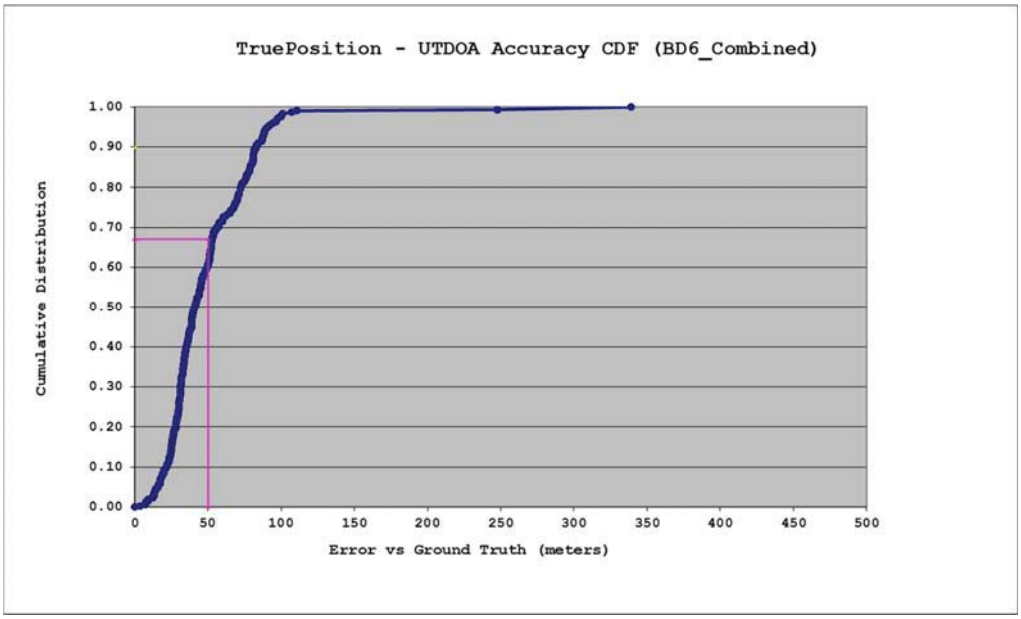

Figure 7.1-9. Bldg. 6 – UTDOA Location Error CDF

Figure 7.1-10. Bldg. 6 – UTDOA Location Scatter

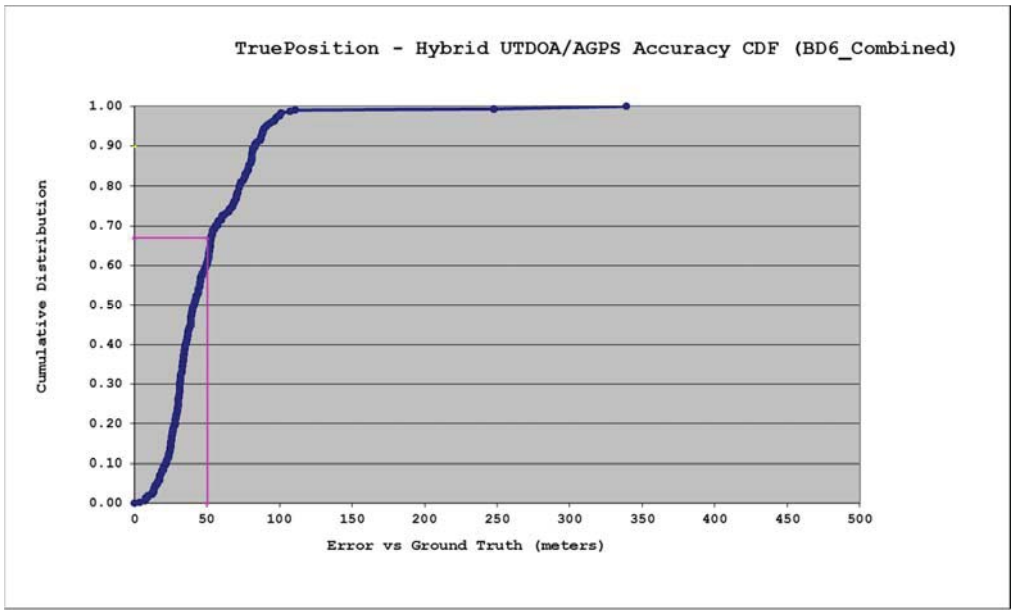

Figure 7.1-11. Bldg. 6 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.1-12. Bldg. 6 – Hybrid AGPS/UTDOA Location Scatter

7.1.4 Bldg. 7: Wilmington Tower, Wilmington, DE

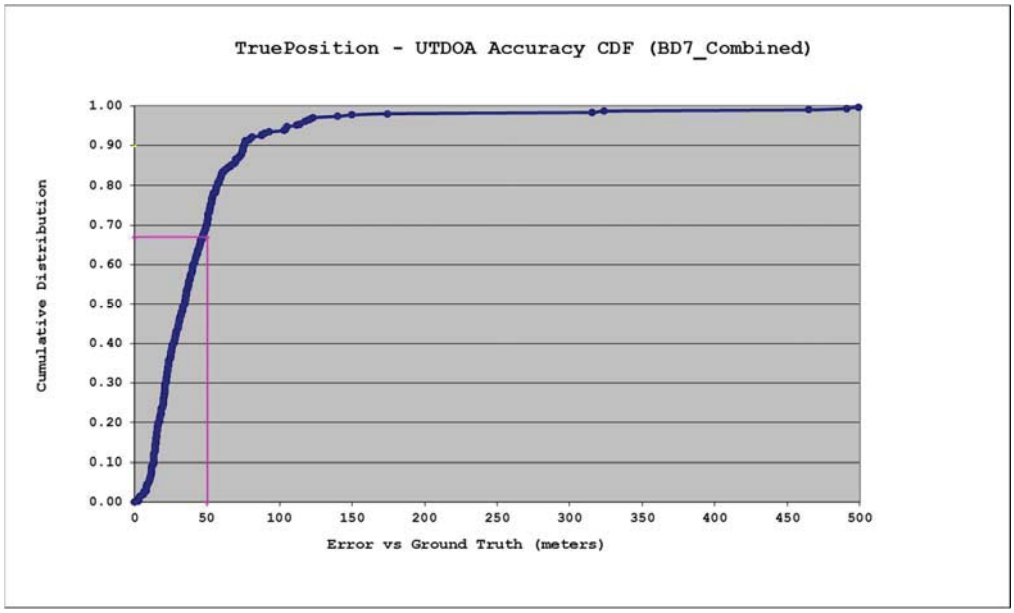

Figure 7.1-13. Bldg. 7 – UTDOA Location Error CDF

Figure 7.1-14. Bldg. 7 – UTDOA Location Scatter

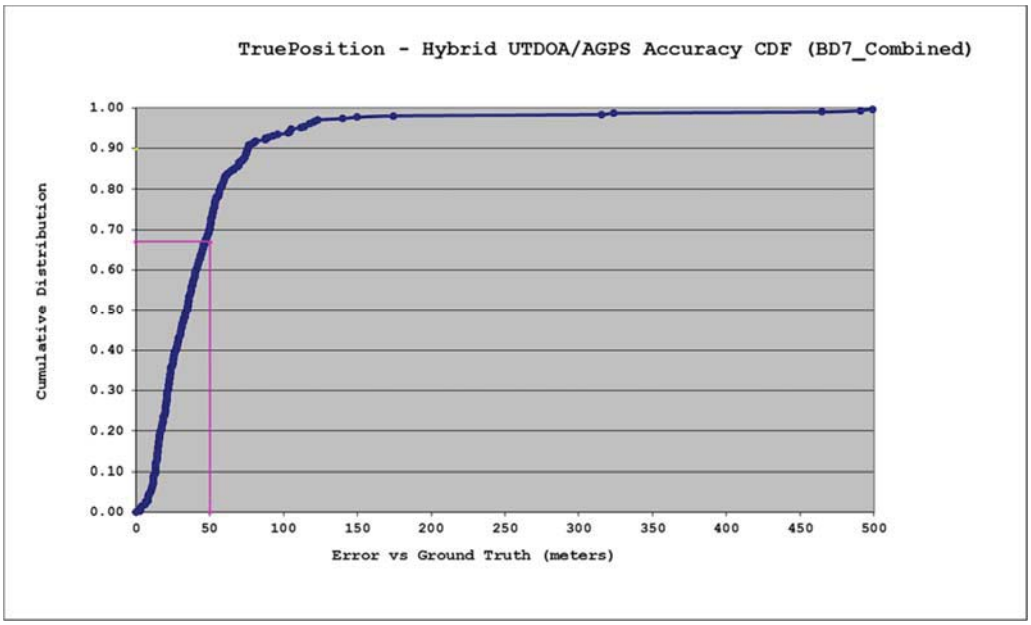

Figure 7.1-15. Bldg. 7 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.1-16. Bldg. 7 – Hybrid AGPS/UTDOA Location Scatter

7.1.5 Bldg. 9: "Tatnall" Building, Wilmington, DE

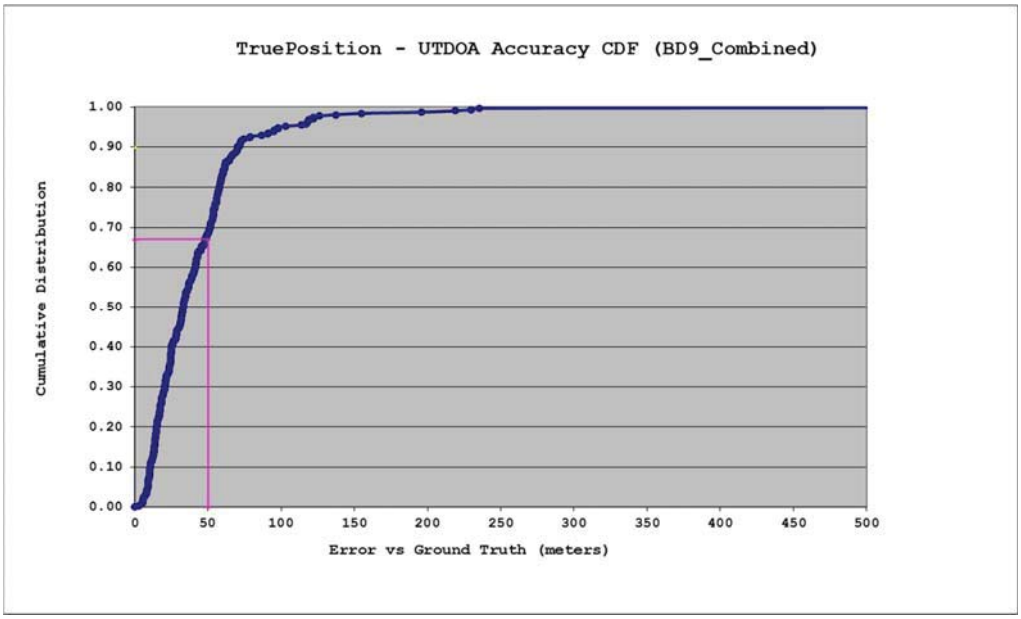

Figure 7.1-17. Bldg. 9 – UTDOA Location Error CDF

Figure 7.1-18. Bldg. 9 – UTDOA Location Scatter

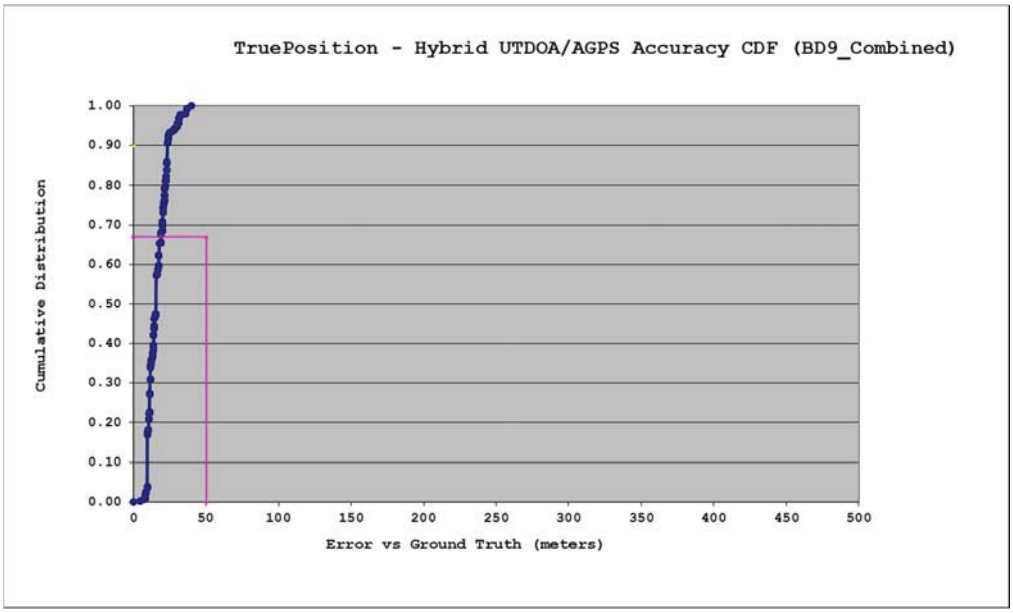

Figure 7.1-19. Bldg. 9 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.1-20. Bldg. 9– Hybrid AGPS/UTDOA Location Scatter

7.1.6 Bldg. 11: Grand Opera, Wilmington, DE

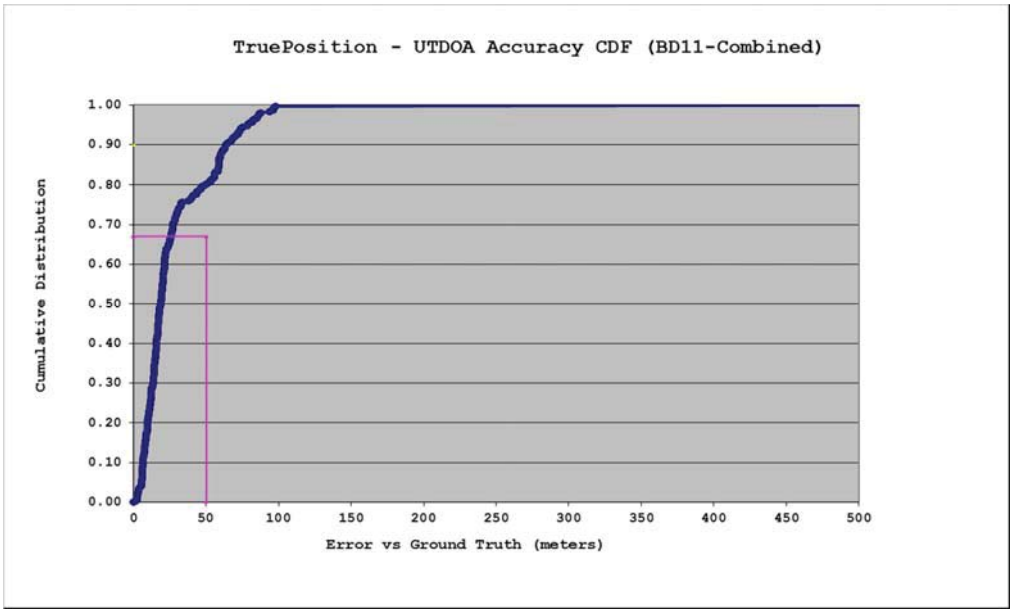

Figure 7.1-21. Bldg. 11 – UTDOA Location Error CDF

Figure 7.1-22. Bldg. 11 – UTDOA Location Scatter

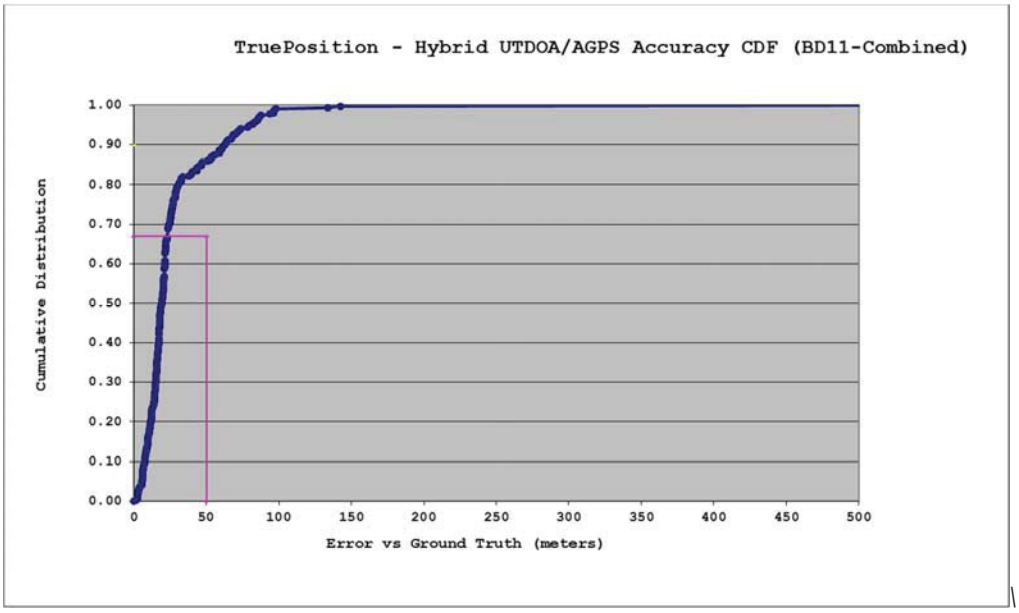

Figure 7.1-23. Bldg. 11 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.1-24. Bldg. 11 – Hybrid AGPS/UTDOA Location Scatter

7.1.7 Bldg. 12: Wilmington Library, Wilmington, DE

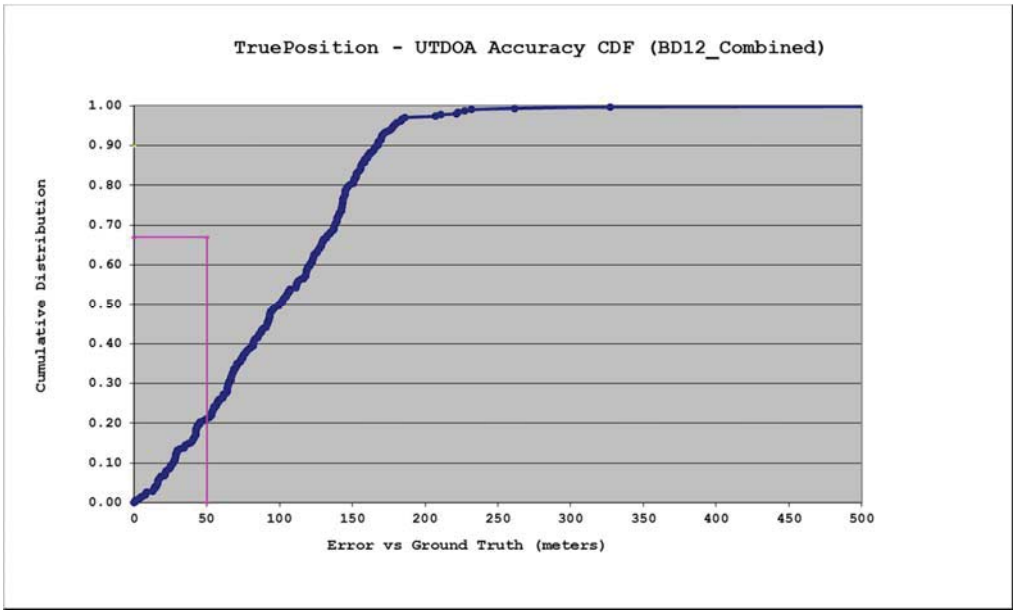

Figure 7.1-25. Bldg. 12 – UTDOA Location Error CDF

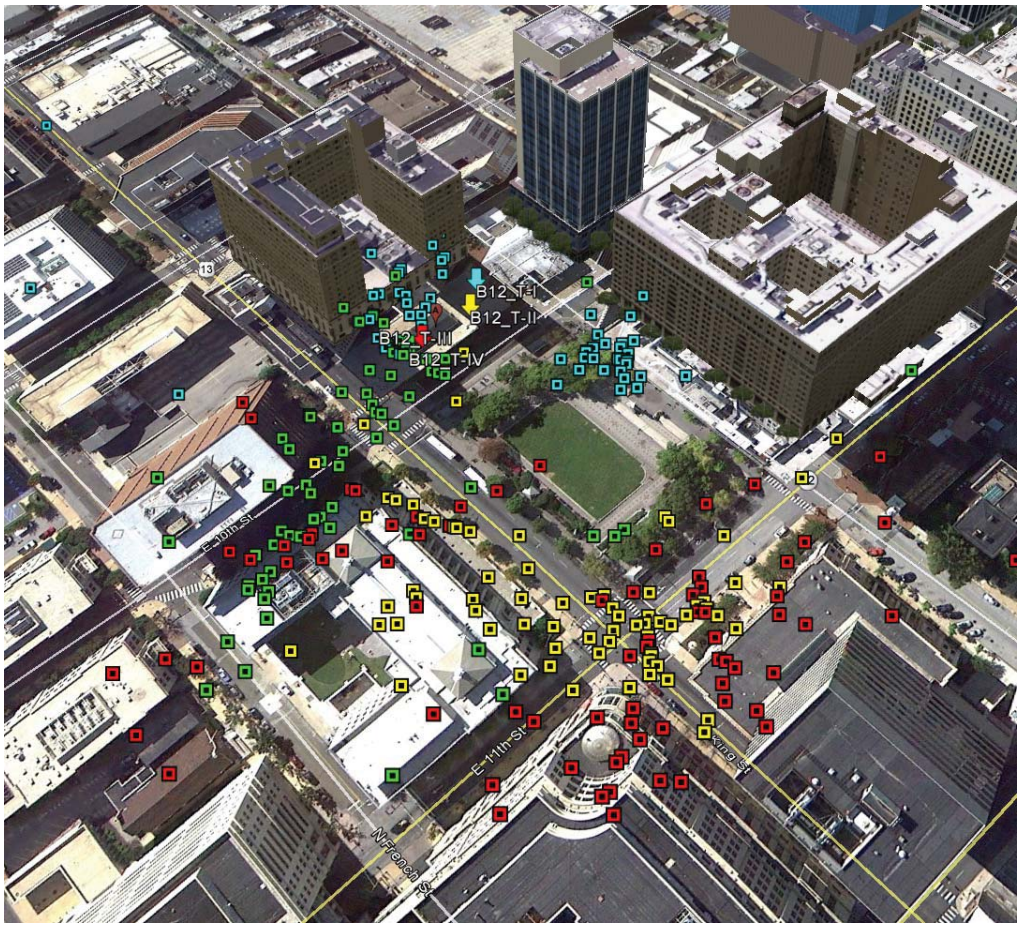

Figure 7.1-26. Bldg. 12 – UTDOA Location Scatter

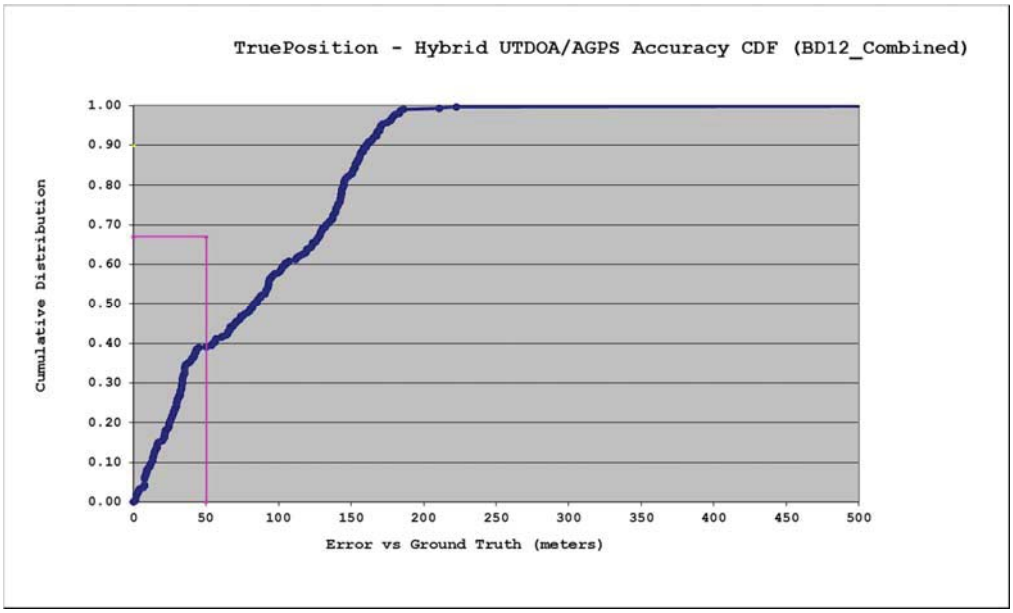

Figure 7.1-27. Bldg. 12 – Hybrid AGPS/UTDOA Location Error CDF

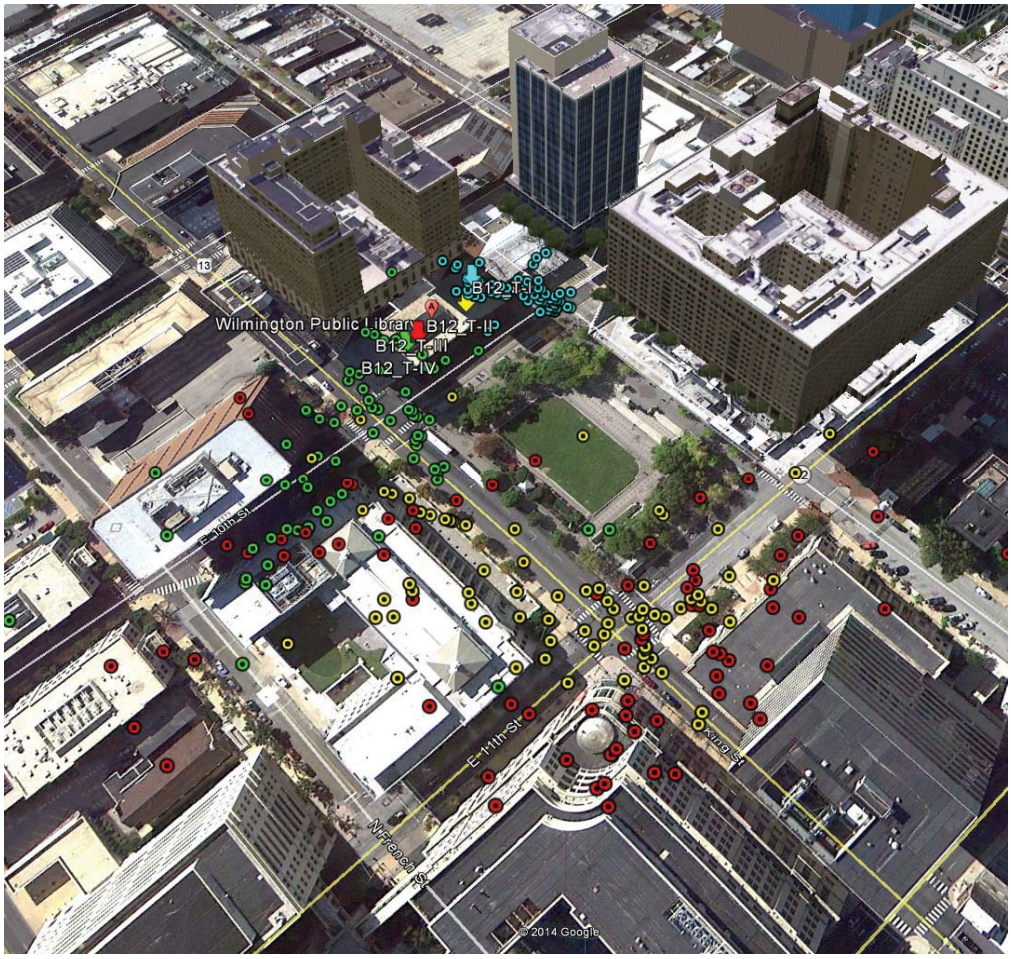

Figure 7.1-28. Bldg. 12 – Hybrid AGPS/UTDOA Location Scatter

7.1.8 Bldg. 13: Courtyard by Marriott, Wilmington, DE

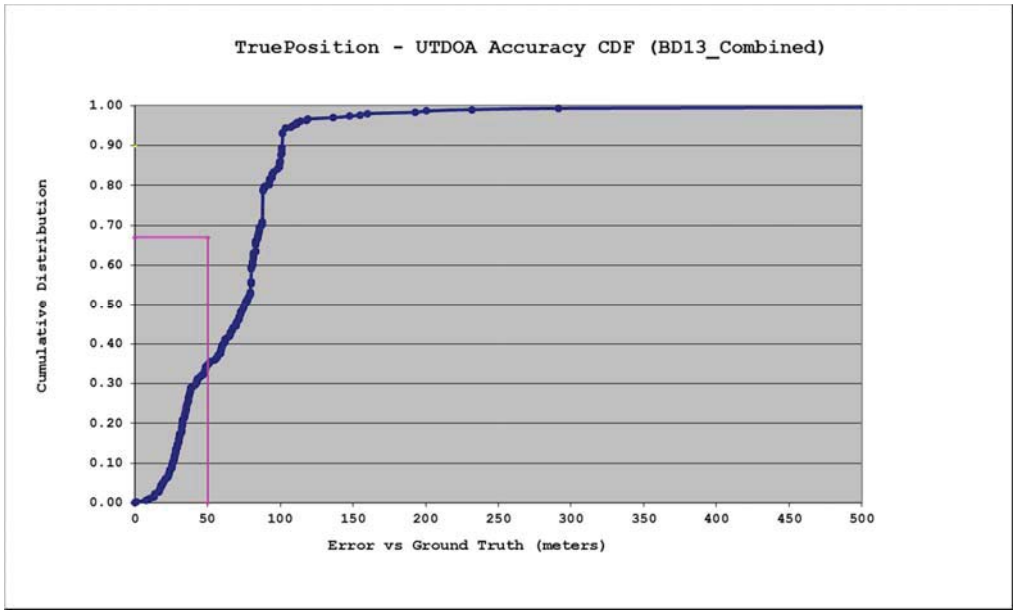

Figure 7.1-29. Bldg. 13 – UTDOA Location Error CDF

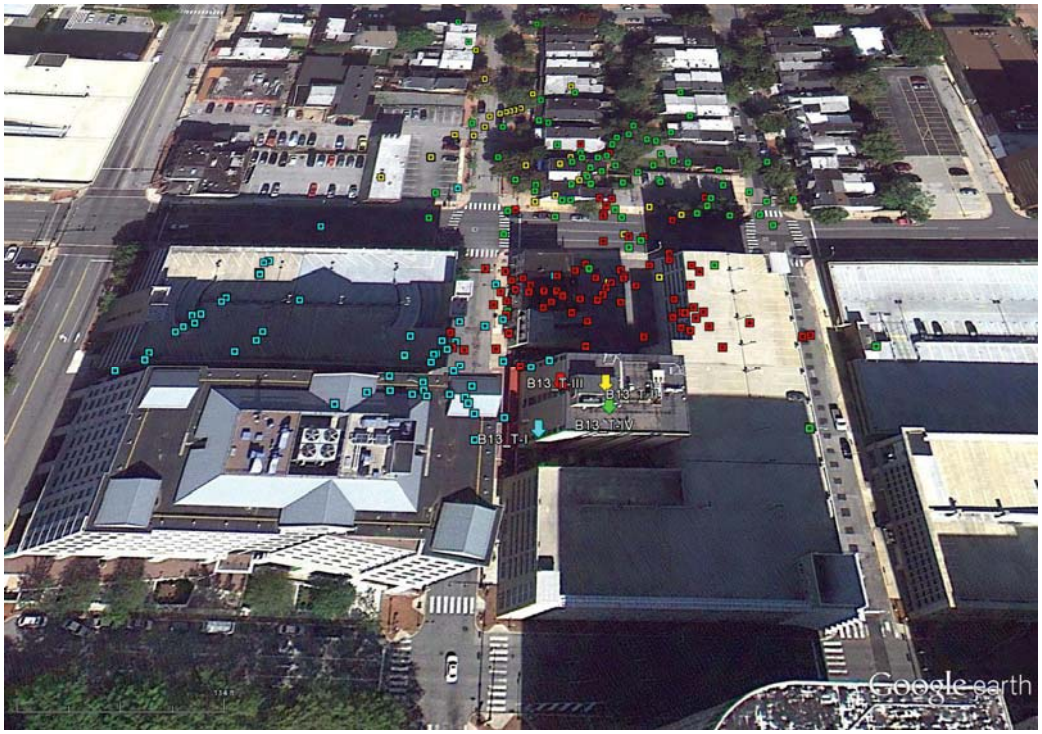

Figure 7.1-30. Bldg. 13 – UTDOA Location Scatter

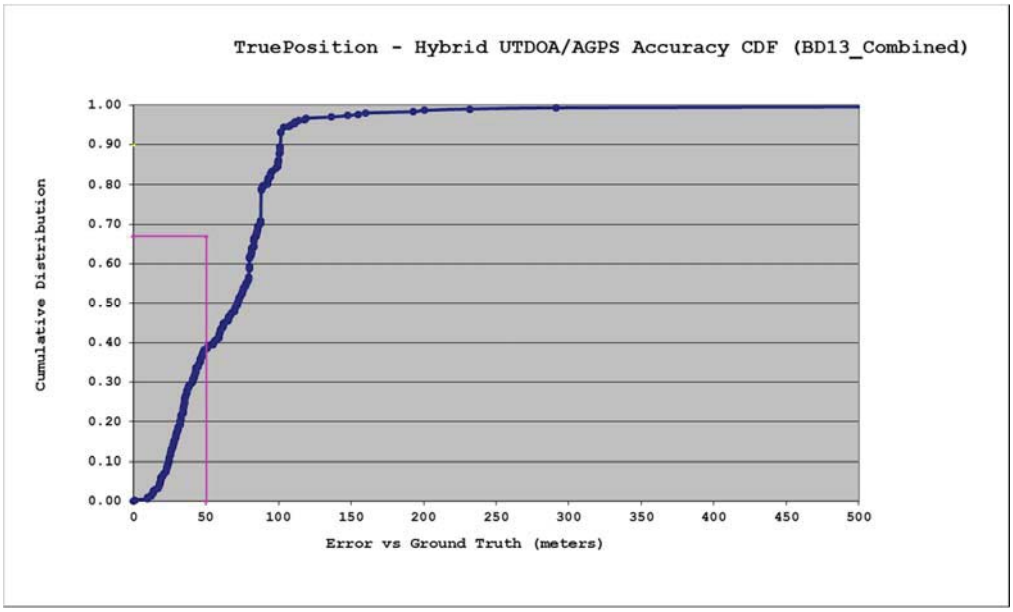

Figure 7.1-31. Bldg. 13 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.1-32. Bldg. 13 – Hybrid AGPS/UTDOA Location Scatter

7.2 Suburban Buildings

7.2.1 Bldg. 1: 2-Story Townhouse, Wilmington, DE

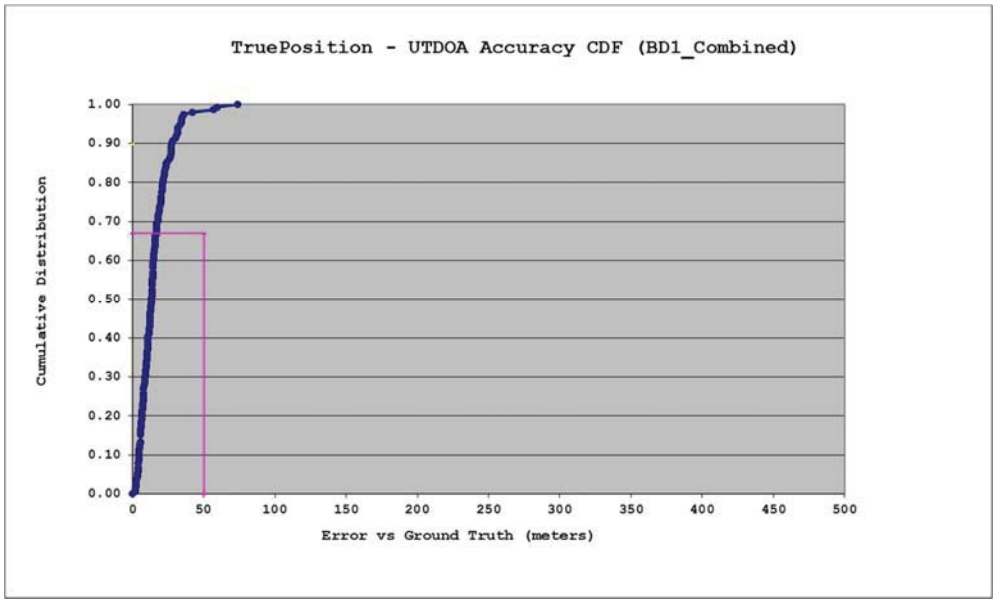

Figure 7.2-1. Bldg. 1 – UTDOA Location Error CDF

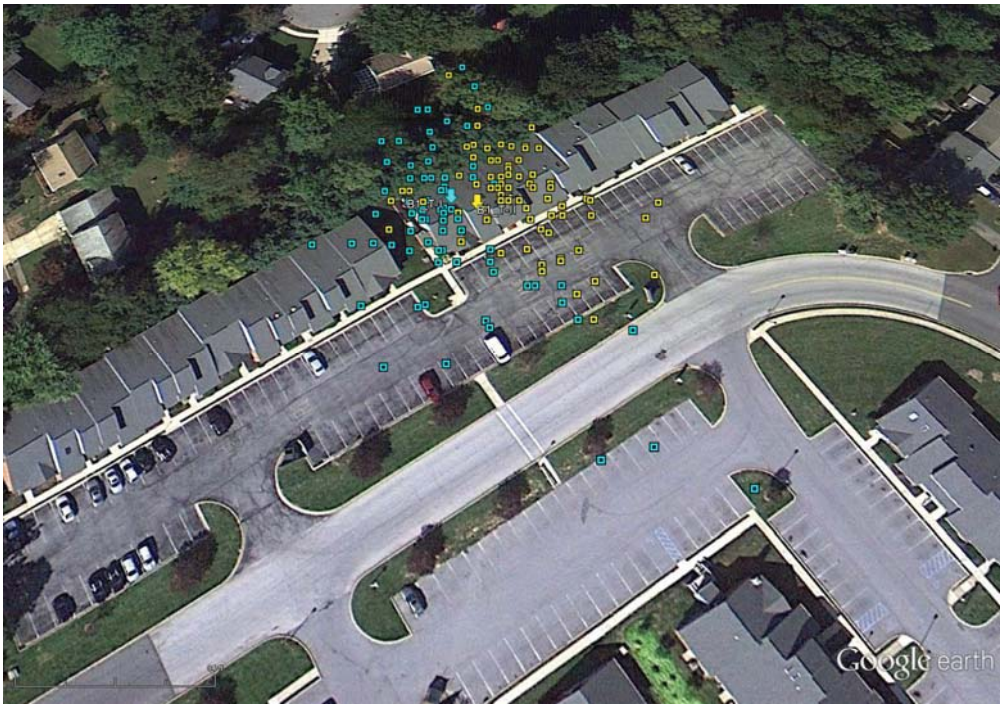

Figure 7.2-2. Bldg. 1 – UTDOA Location Scatter

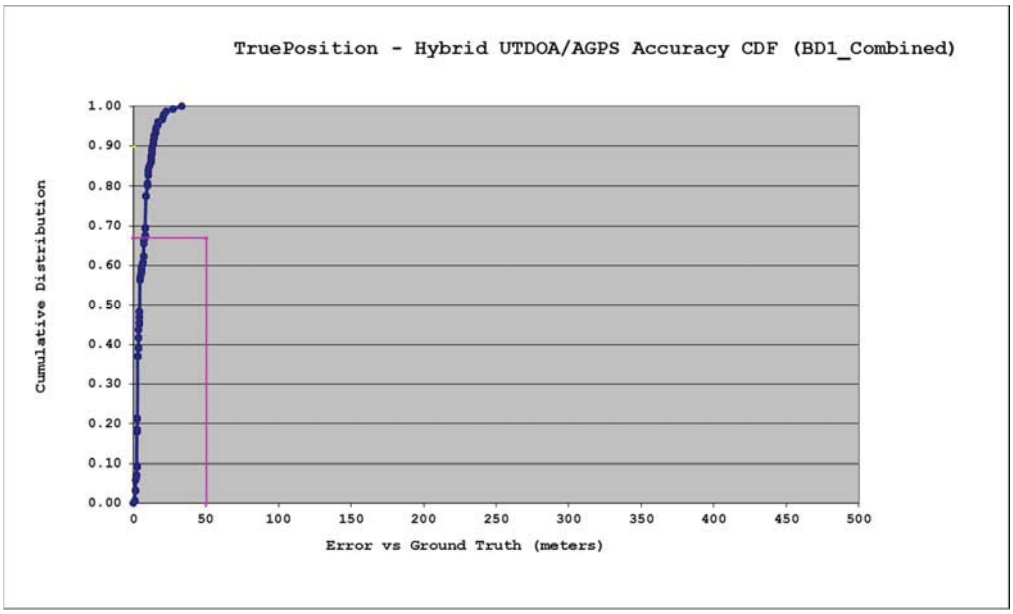

Figure 7.2-3. Bldg. 1 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.2-4. Bldg. 1 – Hybrid AGPS/UTDOA Location Scatter

7.2.2 Bldg. 2: Hilton Hotel, Newark, DE

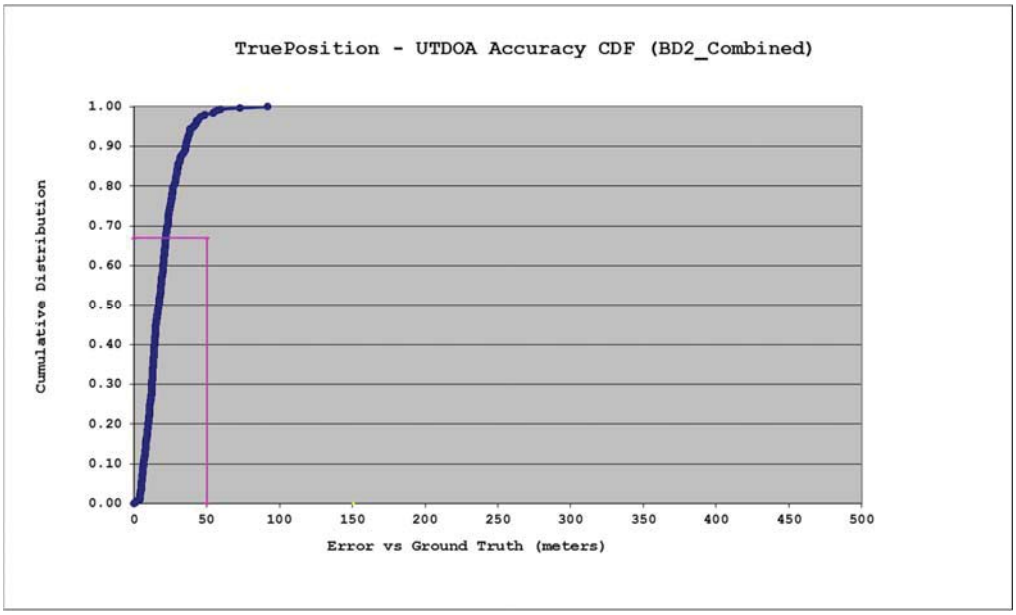

Figure 7.2-5. Bldg. 2 – UTDOA Location Error CDF

Figure 7.2-6. Bldg. 2 – UTDOA Location Scatter

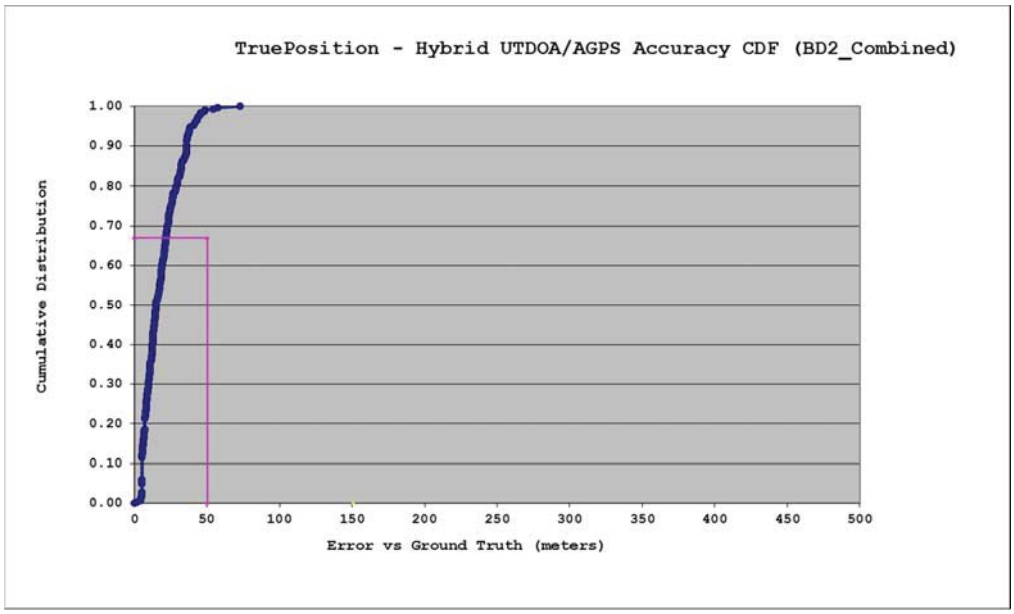

Figure 7.2-7. Bldg. 2 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.2-8. Bldg. 2 – Hybrid AGPS/UTDOA Location Scatter

7.2.3 Bldg. 4: Arbor Point Apartment Complex, Wilmington, DE

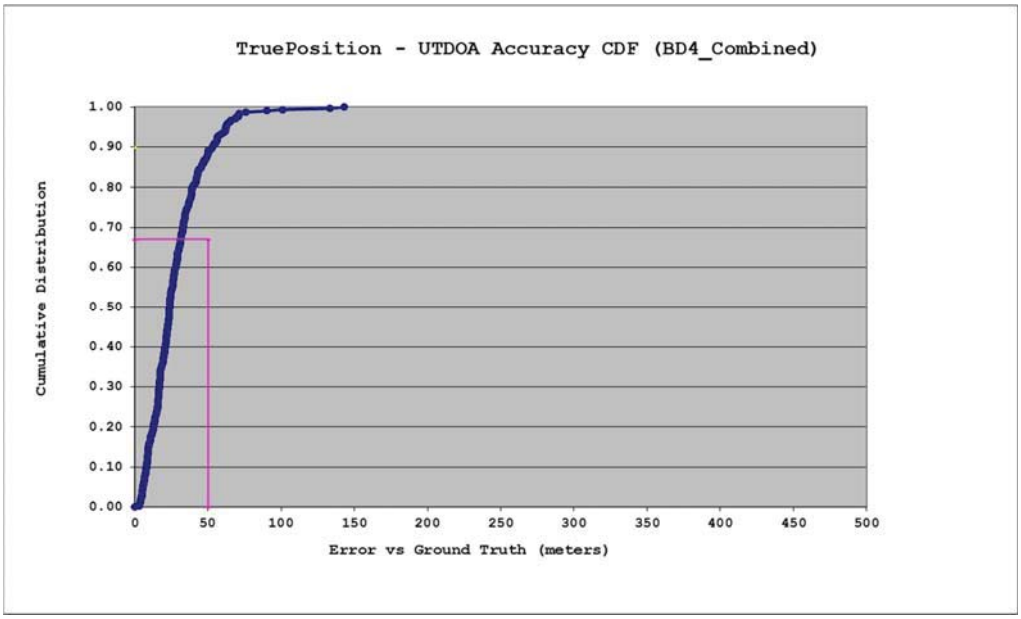

Figure 7.2-9. Bldg. 4 – UTDOA Location Error CDF

Figure 7.2-10. Bldg. 4 – UTDOA Location Scatter

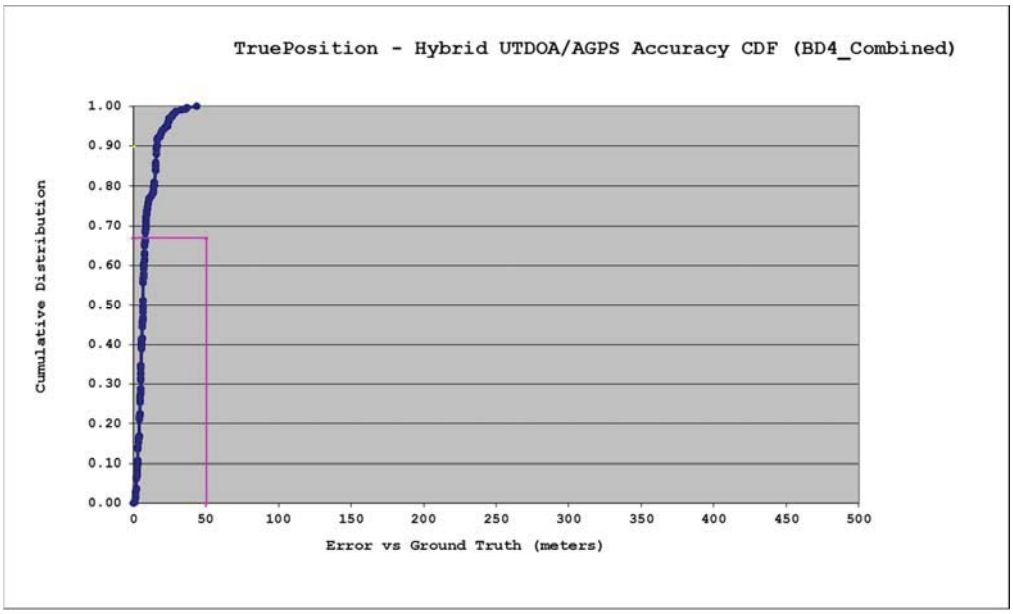

Figure 7.2-11. Bldg. 4 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.2-12. Bldg. 4– Hybrid AGPS/UTDOA Location Scatter

7.2.4 Bldg. 8: "Iron Hill" Office Building, Newark, DE

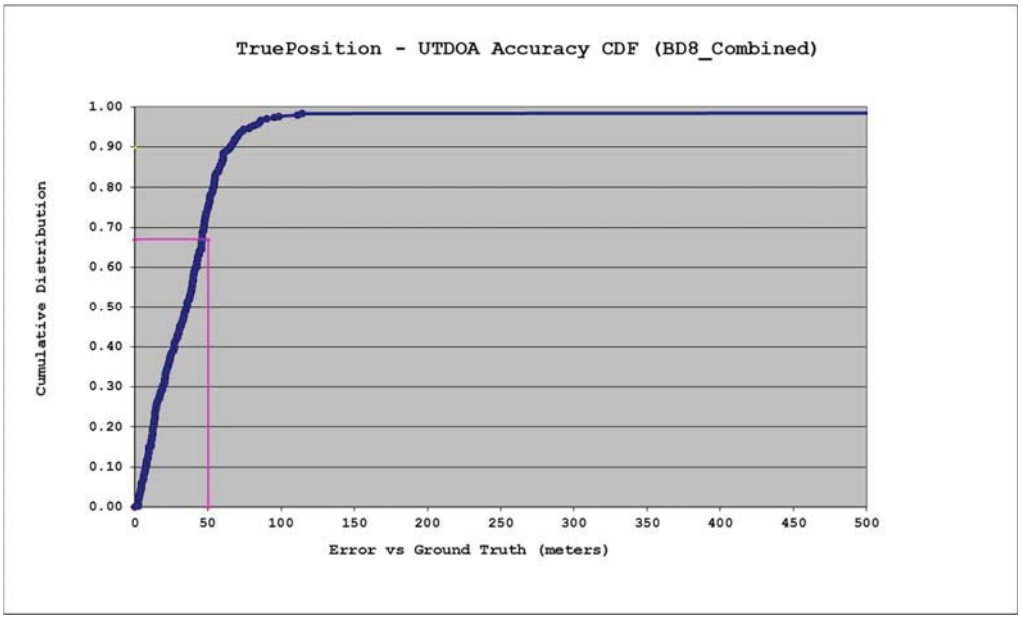

Figure 7.2-13. Bldg. 8 – UTDOA Location Error CDF

Figure 7.2-14. Bldg. 8 – UTDOA Location Scatter

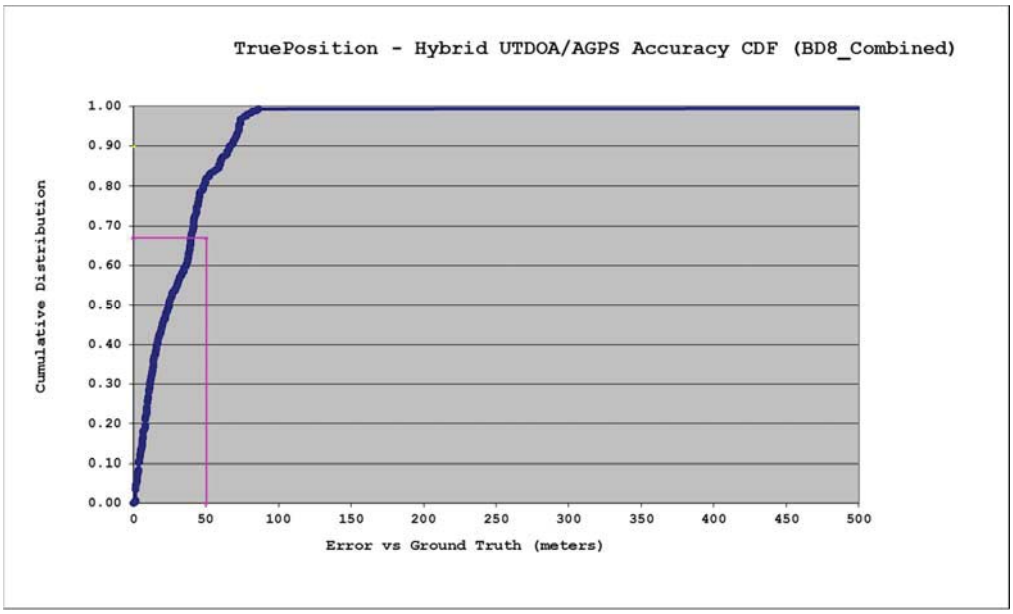

Figure 7.2-15. Bldg. 8 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.2-16. Bldg. 8 – Hybrid AGPS/UTDOA Location Scatter

7.2.5 Bldg. 10: Reybold Storage Building, Wilmington, DE

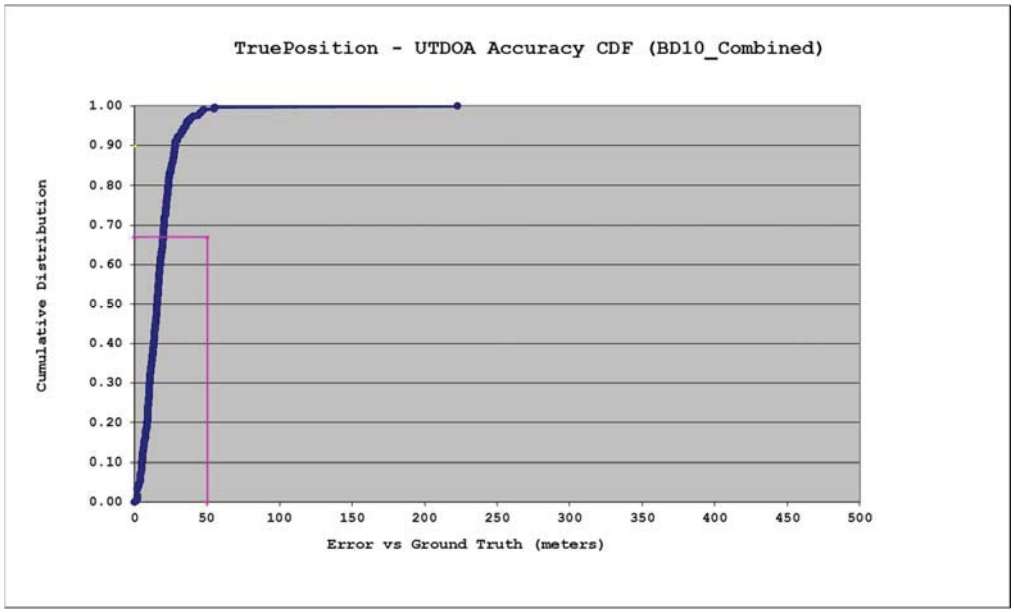

Figure 7.2-17. Bldg. 10 – UTDOA Location Error CDF

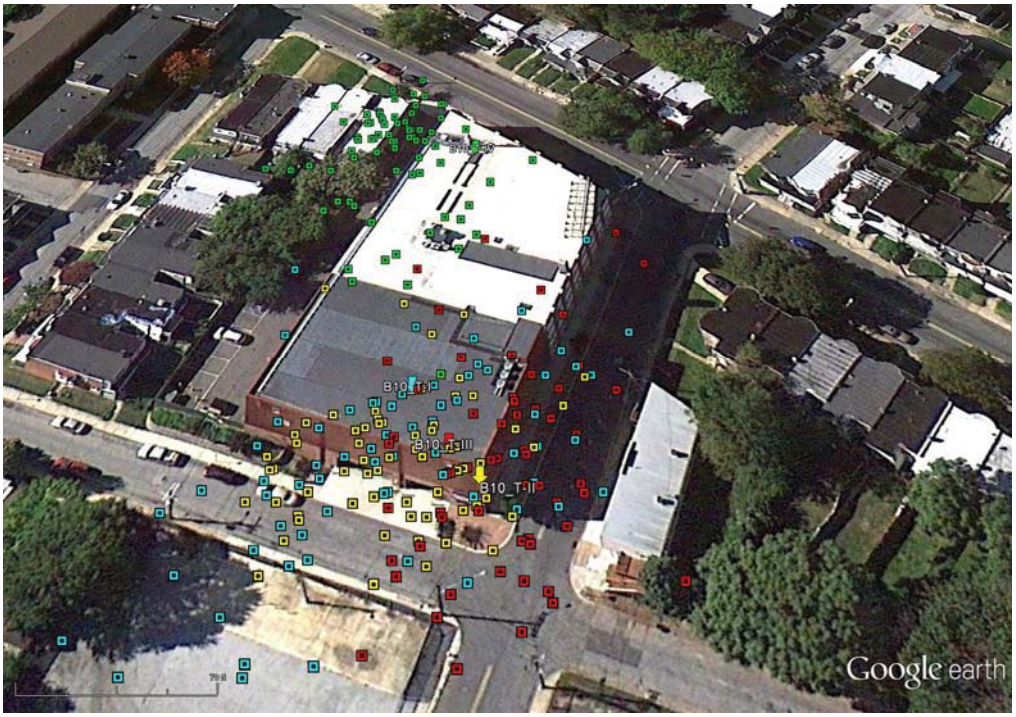

Figure 7.2-18. Bldg. 10 – UTDOA Location Scatter

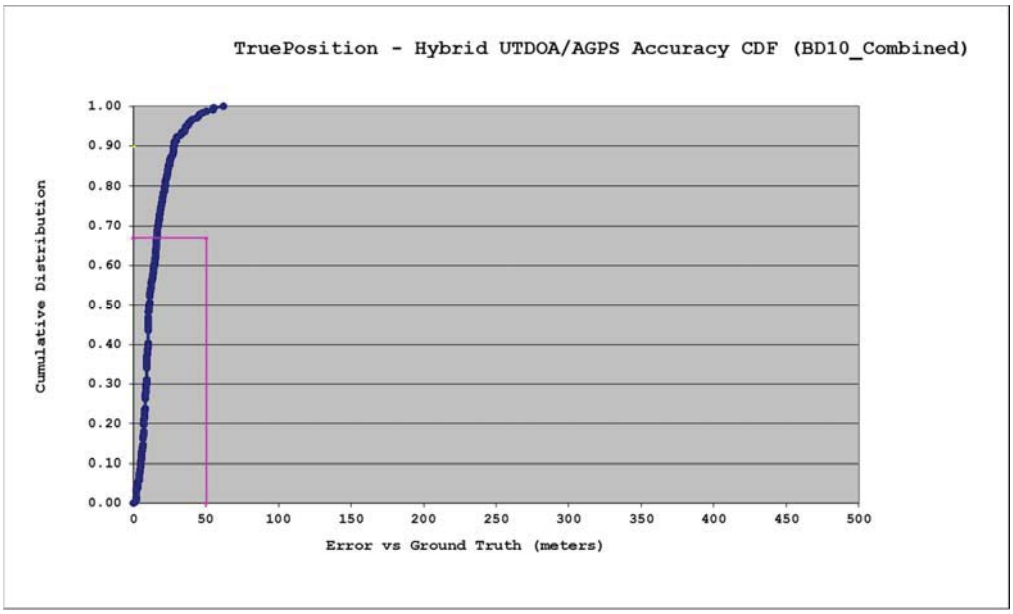

Figure 7.2-19. Bldg. 10 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.2-20. Bldg. 10 – Hybrid AGPS/UTDOA Location Scatter

7.2.6 Bldg. 14: Wilmington University Admissions Center, New Castle, DE

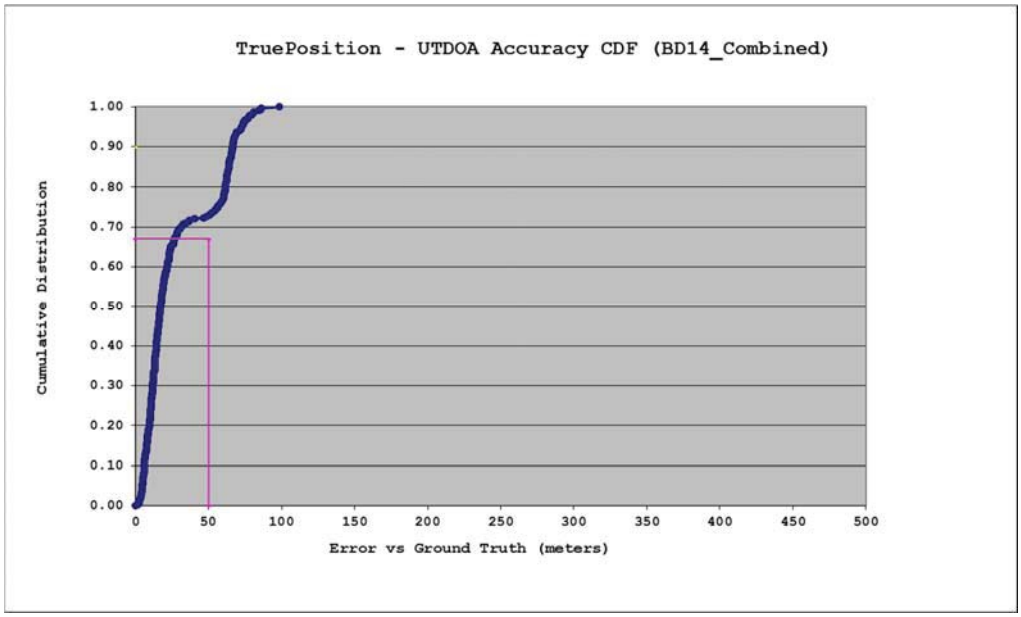

Figure 7.2-21. Bldg. 14 – UTDOA Location Error CDF

Figure 7.2-22. Bldg. 14 – UTDOA Location Scatter

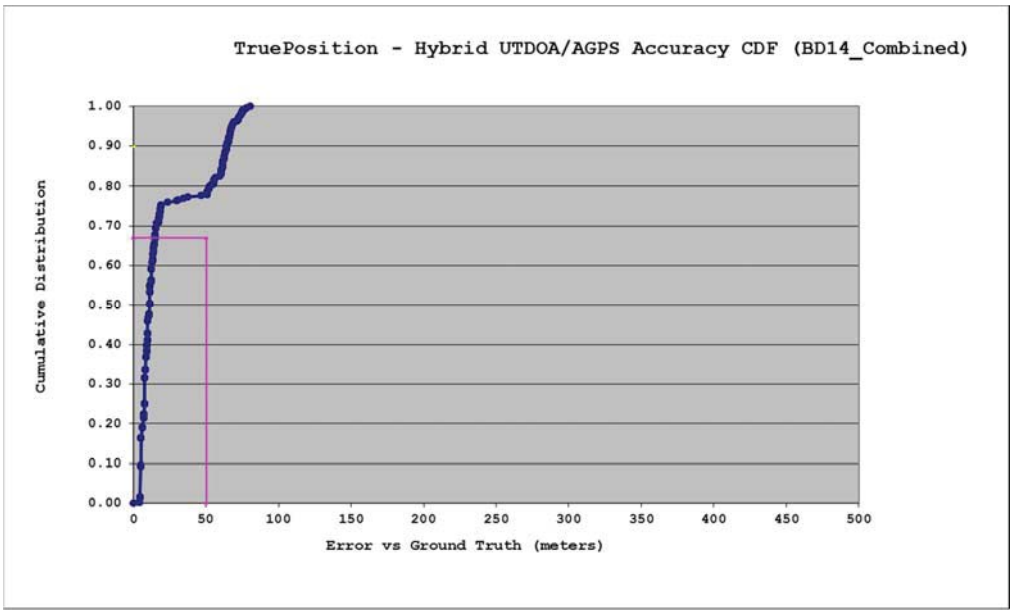

Figure 7.2-23. Bldg. 14 – Hybrid AGPS/UTDOA Location Error CDF

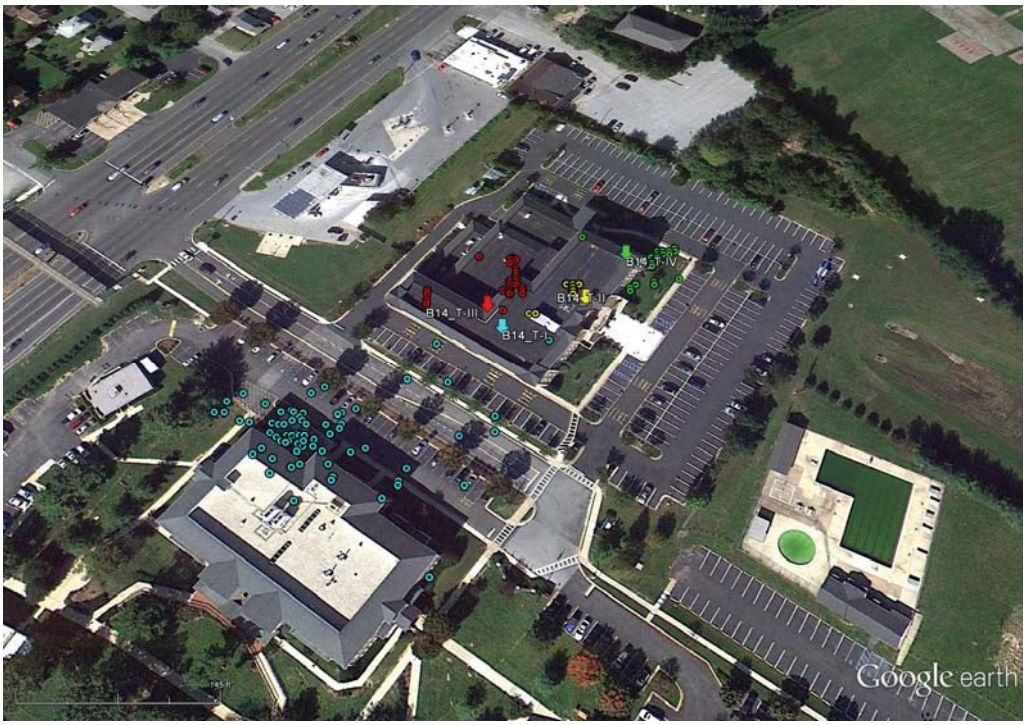

Figure 7.2-24. Bldg. 14 – Hybrid AGPS/UTDOA Location Scatter

7.2.7 Bldg. 15: Buccini Polin Headquarters, Wilmington, DE

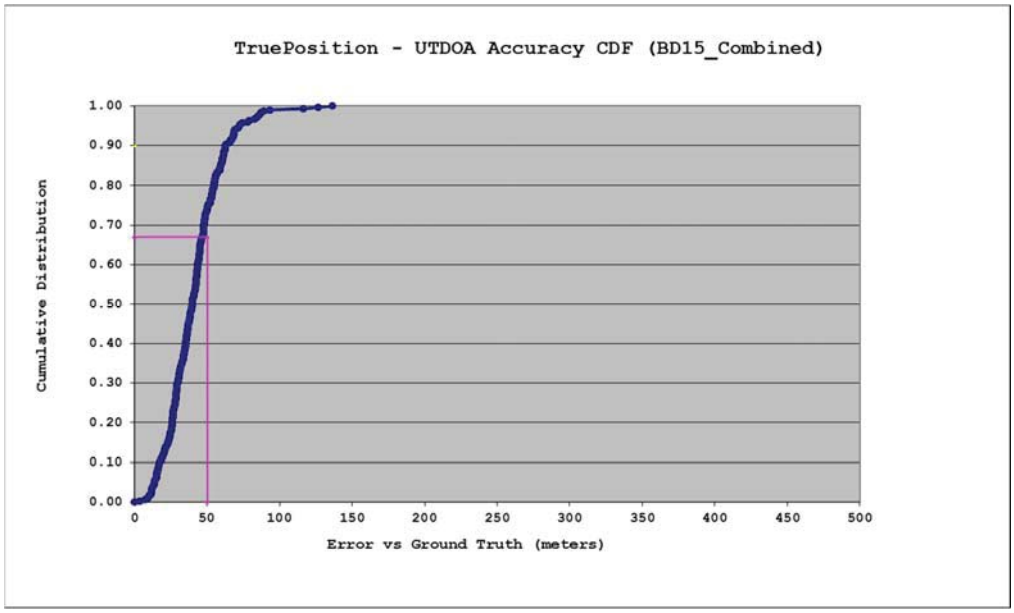

Figure 7.2-25. Bldg. 15 – UTDOA Location Error CDF

Figure 7.2-26. Bldg. 15 – UTDOA Location Scatter

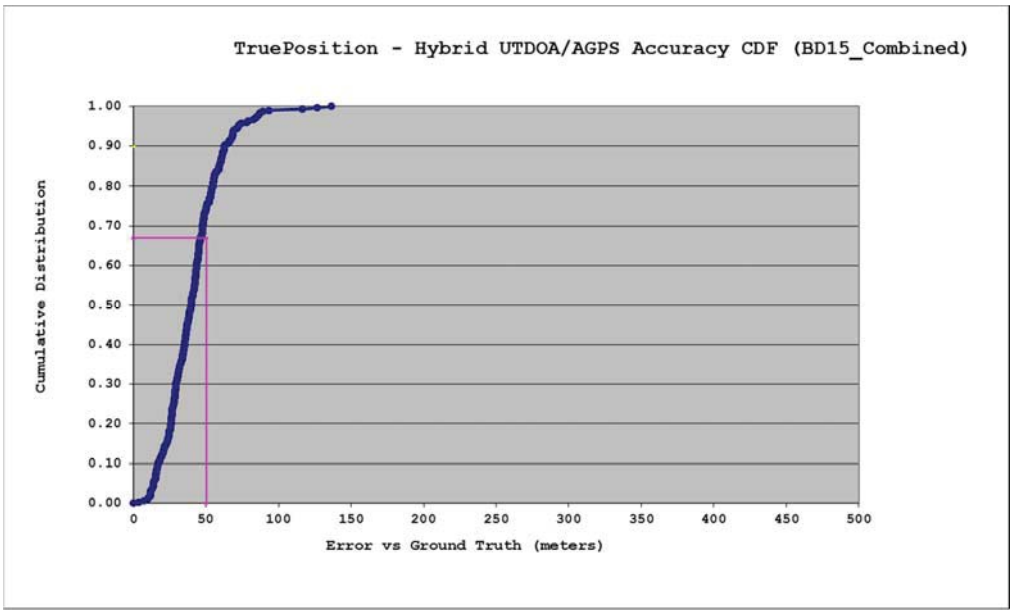

Figure 7.2-27. Bldg. 15 – Hybrid AGPS/UTDOA Location Error CDF

Figure 7.2-28. Bldg. 15 – Hybrid AGPS/UTDOA Location Scatter

7.2.8 Bldg. 16: Larch Business Center, Wilmington, DE

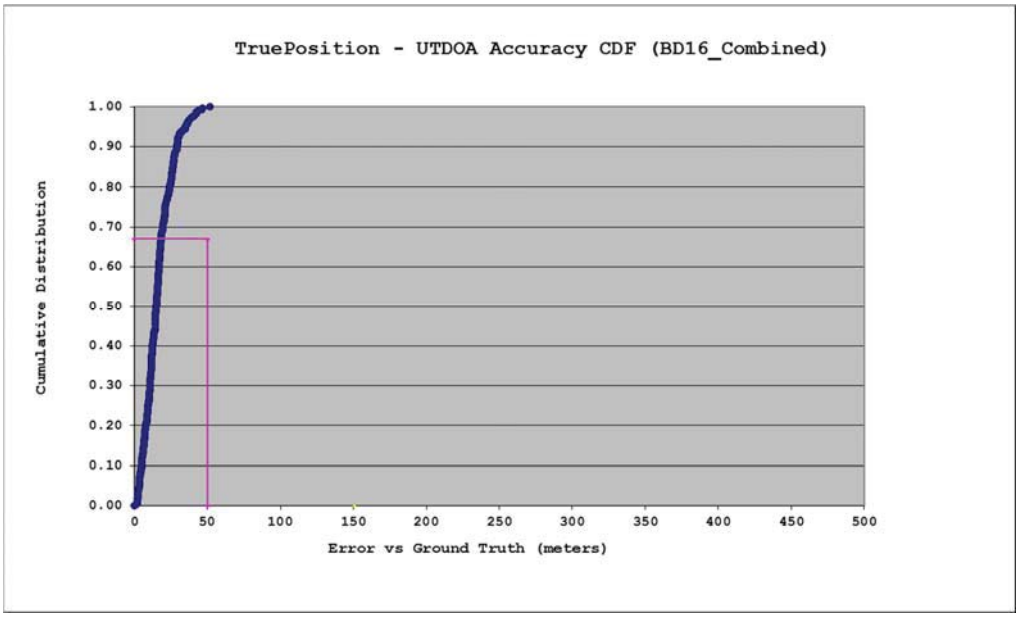

Figure 7.2-29. Bldg. 16 – UTDOA Location Error CDF

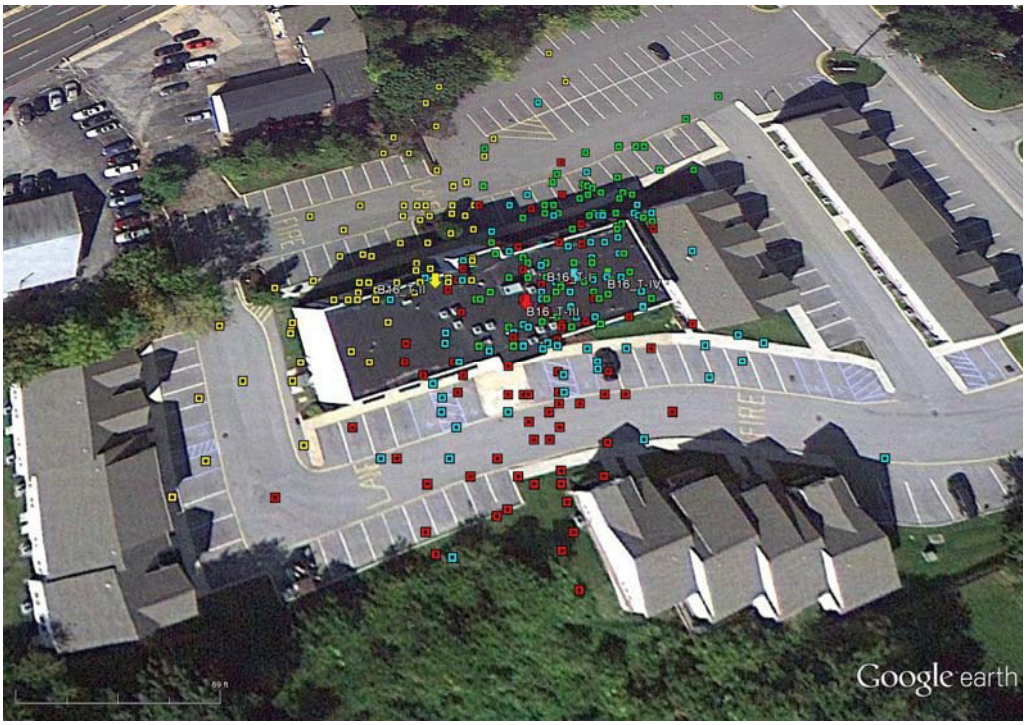

Figure 7.2-30. Bldg. 16 – UTDOA Location Scatter

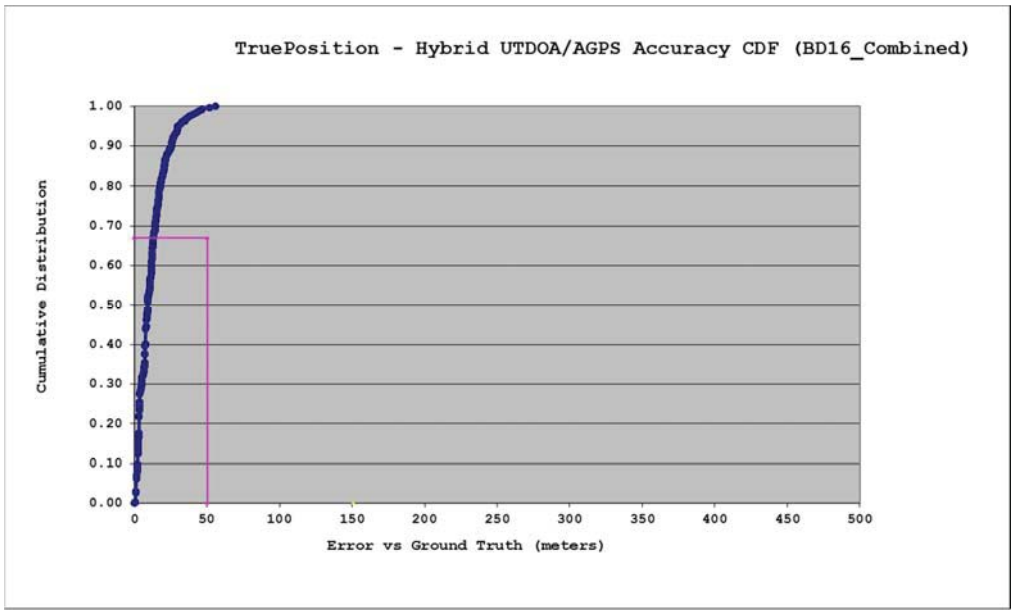

Figure 7.2-31. Bldg. 16– Hybrid AGPS/UTDOA Location Error CDF

Figure 7.2-32. Bldg. 16 – Hybrid AGPS/UTDOA Location Scatter

8 Summary Observations and Conclusions

Both TruePosition's UTDOA and Hybrid AGP/UTDOA solutions operating on emulated powered-up UMTS test calls have demonstrated very good indoor performance across the urban and suburban environments in and surrounding Wilmington, DE.

TechnoCom performed for TruePosition a similar but somewhat smaller scope test on its 2G (GSM) Hybrid UTDOA/AGPS solution in Wilmington in March 2013. The improvement in location accuracy with the current solution on UMTS is very evident. Reductions in the 67th and 90th percentile location errors approximately in the 40 to 60 percent range are observed under very similar morphology and test point conditions. The outcome is a current overall performance that readily meets the FCC's proposed location performance threshold for indoor wireless E911 at the 67th percentile. The demonstrated performance even comes very close to meeting the 50 meter threshold at 80%, which is proposed for 5 years from adoption of the rules.

Notably, a significant improvement in the indoor performance of the UTDOA component of the hybrid is demonstrated with the configuration tested. The higher bandwidth waveform of WCDMA UMTS coupled with the powered-up HSUPA data session (which emulates a powered-up emergency call from the handset) make possible the significant indoor UTDOA performance improvement. A relative improvement in the AGPS performance, albeit less significant, is also observed relative to the prior test in Wilmington. This resulted in better availability of AGPS fixes in challenging deep indoor locations. The test handset was a modern Samsung Galaxy S3, which supports GLONASS in addition to GPS, which likely contributed to the better deep indoor availability. However, in such deep indoor situations the UTDOA fix was very frequently superior in quality; i.e., lower in uncertainty and actual measured error, than the AGPS fix, and was the main location source used by the selection performed in the hybrid algorithm used by TruePosition. This is seen in comparing the per point CDFs provided in Appendix A (UTDOA) and Appendix B (Hybrid AGPS/UTDOA) and to a lesser extent in the per building aggregated CDFs in Section 7 above.

As can be concluded from the summary tables in Section 6, both the UTDOA and Hybrid solutions performed quite well in at least 5 out of the 8 urban buildings tested. Interestingly, the most challenged performance was in the 3 story Wilmington Library, a stone building surrounded by taller urban buildings some of them across an empty block. This created heavy construction material that challenged GPS and a unique geometry of strong reflectors for UTDOA. Equally interestingly, the performance was significantly better in the urban high rise surrounded by clutter, like building 7 the Wilmington Tower. What can be deducted here is that reflections from nearby clutter are less deleterious than reflections from 2 blocks away. This phenomenon is reminiscent of behavior observed in San Francisco during the CSRIC III testing and is an inherent characteristic of urban propagation and multilateration in urban environments. What should be kept in mind, however, is that a sample of buildings contains many more than one peculiar building. A building by itself is interesting anecdotally but is not a sufficient statistical sample.

Both the UTDOA and Hybrid UTDOA solutions performed quite well across all suburban buildings. Those ranged widely, from a storage building with few windows, to 3 story office buildings, to a 3 story university building, to smaller residential units.

Although because of the good performance of UTDOA alone, a relatively modest improvement appears to be gained from Hybrid over UTDOA, the scatter diagrams provided in Section 7 for the buildings shed more light on the qualitative gains from the availability of AGPS along with UTDOA. In several buildings at points where AGPS is of good quality it reduces the spread of the location error about the true location of the test point.

A minor issue identified from the test results pertained to the reliability of the reported uncertainty estimate. The reported uncertainty of UTDOA at times is not an accurate reflection of the actual quality of the location fix, often underestimating the quality of the fix in challenging buildings. This, however,

does not appear to have had material impact on the workings of the hybrid algorithm which used uncertainty comparison as an input.

The results and findings in this Wilmington test report are provided to the FCC so it can consider them, along with the other sources of data, in formulating its plan of action on the pending Third FNPRM.

Appendix A: UTDOA Performance Results Per Test Point

Appendix A is provided in a separate document/file due to size considerations.

Appendix B: Hybrid AGPS/UTDOA Performance Results Per Test Point

Appendix B is provided in a separate document/file due to size considerations.