ATIS STANDARD

ATIS-0500027

ATIS Standard on -

RECOMMENDATIONS FOR ESTABLISHING WIDE SCALE INDOOR LOCATION PERFORMANCE

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ATIS Standard

Recommendations for Establishing Wide Scale Indoor Location Performance

Alliance for Telecommunications Industry Solutions

Approved May, 2015

Abstract

This document provides the methodology to characterize wide-scale indoor location accuracy performance by creating regional test beds and extrapolating their test results. It provides the key parameters for a wide range of possible technologies, the consistency of which needs to be verified to enable the extrapolation process.

Foreword

The Alliance for Telecommunication Industry Solutions (ATIS) serves the public through improved understanding between providers, customers, and manufacturers. The Emergency Services Interconnection Forum (ESIF) provides a forum to facilitate the identification and resolution of technical and/or operational issues related to the interconnection of wireline, wireless, cable, satellites, Internet and emergency services networks.

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes an optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, ESIF, 1200 G Street NW, Suite 500, Washington, DC 20005.

At the time of consensus on this document, ESIF, which was responsible for its development, had the following leadership:

T. Reese, ESIF Chair (Ericsson)

J. English, ESIF 1st Vice-Chair (APCO International)

S. Sherwood, ESIF ESM Co-Chair (Verizon Wireless)

K. Springer, ESIF ESM Co-Chair (AT&T)

The **Emergency Services & Methodologies [ESM]** Subcommittee was responsible for the development of this document.

Executive Summary

This document addresses establishing wide scale indoor E911 location accuracy performance utilizing representative testing in a limited number of regional test beds. It builds upon and extends the methodology from ATIS-0500022, used successfully in the FCC's CSRIC III test bed performed in 2012. It establishes the methodology of extrapolating the test results derived from a given test bed to an area considerably wider than its confines, if certain conditions are met.

The document describes how to define a regional test bed and provides as examples the details for two of proposed six such test beds selected across the U.S to capture its regional variations. Each regional test bed, defined in and around a metropolitan area, is chosen to be sufficiently geographically wide to capture the various wireless environments in its region. Each test bed thus represents a network's morphologies, signal coverage and network technologies associated with E911 location determination and delivery in its region. For the two detailed test beds, the morphology polygon boundaries, applicable test cases, and candidate building types are provided to illustrate the similar technical approach and regional modifications.

This document also provides a compilation of a wide range of location technologies, both established and emerging, that could be used indoors, and a detailed listing of the parameters the similarity of which has to be satisfied to permit the proper extrapolation of the indoor accuracy results. These parameters fall into two broad categories: environmental conditions and location technology deployment options. Key parameters in both categories are identified and enumerated for each type of location technology.

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ATIS Standard –

Recommendations for Establishing Wide Scale Indoor Location Performance

1 Introduction

Over the past decade, ESIF has played a key role in defining the widely accepted test methodologies for wireless E911 location accuracy. The consensus within ESIF ESM among the various E911 stakeholders, including wireless carriers, public safety, location technology vendors, location network infrastructure, and service providers, has fostered the creation of standard methodologies that encompass the perspectives and concerns of all stakeholders, thereby leading to broad adoption of these methodologies.

Over the last several years, the pervasive use of wireless devices and its steadily increasing replacement of wireline telephony has been strongly felt in E911. Today, the majority of emergency calls to 911 are placed from wireless devices and an increasing percentage of those E911 calls are placed from indoor locations. The FCC's 3rd FNPRM in March 2014 on wireless location accuracy and its recent Fourth Report and Order (Feb 2015) specifying current wireless E911 location accuracy requirements reflect the criticality of indoor location.

ESIF has been a key contributor to the FCC's efforts to gather reliable, unbiased information of indoor location performance. This is exemplified by the test methodology definition in ATIS-0500022 provided to the FCC's CSRIC III for its indoor test bed in San Francisco in 2012. The current document is a continuation of ESIF's leading contributions to the test and evaluation of indoor wireless location. It provides detailed recommendations and guidelines for establishing wide scale indoor location performance based on representative testing in a limited number of test bed regions selected across the U.S. The latest FCC's Report and Order accepts this approach as the framework to establish compliance with its E911 location accuracy requirements.

2 Scope, Purpose, & Application

2.1 Scope

This document presents guidelines for creating representative, regional wireless location indoor test beds. The regional test beds selected and presented herein are representative of the different areas of the country (e.g., Philadelphia is representative of the Northeast). Each test bed contains various types of indoor structures typical of its region together with corresponding indoor test scenarios.

These regional test beds can be used in assessing the indoor performance of various wireless location technologies, whether during their initial evaluation or upon wider deployment. Together with approaches defined in this document to extrapolate the results from a given regional test bed, the results can be applied to a much wider area with similar characteristics. The consensus in this ESIF committee is that representative indoor testing in properly selected regional test beds should form the basis for establishing accuracy compliance, in lieu of widespread (and impractical) localized indoor testing, e.g., at the county level. The FCC in its recent Fourth Report and Order has accepted this methodology as the framework to establish network-wide compliance with its stated requirements for E911 location accuracy.

This document with its guidelines, which focuses on indoor location, is separate and distinct from ATIS-0500001 "High Level Requirements for Accuracy Testing Methodologies". ATIS-0500001 provides guidelines for the testing of E911 wireless location technologies for compliance with the E911 Phase II FCC-mandated ***outdoor*** location accuracy requirements outlined in FCC Docket 94-102, Third Report and Order.

Other topics that are not addressed in this document include static versus dynamic indoor testing and use of warm versus hot start (with no erasure of prior position). These topics are to be addressed in future efforts by ESM as technology evolves. Additionally, the topic of how to apply the described test methodology to smaller carriers who may not have coverage in the recommended test regions is deferred to future additions to this document.

2.2 Purpose

The purpose of this document is to identify a framework for testing indoor location technologies for E911 and establishing expected performance of those technologies on a wide scale. It is also intended to support an indoor accuracy compliance process to demonstrate meeting the wireless E911 location accuracy requirements specified in the FCC's Fourth Report and Order. This framework is based on using a set of representative, regional indoor test beds that can be used for indoor location accuracy assessment in lieu of widespread localized indoor accuracy testing. The regional test beds are described along with the parameters that can be used and the requirements to be satisfied in the extrapolation process from a regional test bed to a much wider area with similar characteristics.

For two of the identified test bed locations, the San Francisco Bay Area (including San Jose and its surroundings) and Greater Philadelphia, this document outlines in some detail the polygons around the representative morphologies in each of the test bed areas. It also identifies for those two test beds the region-appropriate types of permanent structures and different call scenarios within a given structure. These details are intended to serve as guidelines for the remaining test bed locations, for the creation of polygons, and the identification of appropriate permanent structures and test scenarios.

2.3 Application

The guidelines in this document are to be used in establishing regional, representative indoor test beds for the assessment of indoor wireless location accuracy, including the identification of associated region-appropriate permanent structures and indoor call scenarios.

3 References

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

3GPP TS 36.305, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; *Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN*, (Stage 2 specifications for OTDOA, U-TDOA and E-CID).[1]

3GPP TS 36.455, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; *Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol A (LPPa)*, (LPP Annex for OTDOA, U-TDOA and E-CID).[2]

FCC 14-13, PS Docket No. 04.114, 3rd FNPRM, *Third Further Notice of Proposed Rulemaking In the Matter of Wireless E911 Location Accuracy Requirements*.[3]

ATIS-0500001, *High Level Requirements for Accuracy Testing Methodologies.*[4]

ATIS-0500013, *Approaches to Wireless E9-1-1 Indoor Location Performance Testing.*[5]

ATIS-0500022, *Test Plan Input for a Location Technology Test Bed.*[6]

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[1] This document is available from 3GPP: <http://www.3gpp.org/specs/specs.htm>.

[2] This document is available from 3GPP: <http://www.3gpp.org/specs/specs.htm>.

[3] This document is available from the Federal Communications Commission, 445 12th Street, SW, Washington, DC 20554: < http://www.fcc.gov >.

[4] This document is available from the Alliance for Telecommunications Industry Solutions, 1200 G Street, NW Suite 500 | Washington, DC, 20005: < https://www.atis.org/docstore/product.aspx?id=26036 >.

[5] This document is available from the Alliance for Telecommunications Industry Solutions, 1200 G Street, NW Suite 500 | Washington, DC, 20005 < https://www.atis.org/docstore/product.aspx?id=25009 >.

BeiDou OSS2.0, *BeiDou Navigation Satellite System Signal in Space Interface Control Document Open Service Signal (Version 2.0).*[7]

CSRIC III-WG3, *Indoor Test Report to CSRIC III-WG3.*[8]

FCC 15-9, PS Docket No. 07-114, *FCC Fourth Report and Order In the Matter of Wireless E911 Location Accuracy Requirements*, Adopted January 29, 2015.[9]

FCC 99-245, CC Docket No. 94-102, *FCC Third Report and Order In the Matter of Revision of the Commission's Rules To Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Adopted September 15, 1999.[10]

Galileo, *European GNSS (Galileo) Open Service Signal In Space Interface Control Document.*[11]

GLONASS, *Global Navigation Sattelite [sic] System GLONASS Interface Control Document.*[12]

IS-GPS-200, *Global Positioning Systems Directorate Systems Engineering & Integration Interface Specification IS-GPS-200, Navstar GPS Space Segment/Navigation User Interfaces*, September 24, 2013.[13]

ESIF-ESM-2015-00038R001, MBS-ICD, *NextNav Metropolitan Beacon System (MBS) ICD*.[14]

4 Definitions, Acronyms, & Abbreviations

For a list of common communications terms and definitions, please visit the *ATIS Telecom Glossary*, which is located at < http://www.atis.org/glossary >.

4.1 Definitions

4.1.1 GNSS (Global Navigation Satellite System): GNSS is a system of satellites that provide autonomous geo-spatial positioning with continuous global coverage; GPS is considered to be the first GNSS system. GNSS receivers operate primarily in the 1559-1610 MHz Radio Navigation Satellite Service (RNSS) allocation. Other GNSS operations include Russia's Global Navigation Satellite Systems (GLONASS) system (which is the only globally operational system other than GPS), and the Chinese BeiDou (COMPASS) and European Galileo systems (which are not yet operating globally).

4.1.2 Morphology: Used here to describe building density and height as in rural vs. dense urban.

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[6] This document is available from the Alliance for Telecommunications Industry Solutions, 1200 G Street, NW Suite 500 | Washington, DC, 20005: < https://www.atis.org/docstore/product.aspx?id=27856 >.

[7] This document is available from the China Satellite Navigation Office:
< http://www.beidou.gov.cn >.

[8] This document is available from the Federal Communications Commission, 445 12th Street, SW, Washington, DC 20554: <http://www.fcc.gov > .

[9] This document is available from the Federal Communications Commission, 445 12th Street, SW, Washington, DC 20554: < http://www.fcc.gov >.

[10] This document is available from the Federal Communication Commission, 445 12th Street, SW, Washington, DC 20554: < http://www.fcc.gov >.

[11] This document is available from the European Commission: < http://ec.europa.eu >.

[12] This document is available from Russian Space Systems: < http://www.spacecorp.ru >.

[13] This document is available from the National Coordination Office for Space-Based Positioning, Navigation, and Timing: < http://www.gps.gov >.

[14] ESIF committee participants can access this document at < http://access.atis.org >. Copies of this contribution will be made available to all other interested parties upon request. Such request should be to the ATIS Document Center Administrator at < doccenter@atis.org >.

4.1.3 Position Calculation Methods:

- Proximity: Can hear signal X, therefore must be “close” to the position of signal X
    - E.g., Cell sector, Wi-Fi beacon, Blue Tooth LE beacon
- Multilateration: Uses distance from multiple transmitters to find common point of intersection
    - E.g., GPS, OTDOA, AFLT, TBS, U-TDOA, Wireless WAN RTT, Wi-Fi RTT
- Signal Strength: stronger signals are closer, weaker signals are farther away
    - E.g., RF Pattern matching, Wi-Fi RSSI

4.2 Acronyms & Abbreviations

AFLT	Advanced Forward Link Trilateration
A-GLONASS	Assisted GLONASS
A-GNSS	Assisted Global Navigation Satellite System
A-GPS	Assisted Global Positioning System
ATIS	Alliance for Telecommunications Industry Solutions
CSRIC	Communications Security, Reliability and Interoperability Council
DAS	Distributed Antennae System
ESIF	Emergency Services Interconnection Forum
ESIF-ESM	Emergency Services & Methodologies (subcommittee of Emergency Services Interconnection Forum)
ESRI	Commercial GIS company (Originally: Environmental Systems Research Institute)
FCC	Federal Communications Commission
FNPRM	Further Notice of Proposed Rulemaking
GIS	Geographic Information System
GLONASS	Global Navigation Satellite System (Russian)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HVAC	Heating Ventilation Air Conditioning
LMU	Location Measurement Unit
OTDOA	Observed Time Difference of Arrival
PRS	Positioning Reference Signal
PSAP	Public Safety Answering Point
QGIS	Quantum GIS – a specific example of a GIS system that is an open source software project
RF	Radio Frequency
RF Pattern Matching	Radio Frequency Pattern Matching
RTT	Round Trip Time

TBS	Terrestrial Beacon System
U-TDOA	Uplink Time Difference of Arrival
Wi-Fi	wireless local area network (WLAN) using (IEEE) 802.11 standards

5 Proposed Performance Characterization Approach

Performance characterization of indoor wireless location environments requires a different approach from that used in the characterization of outdoor location system performance. The indoor environment is typically defined as any environment with a covered structure. Performance of a location system varies widely in indoor environments because of the morphology where the indoor location is situated, the building construction type, where inside the building the tests are being conducted, etc. Unlike the outdoor environment where widespread drive tests are possible, the indoor environment does not scale as easily and therefore requires a more nuanced and balanced approach to testing.

A variety of factors contribute to the major differences between indoor and outdoor testing. Building access is one major challenge. The second is cost. Since this testing is indoors, surveying indoor locations to obtain accurate ground truths is more expensive than the outdoors, where use of vehicle-based differential GPS most often suffices. A good balance between these two constraints was struck by an approach of 'representative testing' in different environments. This approach was successfully trialed in 2012 by CSRIC III during its San Francisco Bay Area Test Bed; it is now considered a good basis for characterizing indoor environments across the country. ATIS' ESIF recommends an extension of this same approach for nationwide characterization.

Representative testing involves testing in distinct wireless usage morphologies. These include Dense Urban, Urban, Suburban, and Rural environments.

As depicted in Figure 5.1, in each morphology a number of different buildings of different sizes and types need to be identified. Within each building different test points need to be selected to represent the range of different conditions that could be experienced within the building. The number of test points in the building depends on its size and complexity. This could include testing at different heights of a building, various depths inside a building, different settings inside the building, and so on.

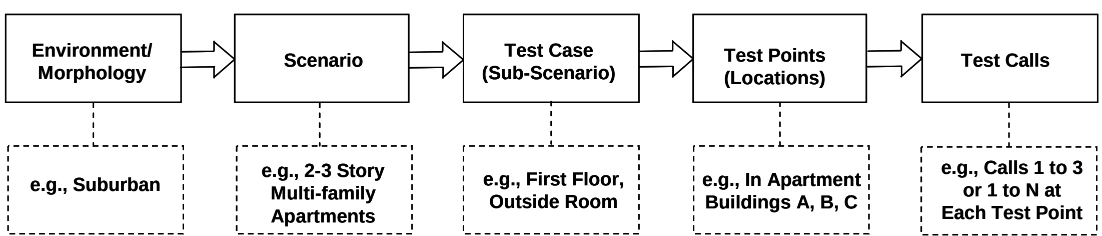

Figure 5.1 - Morphology to Test Point Flow Down

When characterizing the performance across the nation, it does become important to characterize the local conditions. For instance, residences on the west coast are typically built out of wood and lack a basement. Residences on the east coast, on the other hand, typically have a basement and are made out of brick. As an approach to capture these regional variations nationwide, a set of 5+1 distinct regional representations, or regional test beds, is recommended. These are San Francisco, Denver, Chicago, Atlanta, Philadelphia, and Manhattan in New York City. Each of these five regional test beds would be large enough and geographically wide enough to encompass the range of dense urban, urban, suburban, and rural environments in and around that city. Manhattan in the City of New York is the unique "+1" because of its very distinct and important dense urban characteristics. Hence, it is recommended that only dense urban Manhattan be tested in NYC. Metropolitan Philadelphia is otherwise the representative test bed for the Northeast.

The rationale behind these 5+1 test regions is that they sufficiently characterize environments in a region well beyond their immediate boundaries. For instance, the urban or suburban environments in Denver are characteristic of the southwest regions of the country, e.g., in Salt Lake City, Reno, or Albuquerque. As long as the location system and the parameters used in the location system are identical, the expectation is that the region as a whole, and in turn the nation as a whole, is well characterized. These parameters for different location systems are discussed in the next section. The modified test flow diagram characterization is shown below in Figure 5.2, where the regional extension step is shown shaded. Additionally, the conditions that must be satisfied to permit extrapolation of the indoor results from a given test bed to its wider region are discussed in Section 11.

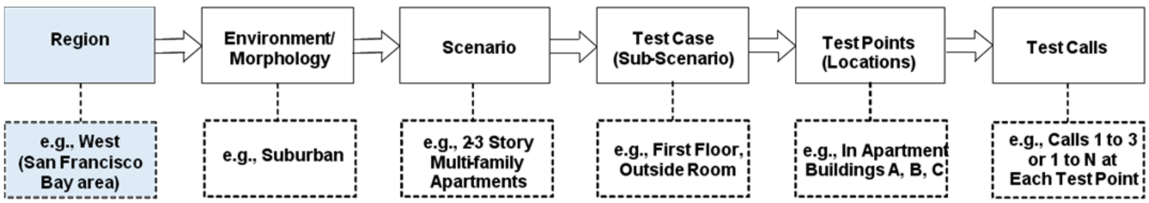

Figure 5.2 -Morphology to Test Point Flow Down Applied to the Regional Test Beds

6 Parameters Affecting Indoor Wireless Location

One of the challenges of representative testing is to ensure that empirical test results established in a test bed are reflective of performance achievable from the same location technologies deployed under similar conditions in other indoor locations where 911 calls are made. To accomplish this goal, it is important to consider the key parameters that affect the performance of various location technologies currently in use and in development.

There are a number of variables and parameters that can affect indoor location performance. Each different positioning method tends to have a different set of specific parameters that most affect its performance. Some key parameters which may impact indoor location performance for various location technologies of interest are listed below. Some parameters are unique to a particular positioning method, while others are relevant to multiple methods. In addition, some listed parameters can be interrelated; for example, the density of surrounding transmission sources and the morphology or the quantity of measurable transmission sources and the building construction. While not intended to be an exhaustive list, these considerations should prove helpful to the test designer both in establishing the test bed methodology and in extrapolating the test bed results (as discussed in section 11). It should also be noted that while the factors listed below affect each technology performance in general, some factors, for example those pertaining to the handset, do not generally play a significant role in the extrapolation of test results, assuming similar devices are being used throughout.

1. A-GPS/A-GLONASS
   - Quantity of measurable satellites
   - Building-under-test and surrounding buildings
     - Building spacing
     - Building height
     - Construction materials (influences RF attenuation and reflections)
     - Building usage (commercial or retail, residential, industrial, special use facility) – influences interior walls, wireless deployment, and 911 use case scenarios
   - Geometry of measurable satellites
   - “Morphology” (dense urban, urban, suburban, rural) – attenuation, blockage, multipath
   - Quality of assistance information
   - Accuracy of time assistance (coarse time vs. fine time)
   - Latitude
2. OTDOA
   - Quantity/density of surrounding macro cell sites
   - Frequency/duration of PRS and PRS coordination/muting
   - Accuracy of downlink synchronization
   - Accuracy of provisioned network data (e.g., latitude/longitude of antennas, cable delays)
   - Quality of assistance information
   - Bandwidth of cellular downlink
   - Building-under-test and surrounding buildings

  - Building spacing
  - Surrounding building heights
  - Construction materials (influences RF attenuation and reflections)
  - Building usage (commercial or retail, residential, industrial, special use facility) – influences interior walls, wireless deployment, and 911 use case scenarios
- Geometry of surrounding macro cell sites
  - “Edge-of-Coverage” effects – i.e., situations where beyond a certain boundary/region (such as a coastal line) no macro cell sites reside
  - “String-of-pearls” – i.e., areas where surrounding cell sites lie essentially in a straight line
- “Morphology” (dense urban, urban, suburban, rural) – attenuation, blockage, multipath

3. U-TDOA
   - LMU deployment density – typically tied to quantity/density of surrounding macro cell sites
   - Accuracy of provisioned network data (e.g., latitude/longitude of antennas, cable delays)
   - Bandwidth of cellular uplink
   - Cellular technology and specific features implemented to optimize U-TDOA (e.g., power-up for emergency call)
   - Building-under-test and surrounding buildings
     - Building spacing
     - Surrounding building heights
     - Construction materials (influences RF attenuation and reflections)
     - Building usage (commercial or retail, residential, industrial, special use facility) – influences interior walls, wireless deployment, and 911 use case scenarios
   - Geometry of surrounding LMUs (surrounding macro cell sites)
     - “Edge-of-Coverage” effects – i.e., situations where beyond a certain boundary/region (such as a coastal line) no macro cell sites reside
     - “String-of-pearls” – i.e., areas where surrounding cell sites lie essentially in a straight line
   - “Morphology” (dense urban, urban, suburban, rural) – attenuation, blockage, multipath
4. RF Pattern Matching
   - Quantity/density of surrounding macro cell sites
   - Quality of RF pattern matching database
   - Accuracy of provisioned network data (e.g., latitude/longitude of antennas, cable delays)
   - Bandwidth of cellular downlink
   - Building-under-test and surrounding buildings
     - Building spacing
     - Building height
     - Construction materials (influences RF attenuation and reflections)
     - Building usage (commercial or retail, residential, industrial, special use facility) – influences interior walls, wireless deployment, and 911 use case scenarios
   - Geometry of surrounding macro cell sites
     - “Edge-of-Coverage” effects – i.e., situations where beyond a certain boundary/region (such as a coastal line) no macro cell sites reside
     - “String-of-pearls” – i.e., areas where surrounding cell sites lie essentially in a straight line
   - “Morphology” (dense urban, urban, suburban, rural) – attenuation, blockage, multipath
   - Density or presence of short-range cell sites
5. Terrestrial Beacon Systems (TBS)
   - Quantity/density of surrounding terrestrial beacons
   - Bandwidth of terrestrial beacon downlink
   - Building-under-test and surrounding buildings
     - Building spacing
     - Surrounding building heights
     - Construction materials (influences RF attenuation and reflections)
     - Building usage (commercial or retail, residential, industrial, special use facility) – influences interior walls and 911 use case scenarios
   - Geometry of surrounding terrestrial beacons
     - “Edge-of-Coverage” effects – i.e., situations where beyond a certain boundary/region (such as a coastal line) no terrestrial beacons reside
   - “Morphology” (dense urban, urban, suburban, rural) – attenuation, blockage, multipath

6. Wi-Fi Access Points
    - Quantity/density of surrounding Wi-Fi access points
    - Quality of Wi-Fi access point database
        - Managed versus crowd-sourced
    - Wi-Fi positioning technique used
        - Access point technology generation/band
    - Geometry of surrounding Wi-Fi access points
    - Building-under-test
        - Construction materials (influences RF attenuation and reflections)
        - Building usage (commercial or retail, residential, industrial, special use facility) – influences interior walls, wireless deployment, and 911 use case scenarios
7. Bluetooth Beacons
    - Quantity/density of surrounding Bluetooth beacons
    - Quality of Bluetooth beacon database
    - Bluetooth positioning technique used
    - Geometry of surrounding Bluetooth beacons
    - Building-under-test
        - Construction materials (influences RF attenuation and reflections)
        - Building usage (commercial or retail, residential, industrial, special use facility) – influences interior walls, wireless deployment, and 911 use case scenarios
8. Barometric Pressure Based Altitude
    - Quality of barometric pressure sensor in handset[15]
        - Relative measurement error (“measurement noise”)
        - Absolute error (“sensor drift”)
    - Quality/locality/age of atmospheric pressure calibration (reference) data
        - Pressure reference outdoors or indoors--must be sufficiently representative of indoor environments
        - Distribution and density of pressure sensors
        - Accuracy of pressure sensor sources
    - Building-under-test
        - Building height
        - Building environmental design (e.g., HVAC systems, building envelope and sealing)
        - Building “infiltration rate” (i.e., the extent to which the building is “sealed” or “leaky” relative to outside air)
        - Vertical porosity/stack effect
    - Building characteristics
        - Distribution of building ages (factors such as air handling systems and sealing of buildings is likely to depend upon when the buildings were built and the range of weather conditions)
    - Environmental conditions
        - Temperature differences between outdoors to indoors/ seasons (for external calibration sensors)
        - Wind (affects both air infiltration into the building as well as the static pressure measurement affecting accuracy of an external calibration sensor)
        - Range of temperatures in the city
        - Impact of wind and storm conditions
9. Network Fallback Methods (e.g., AFLT, RTT)
    - Quantity/density of surrounding macro cell sites
    - Accuracy of downlink synchronization (for AFLT)
    - BSA accuracy and completeness (AFLT)
    - Average cell coverage radius (for RTT)
    - Multi-cell versus single-cell measurement (for RTT)
    - Bandwidth of cellular downlink
    - Geometry of surrounding macro cell sites

[15] Sensor calibration would typically be done as a routine part of handset manufacturing.

The above list applies to specific standalone technologies. Some factors, e.g., related to edge of coverage, would need to be evaluated in the context of possible hybrid utilization of one or more technologies.

For areas of comparable morphology and transmission source density, experience has shown that performance of a given positioning method is affected more by the underlying configuration options employed by the wireless service provider or location technology vendor than by the specific area tested. For example, OTDOA performance in a certain type of environment depends more on how Positioning Reference Signals (PRS) are utilized (including the use of PRS coordination/muting) than on where the test is conducted.

There will always be “corner case” environments that are not practical to specifically test, such as a houseboat in a remote canyon, a secluded mountain cabin, an isolated island, etc.

There are also special use cases – such as “small cells” or DAS systems – which because of their unique nature should have location performance studied and/or extrapolated separately.

7 Six Candidate Regional Test Bed Areas

The consensus within ESIF-ESM is that more thorough testing of a fairly small number of test regions is preferable to lightly testing in a larger number of regions. However, those few test bed regions need to reflect the varying environments around the country, especially relating to prevailing building architectures and construction materials, as well as distinct urban layouts/density and vegetation that could impact indoor performance. Finally, those few test beds need to be sufficiently dispersed around the country to be of reasonable “regional proximity” to PSAPs in each region.

The recommended “5+1” test beds are centered around five metropolitan hubs, and with the exception of the “+1” of dense urban Manhattan, will have sufficient surrounding areas included in each case to account for as many morphologies as required in the test bed region. This is exemplified in the San Francisco Bay Area test bed described in Section 9, which extends about 90 miles in a north-south direction, and the proposed Northeast Region Test bed in and surrounding Metropolitan Philadelphia which extends at least 50 miles across. The Philadelphia test bed is addressed in Section 10. The selection of metropolitan hubs facilitates transportation to and from the test bed areas and reduces cost, yet at the same time captures the different relevant regional characteristics critical to indoor testing.

The proposed regional test beds identified below provide a good mix of the different location-affecting parameters listed above, are distributed across the country, have good local mixes of the various morphologies as well as building construction materials, and building densities and heights. They also span the range of latitudes and average cell site radii seen across the country, and include coastal edge-of-coverage effects.

The following list provides the metropolitan areas of each regional test bed and their representative characteristics that apply to the wide region in which those characteristics are found. Examples of cities where regional extrapolation could be applied are provided under each regional test bed. Results from more than one regional test bed could be applied in a target area to provide the best match based on their representative characteristics.

1. San Francisco Bay Area
    - *a.* Pacific region
    - *b.* Represents: LA, Seattle, San Diego, Portland, and San Jose
    - *c.* From semi-arid to relatively densely vegetated hills and mountains surrounding populated basins, valleys and canyons
    - *d.* If testing occurs on the peninsula, it might be able to replicate an island test
2. Chicago
    - *a.* Midwest region
    - *b.* Lake/shoreline
    - *c.* Dense urban core
    - *d.* Extensive urban residential areas
    - *e.* Extends to rural Midwest surroundings
    - *f.* Represents: Cincinnati, Detroit, Cleveland, St. Louis, Minneapolis, St. Paul, Milwaukee, Indianapolis, Columbus, and Buffalo (lake side setting)
3. Atlanta
    - *a.* Southeast region
    - *b.* Extends to heavily forested mountain terrain

   c. Newer and older construction common to the South
   d. Represents: Charlotte, Richmond, Birmingham, Dallas, Nashville, Memphis, Houston, Austin, Jacksonville, Fort Worth, and to some extent Miami
4. Denver/Front Range
   a. Mountain region
   b. Mountainous and basin terrain
   c. Elevation (1 mile high)
   d. Southwest region example
   e. Represents: Salt Lake City, Tuscan, Las Vegas, San Antonio, and Phoenix
5. Philadelphia
   a. Northeast region
   b. Typical Northeast city and its environs
   c. Denser older urban areas, dense suburbs to more sparse more heavily vegetated suburbs, flat and hilly rural areas
   d. Represents: Boston, Wilmington, Baltimore, suburban NYC, and Washington, D.C.
6. Manhattan (dense urban only)
   a. Northeast special region
   b. Extreme dense urban morphology
   c. Extremely high cell site densities
   d. Extreme population center

Wireless service providers and/or location technology vendors or involved third parties need to ensure the validity of the critical parameters that allow the mapping and extrapolation of the results from one of these regional test beds to the much broader areas they represent nationwide. Those parameters affecting indoor location performance have been identified in Section 6 and the extrapolation process and the constraints on the various critical parameters that permit extrapolation are described in detail in Section 11.

8 Tools & Procedures For Test Polygon Development

Several tools are available to assist in the process of identifying test polygons of similar building construction and thus comparable accuracy. These range from free interactive map displays in a computer browser (e.g., Google Maps, BING, or Yahoo Maps) to high end GIS (Geographic Information Systems). GIS systems range from free open source projects such as QGIS to commercially supported systems from ESRI.

Types of data that are displayed, analyzed, or correlated within the tools above range from single sheet aerial photos that can be manually inspected to multiple layers of point or polygon regions representing numerical values such as population, building height, or zoning regions for building use.

Sources of data that can be merged are from commercial companies, to federal, state and county, or city entities. Merging data from different sources may require transformation or translation. For example, regional zoning definitions may differ by state or region.

Ideally, the team working in a given region would have access to the local E911 detailed GIS data, which has merged multiple data sets from various sources and validated the combined database via field observations.

Region definitions in such a local database can be matched to the range of “rural, suburban, urban, and dense urban” used in this report to produce regions of comparable accuracy for extrapolation of results.

8.1 Manual Polygon Selection - Desktop Mapping & Visual Inspection

Visual inspection of building height using a desk top mapping program can easily spot the regions of tall buildings (for example see Figure 8.1).

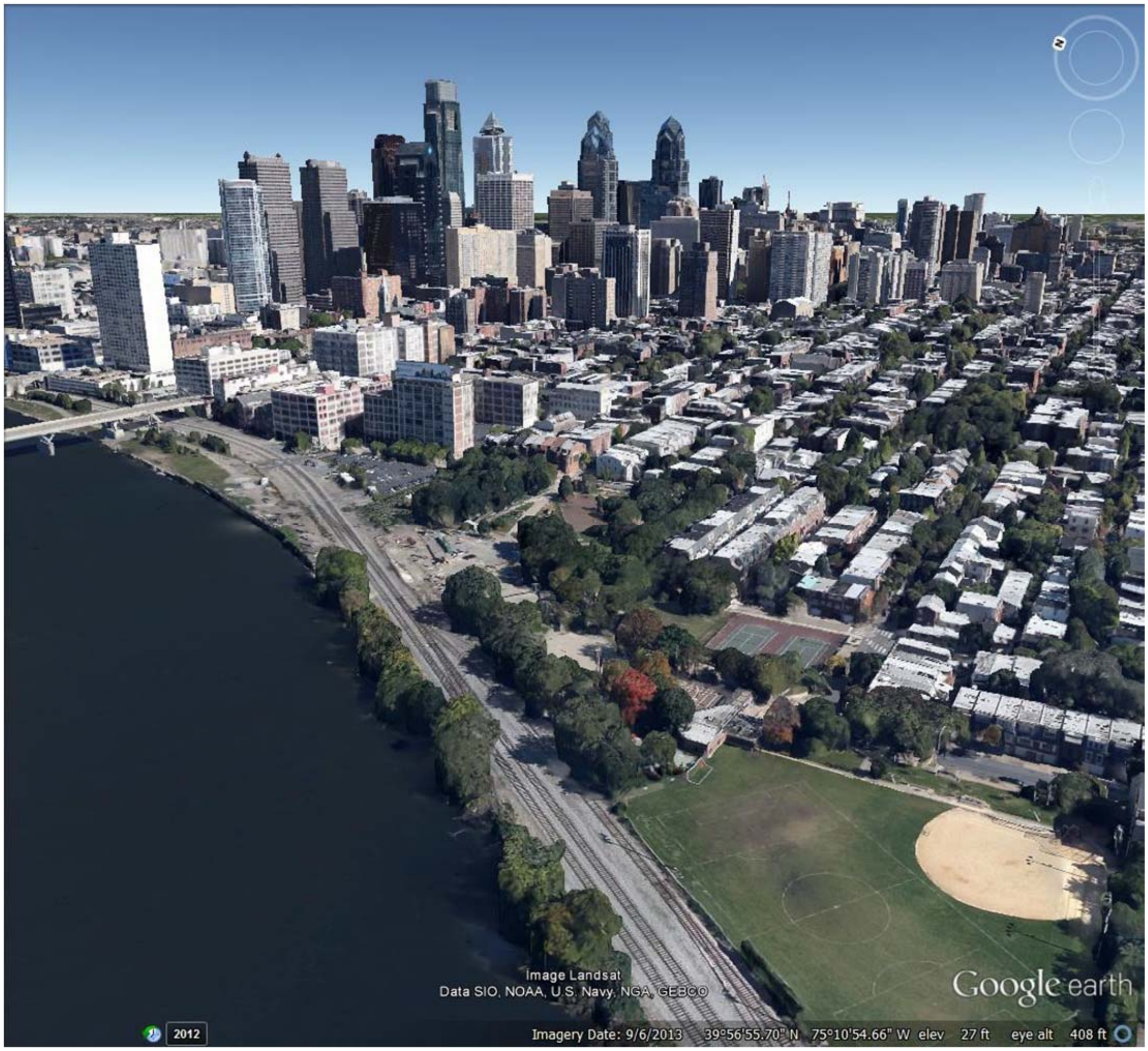

Figure 8.1 - Google Earth 3D Buildings of Downtown Philadelphia

Walking through a city to find areas of similar building height and density can be done with desk top mapping programs flying over a city. Usually, "dense urban" regions, where the buildings are taller than 10 stories, are the easiest to define, since they are often co-located in an urban core. "Urban" where the building height is 3 to 10 stories is next, and usually is a region surrounding the dense urban core. "Suburban" is usually a quite large percentage of the geographical area of a metropolitan region, from which a convenient test area can be selected. Rural can be surprisingly hard to find, because the definition of "rural" includes cell tower density that is not visible on the desk top mapping program, unless the carriers' tower database is also plotted on the map. This method uses circles or polygons drawn manually on the screen and the maps are included in the field test plan for the site selection team to identify individual buildings that have reasonable access.

8.2 Polygon Selection Using Land-Use Classification from Local or Regional Planning Commissions

Land use or zoning databases are usually displayed as colored polygons in flat layers that can be turned on or off for visibility.

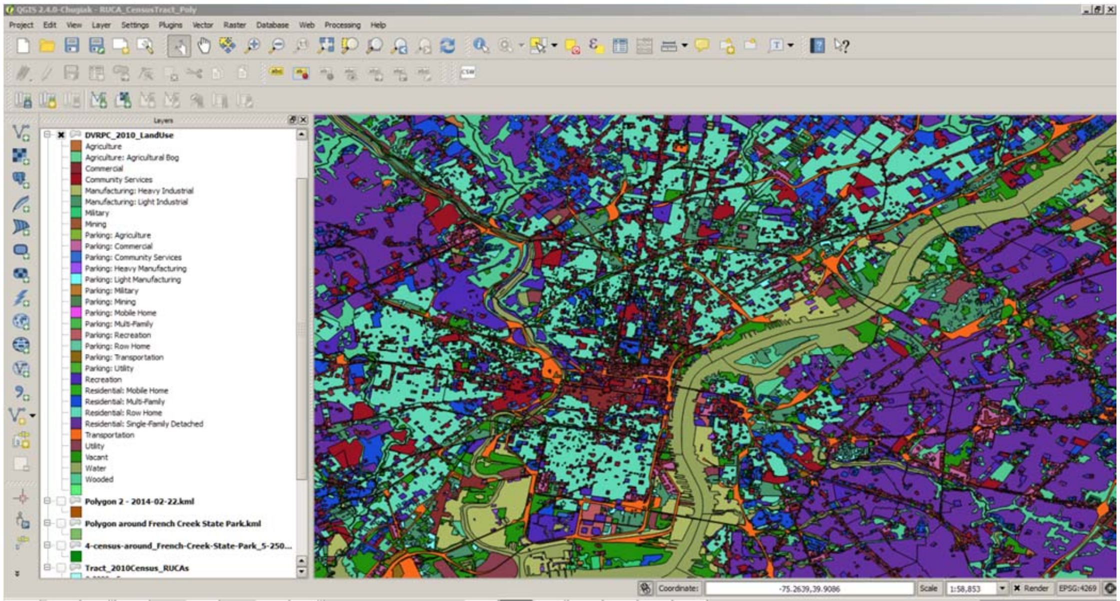

Figure 8.2 - QGIS Program Displaying Land Use Planning Data Set

Data sets shown in Figure 8.2 are supplied by Delaware Valley Regional Planning Commission: < http://www.dvrpc.org/Mapping/data.htm >.

Note that the polygons on the left side in the figure are annotated with the type of activity in the building (e.g., commercial, manufacturing, and residential). These will need to be translated into the testing categories of building height and building density.

Maps from the city or regional planning commission have polygons defined that show zoning classifications and land use. There is no uniform methodology for incorporating building height information into these maps, but comparing the manually generated regions from 8.1 with planning commission methodology will allow a translation table to be built.

Identifying industrial buildings separate from residential or office buildings is very useful in test planning. Industrial buildings often have very few interior walls, as compared to office buildings, so the location performance will differ. Building construction may differ as well in a warehouse or factory as compared to an office building of similar height, again providing differing location accuracy.

8.3 Polygon Selection Using Population Density Database

The U.S. Census Bureau database covers the complete geographical area of the U.S. There is a "rural" area classification, but this is not based on building density and may not be a good basis for defining indoor building location accuracy. The smallest polygon region that the census bureau defines is the census tract.

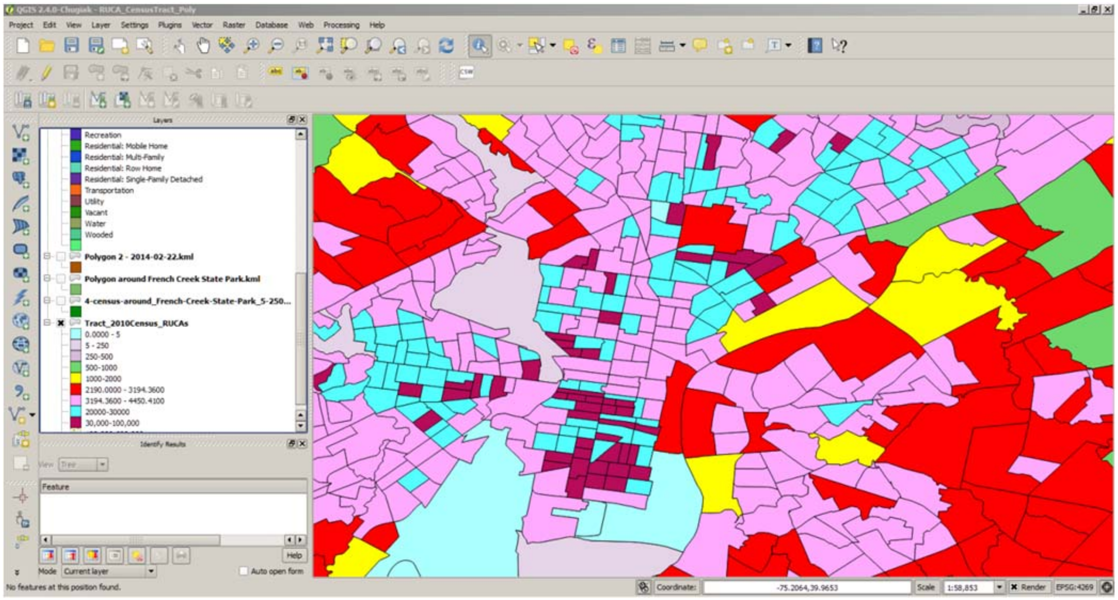

Figure 8.3 - QGIS Display of Census Bureau Polygons, Coded by Population Range

The population in the tract can be divided by the square miles to derive a population-per-square mile (ppsqm) value. Tracts with less than 5 ppsqm are typically rural, but may not have any cellular coverage, so those areas will need to be correlated with carrier coverage maps. Tracts in the 100 to 500 ppsqm are typically classified suburban. Tracts in the 1000 to 10000 ppsqm are typically urban and dense urban. Note there are gaps in the coverage ranges that will need to be filled in based on a given region. Census data can be used to help identify rural areas and guide region selection across all population densities. This may be a useful first step in creating an automated process to assign a classification to an entire region.

8.4 Effect of Indoor Emitters on Region Definition

Today, E911 positions for both indoor and outdoor locations are based on radio signals from either GPS satellites in the sky or outdoor cell towers. Indoor location accuracy currently is mostly a function of how many of these signals get into the building, how much they have been attenuated, and how much noise has been added to the signal by reflecting off the many surfaces of various buildings. Thus today, region selection is based on buildings having similar construction, similar materials used in construction, similar depth for the signal to penetrate into the core of the building, and similar building density for signal blockage.

Today, visual inspection of the exterior of a building gives a reasonable estimate of the probable accuracy indoors, based on height and materials used. However, increasing reliance on cellular signals placed inside of buildings from “small cells”, and the potential incorporation of Wi-Fi signals placed inside of buildings may require the test polygon development process to use databases of cell tower positions and, as needed, Wi-Fi access point density.

As an example, if one office building has a small cell deployed on every floor, then the cell proximity information will improve the location accuracy within that building as compared to a building with no transmitters inside. Another example could be a stadium with an indoor DAS (Distributed Antenna System) deployed to provide high volume cellular coverage, which will have different accuracy than an industrial building of comparable size, with no internal transmitters.

If the location technologies deployed in a given region are predominantly based on indoor transmitters, then the density of such transmitters should be taken into account in defining polygons. Hence a source of indoor emitter locations may need to be built into the polygon development process at some point.

9 First Regional Test Bed: San Francisco Bay Area

The test methodology established within ESIF for indoor testing, embodied in ATIS-0500013 and used in formulating the test plan (ATIS-0500022) provided to and adopted by CSRIC III WG3, relies on the definition of polygons that contain boundaries for the distinct wireless use environments or morphologies. Those are the dense urban, urban, suburban, and rural environments in which the indoor testing would be conducted.

The Greater San Francisco Bay Area was chosen by CSRIC III WG3 in 2012 as the regional test bed of choice because it contained the various distinct morphologies sought. Furthermore, it enabled efficient testing that could be achieved with one test team, with a reasonable amount of travel within the overall area.

That test bed was the first sample implementation of the ESIF–defined indoor test methodology. It provided the FCC with key data (e.g., in Indoor Test Report to CSRIC III-WG3) upon which it has proposed its further rule makings, e.g., as discussed in the FCC's 3rd FNPRM. Due to the strong success of that Bay Area test bed, it has been retained as one of the 5+1 regional test beds in the current recommendation for nationwide representative indoor testing.

9.1 Defined Test Polygons

For the CSRIC-III test bed, a large enough expanse in and around the Bay Area was considered to enable an adequate representative selection of the four morphologies in diverse settings. The overall area spanned the region from the San Francisco Peninsula to the north, through Santa Clara County and San Jose 45 miles south, to sparse rural environs in the vicinity of Hollister, CA 40 miles further south from San Jose. An overall high level map of that regional test bed area is shown in Figure 9-1. The dense urban polygon in San Francisco, as well as the urban polygons in San Francisco and Downtown San Jose, are so small compared to the size of the overall area that they are hard to see in Figure 9.1. It is expected that a similar situation could arise in any of the four other sizeable regional test beds recommended in this document.

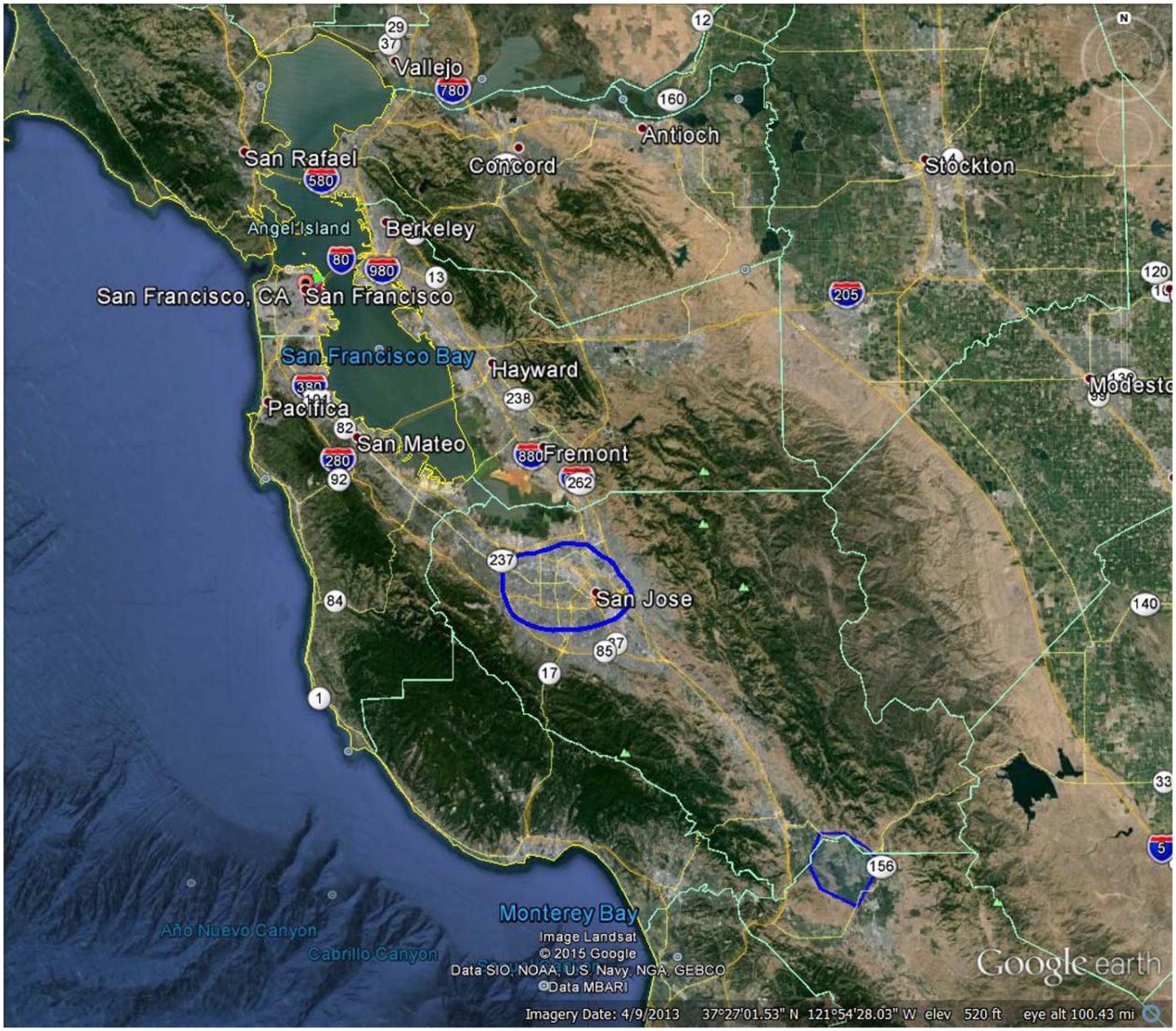

Figure 9.1 -Geographical Extent of the San Francisco Bay Area Test Bed

The dense urban polygon in downtown San Francisco is a contiguous area of very tall buildings that comprises the central business district of the city. Initially, relying on general knowledge of the City of San Francisco and satellite/aerial maps, primarily from Google Earth as a tool, two polygons were identified, with an "internal" polygon situated one row of tall buildings inside the dense core. Subsequently, during the process of building identification in the field and initial site visits, a more expanded dense urban polygon was defined to better reflect the nature of the area. Buildings in this dense urban polygon include a host of tall buildings that create a number of urban canyons and include commercial office buildings, hotels, and government buildings of varying construction types and heights, including some structures that rise above 50 stories.

The preliminary proposed polygon and the final polygon, as updated based on field observations, are shown in Figure 9.2, in green and light blue respectively. The adjacent boundary of the urban polygon in San Francisco is outlined in the figure in purple. The expanded dense urban polygon provides more dense urban building selection options. Six buildings were selected to test within that expanded polygon. A polygon refinement step is mentioned here to highlight the real world variables that can be encountered in defining an indoor test bed.

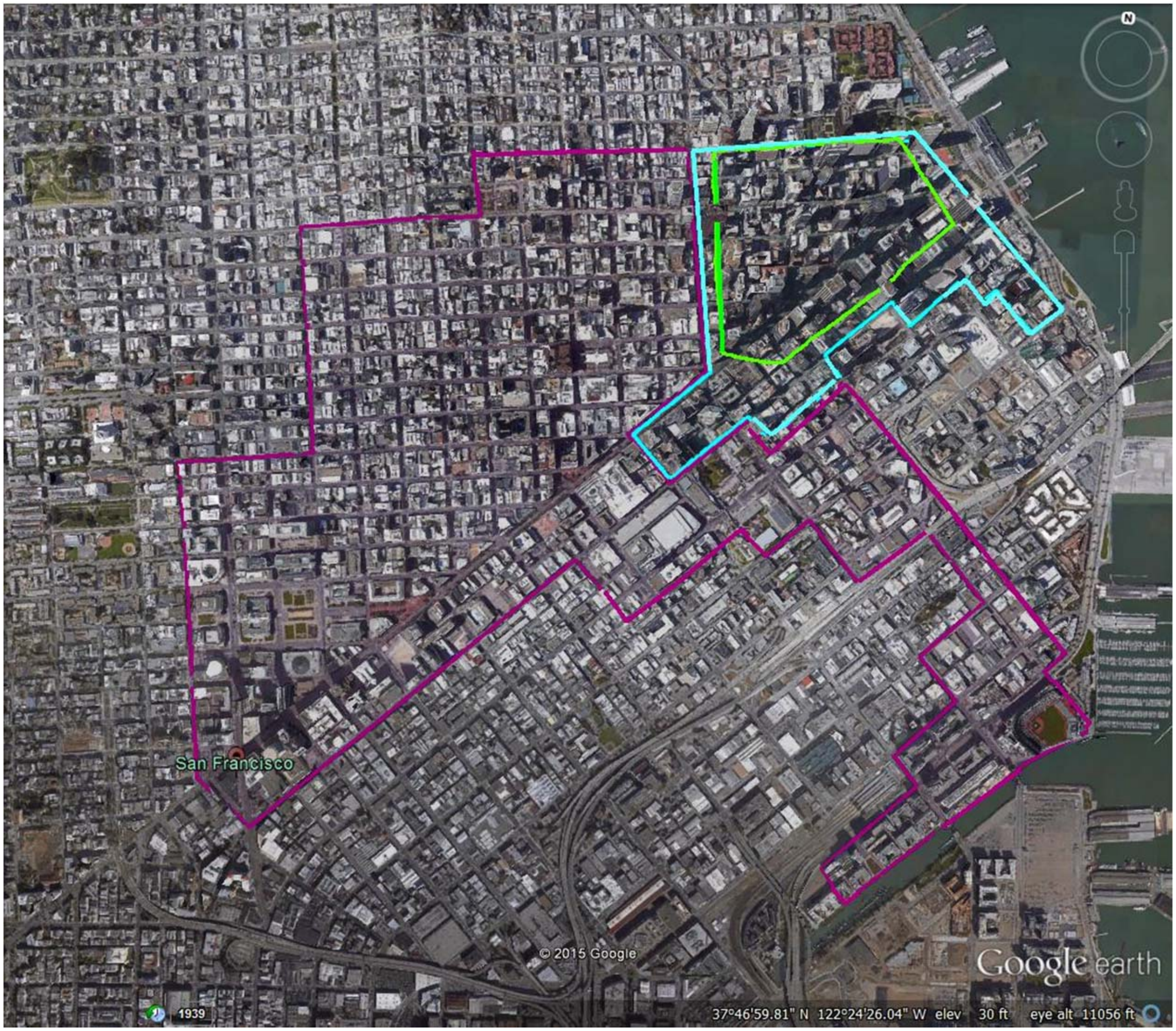

Figure 9.2 - Dense Urban and Urban Polygons in the San Francisco Area

The urban polygon in San Francisco contains varied building densities and construction types that range from larger commercial buildings (near the downtown dense urban polygon), to older mixed-use neighborhoods with medium and smaller sized buildings (both commercial and residential in the middle of urban clutter), as well as newer, redeveloped areas with medium height residential and commercial buildings, city government buildings, and a large stadium. The San Francisco urban polygon is typical of an "older urban" area with densely packed construction (regardless of building height), somewhat narrower streets, and similar or at times narrower building separation than the dense urban polygon. Five buildings were selected to perform indoor tests in this polygon.

An urban polygon in San Jose representative of "newer urban" development was also selected and included in the targeted indoor testing representative sample. It contained a relatively newer downtown environment typified by tall buildings of up to 30 stories, but with somewhat wider streets and greater building separation than in older urban or dense urban morphologies. Its boundary is depicted in Figure 9.3. One tall building with unique properties to this newer downtown setting was chosen in this polygon to compliment the 4 chosen in the urban San Francisco polygon.

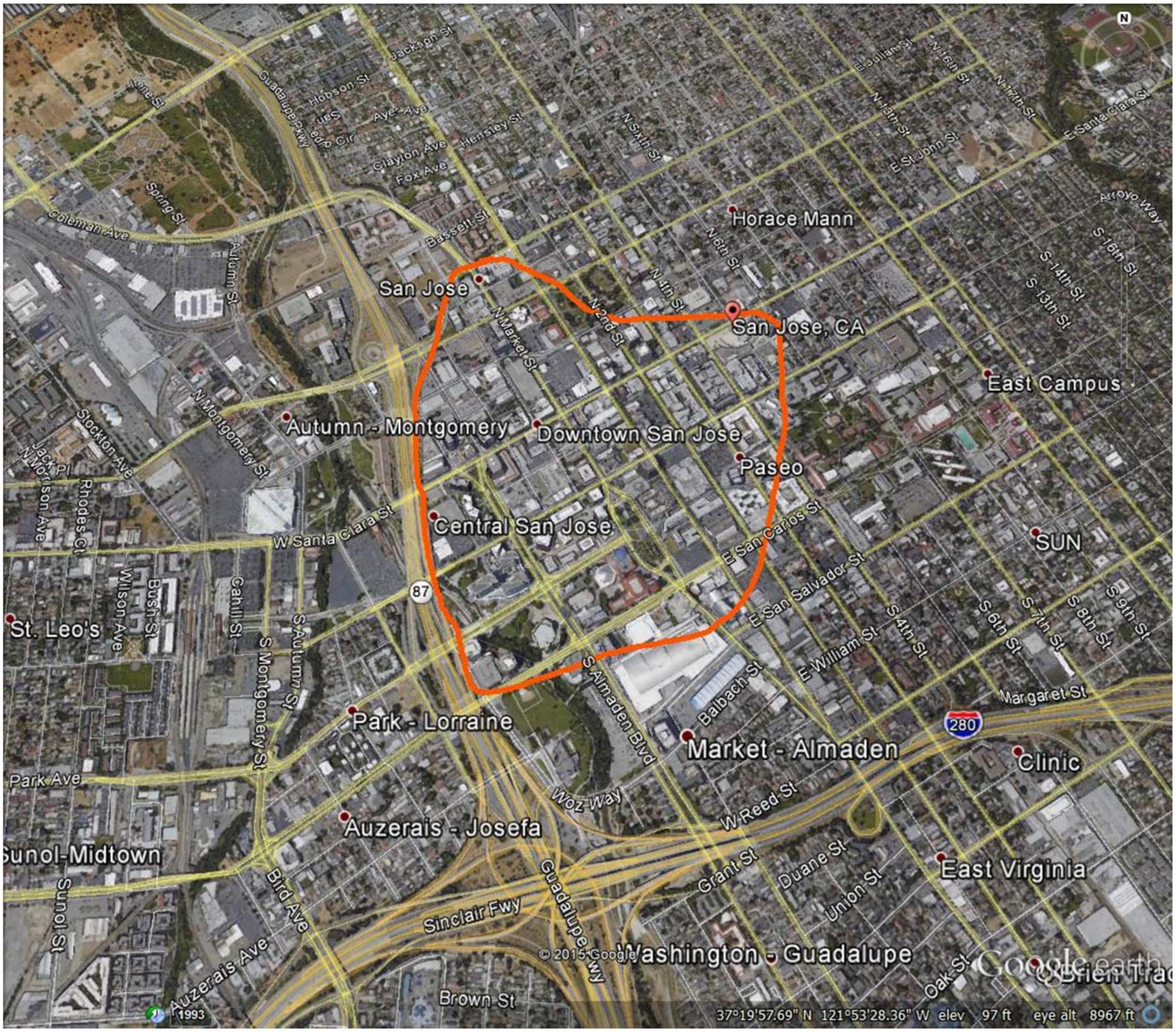

Figure 9.3 - Urban Polygon in Downtown San Jose

The suburban polygon defined for the Bay Area test bed is shown in Figure 9.4. It covers a wide expanse of "Silicon Valley" in Santa Clara County adjacent to the City of San Jose and surrounding its urban downtown. The suburban polygon included a variety of suburban office buildings, industrial and commercial complexes, government buildings, and a range of residential buildings, including single and multi-family dwellings. Also included in the suburban polygon were shopping malls, large discount retail buildings, and an airport. Six suburban buildings were selected to test within this polygon.

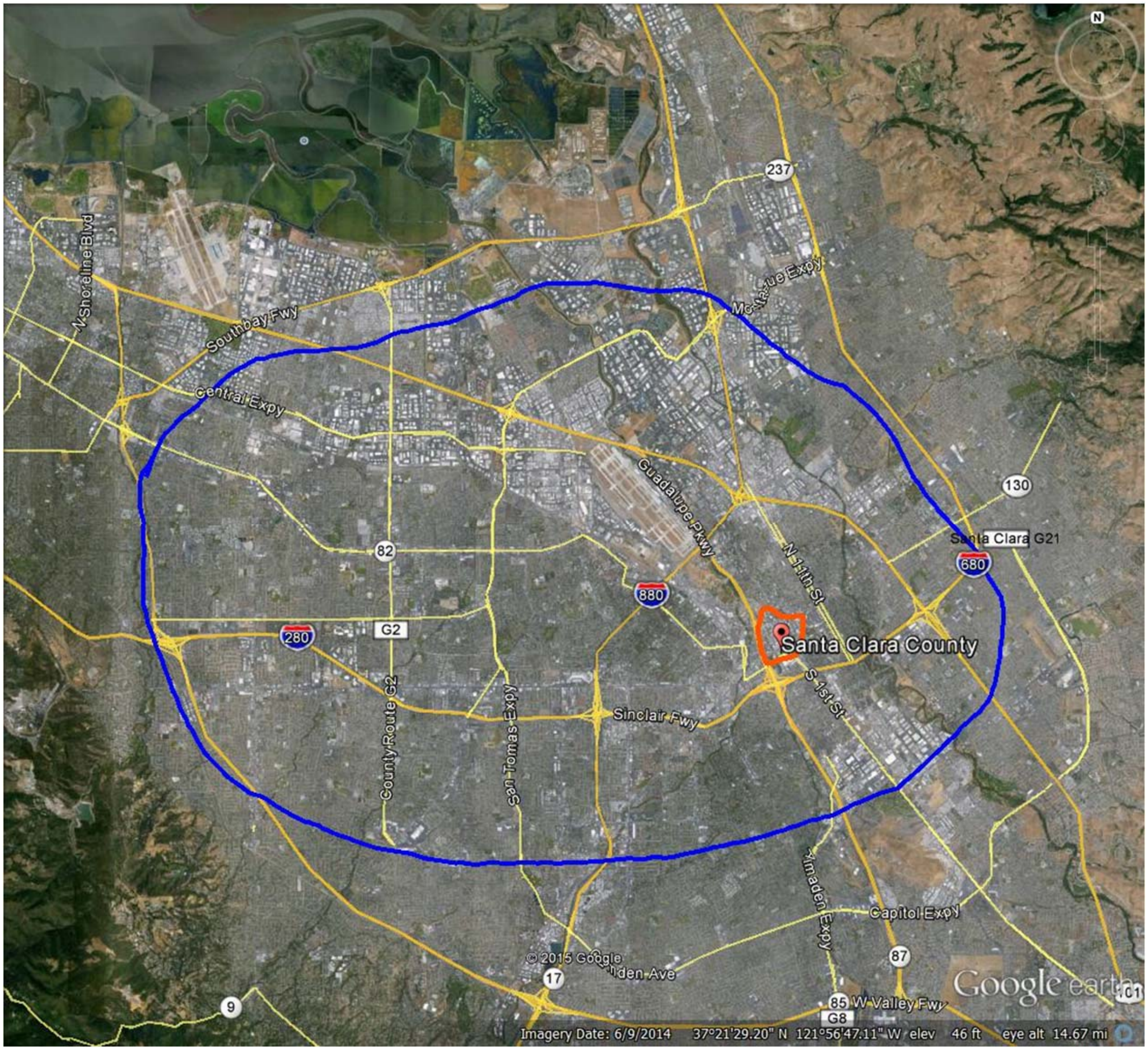

Figure 9.4 -Suburban Polygon in Santa Clara County

The rural polygon is located in the area between Gilroy and Hollister, CA and is depicted in Figure 9.5. It is characterized by large farming tracts, isolated residences, and limited commercial development. Of particular note is the low density of cell sites prevalent due to distances and the intervening terrain on the periphery of the area. The low cellular site density was a key factor in the selection of this polygon, which is about 40 miles south of downtown San Jose. Note that the towns of Gilroy and Hollister themselves were not suitable as a rural selection because they contained cell site densities closer to that found in some suburban areas in the Western U.S.

A similar situation with significant distance from the core of the urban market is expected in most other test bed regions, e.g., in the Northeast (Philadelphia), to achieve the low cell site density that is representative of large rural swaths of the United States within the scope of each regional test bed.

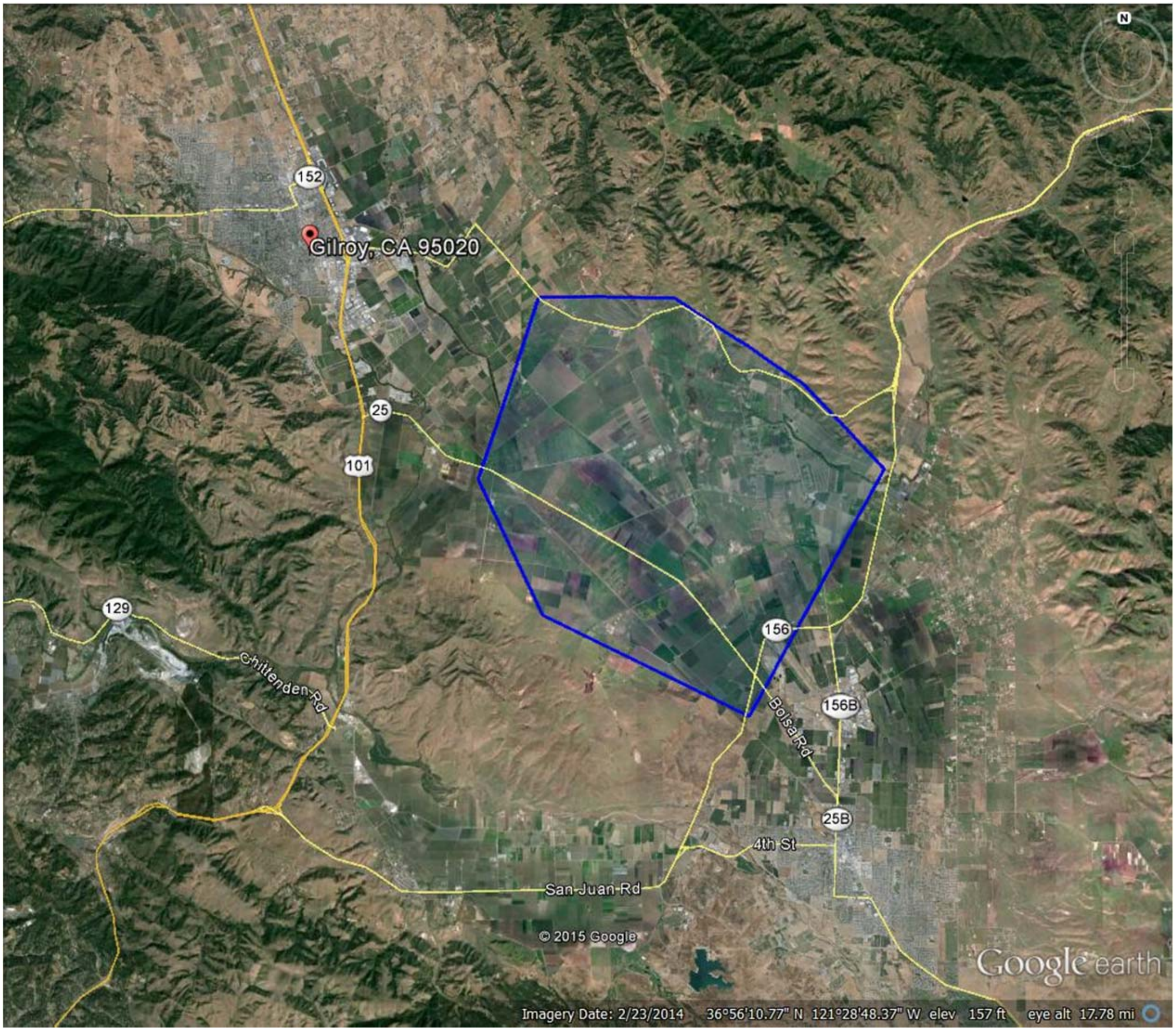

Figure 9.5 -Rural Polygon Between Gilroy and Hollister, CA

9.2 Bay Area Indoor Test Cases

As mentioned earlier, the indoor test methodology adopted by CSRIC III WG3 is the standard indoor test methodology that had been developed within ESIF ESM and documented in detail in ATIS-0500013. That basic methodology was shown earlier in Figure 5.1 and extended regionally as in Figure 5.2.

CSRIC III WG3 sought input from ESIF ESM on a general test plan for its then proposed test bed in the San Francisco Bay Area. In June 2012 ESIF ESM created such a broad test plan (ATIS-0500022) that would apply, with minor adaptation, to any regional test bed in the U.S. That test plan provided the recommended indoor test cases, building types and test scenarios across the four basic morphologies, namely, dense urban, urban, suburban, and rural. This plan included testing approximately 135 test cases in 37 test buildings (six dense urban, 13 urban, 12 suburban, and six rural). The table with this complete set of test cases is provided in the Appendix.

To accommodate very strict time limits as well as complex budgetary constraints within CSRIC III, WG3 scaled down the above test plan by sampling among the various building categories creating a smaller version that would meet these CSRIC III constraints, yet still be representative of the most likely scenarios in the Bay Area. The number of buildings was reduced from 37 to 19 and the test cases down from 135 to 75. Relative emphasis was placed on the dense urban environment and least emphasis on the rural setting. The set of proposed 75 test cases in 19 buildings is listed in Section 9.2.1.

Whereas the following list reflects what was used during the CSRIC III testing, in future testing the selected set of test buildings and test scenarios may be adapted to take into account the statistics of prevailing indoor wireless 911 calls in refining the sample of selected test cases. This may depend on the specific objective of a test campaign, e.g., technology validation versus compliance testing.

9.2.1 Indoor Test Cases Proposed for San Francisco Bay Area Test Bed

Dense Urban

I. Residential

A. Multi-family

1. 6-8 story steel/concrete frame with wood or plaster finish – surrounded by taller buildings
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallways if possible)*

II. Commercial

A. High rise building and major commercial center

1. 3-4 story mixed use commercial center surrounded by high rises
    - *a) Inside major entrance (>5m from doors)*
    - *b) In main hall near middle of building lower level (away from atrium if applicable)*
    - *c) Inside interior retail or office space lower floor*
    - *d) Inside interior retail or office space upper floor*
2. 20+ story steel/concrete frame with plaster or brick finish
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*
3. 20+ story steel with glass only exterior
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*

Urban

I. Residential

A. Multi-family

1. 3-story wood with plaster or stucco
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Interior room not on top floor (where obtaining ground truth is not impractical)*
    - *d) Building lobby (>3m from entry door)*
2. 6-story steel/concrete frame with wood or plaster finish
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*

3. 15-story steel/concrete frame with wood or plaster finish
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*

II. Commercial

A. Smaller retail, business (office), warehouse, entertainment

1. 2-story single structure- masonry, brick or brick veneer
    - *a) Outside room with windows (>3m from window)*
    - *b) Interior office or space lower floor*
    - *c) Interior office or space upper floor or level*

B. Larger professional office/major commercial center

1. 4-6 story professional building
    - *a) Building lobby*
    - *b) Attached parking garage if available (one floor below garage roof)*
    - *c) Outside office with windows lower floor (>3m from window)*
    - *d) Interior office or space lower floor (visible from outside office on same floor)*
    - *e) Outside room with windows upper floor (>3m from window)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*

C. Arena

- *a) Near concession stand – main floor*
- *b) Lower stand – relatively close to arena floor*
- *c) Upper stand – section facing one used for lower stand*

D. Convention hall or center

- *a) Lobby/esplanade – main/lower floor (near typical registration areas)*
- *b) Deep inside exhibit hall – main exhibit hall floor*
- c) *In interior meeting room*

Suburban

I. Residential

A. Single family (stand-alone structure)

1. 1-story wood with stucco
    - *a) 1st floor outside room with windows (>3m from window)*
    - *b) 1st floor inside away from windows (e.g., hallway)*
2. 2-story brick or brick veneer
    - *a) 1st floor outside room with windows (>3m from window)*
    - *b) 1st floor inside away from windows (e.g., hallway)*

B. Multi-family

1. 3-story wood with plaster or stucco
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Interior room not on top floor (where obtaining ground truth is not impractical)*
    - *d) Building lobby (>3m from entry door)*

II. Commercial

A. Smaller retail, business (office), warehouse, entertainment

1. 2-story single structure – wood or steel framing, plaster or wood
    - *a) Outside room with windows (>3m from window)*
    - *b) Interior office or space lower floor*
    - *c) Interior Office or space upper floor or level*

B. Larger professional office/major commercial center/mall

1. 2-3 story major mall
    - *a) Inside major entrance (>5m from doors)*
    - *b) In main hall near middle of mall lower level (away from atrium if applicable)*
    - *c) Inside interior retail space lower floor*
    - *d) Inside interior retail space upper floor*
2. 4-6 story professional building

a) *Building lobby*
b) *Attached parking garage if available (one floor below garage roof)*
c) *Outside office with windows lower floor (>3m from window)*
d) *Interior office or space lower floor (visible from outside office on same floor)*
e) *Outside room with windows upper floor (>3m from window)*
f) *Interior office or space lower floor (visible from outside office on same floor)*

Rural/Sparse

I. Residential

A. Single family (stand-alone structure)

1. 2-story wood frame (home, barn, etc.)
    a) *1st floor outside room with windows (>3m from window)*
    b) *1st floor inside away from windows (e.g., hallway)*

II. Commercial

A. Agricultural/light industry structure, government building, warehouse, barn

1. 2-story agricultural/light industry building with metal roof
    a) *Peripheral space or room near outside door or windows (>3m from opening)*
    b) *Interior office or space lower floor*
    c) *Interior office or space upper floor or level*

Typical actual buildings selected from the four morphologies in the San Francisco Bay Area are shown for illustration purposes in Figure 9.6. The distribution of buildings among the four morphologies is also shown in the figure. The minor deviation in the actual selection from the proposed mix of buildings is in using six instead of four dense urban buildings, offset by five instead of seven urban buildings. This was driven by availability of buildings to test in within the very tight time constraints of the CSRIC III test bed. This still yielded the overall indoor performance characterization sought after from the San Francisco Bay Area test bed, the extensive results of which are found in Indoor Test Report to CSRIC III WG3 and CSRIC III WG3 Report to the FCC.

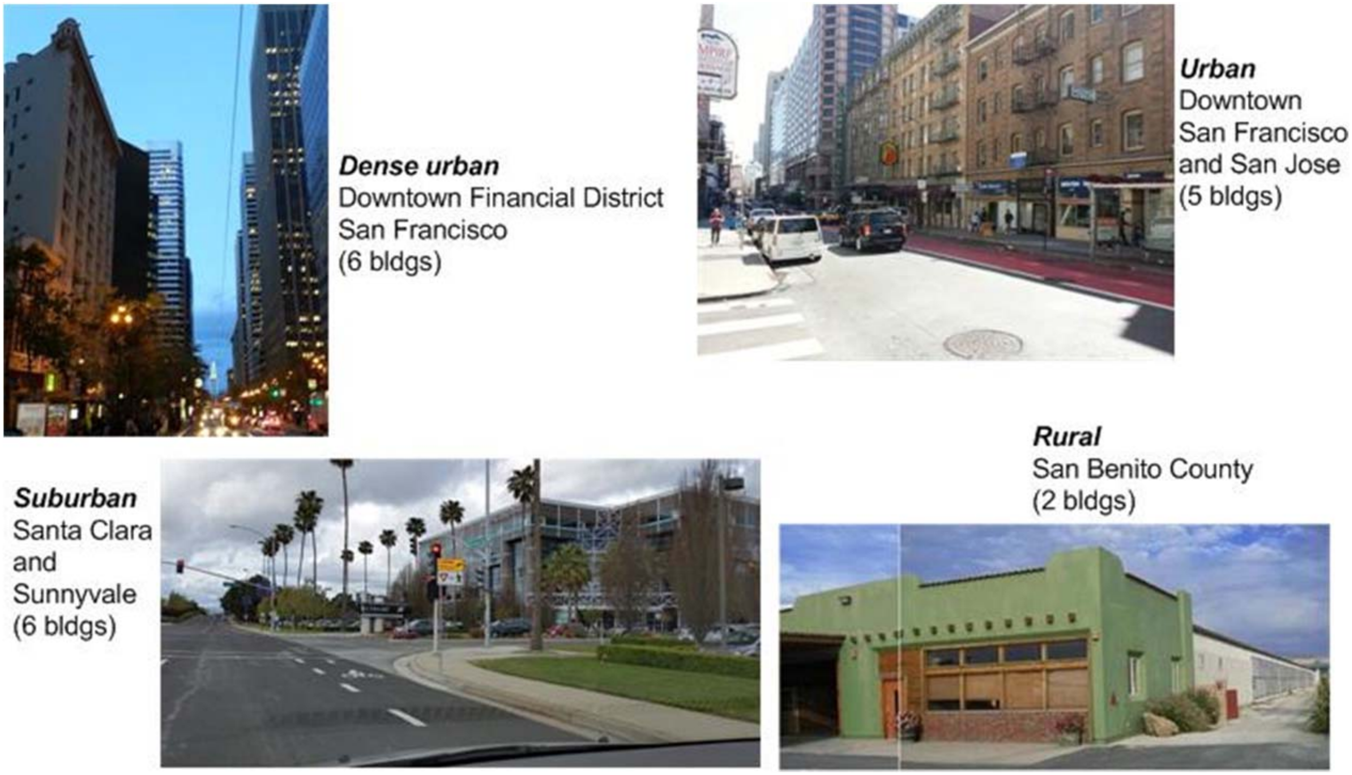

Figure 9.6 Actual Sample Test Buildings from the San Francisco Bay Area Test Bed

Similar to the San Francisco Test bed, adaptation and some scaling of the test cases in the comprehensive indoor test plan listed in the Appendix can be performed for each of the 5+1 regional test beds. This is illustrated in the next section addressing Metro-Philadelphia.

10 Sample Regional Test Bed: Greater Philadelphia

The Greater Philadelphia area offers diversity of environments and construction characteristics typically found throughout the Northeastern U.S. The geographic morphologies, building styles and construction material, and construction density found in this area are considered representative of other large metropolitan areas such as Boston MA, Wilmington DE, Baltimore DE, suburban New York City (in both NY and NJ), and Washington, D.C.

The Greater Philadelphia regional test bed is centered on the City of Philadelphia, and potentially can include the following counties:

- City of Philadelphia (Philadelphia County), PA
- Montgomery County, PA
- Delaware County, PA
- Chester County, PA
- Berks County, PA

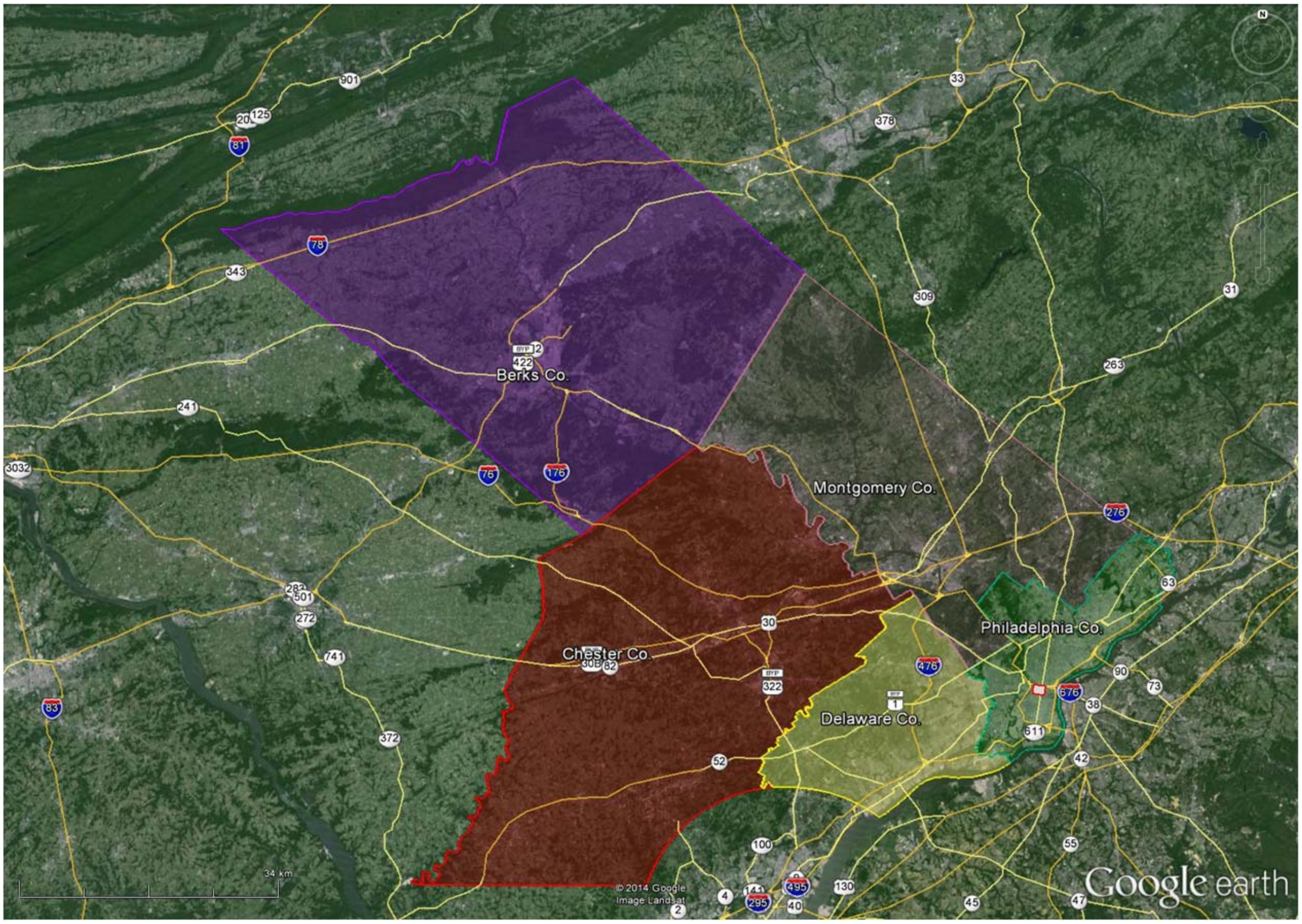

Figure 10.1 - Greater Philadelphia Test Bed Counties

10.1 Morphology Polygons

10.1.1 Dense Urban

The Dense Urban morphology is characterized by the abundance of tall buildings and skyscrapers forming "urban canyons" in a small geographic area. Within this morphology multiple hotels and restaurants, public offices, large, multi-level stores and a shopping mall, and a high concentration of public parking structures can be used as test points. There are also a number of high-rise luxury apartment buildings.

For the Greater Philadelphia regional Test bed, the Dense Urban morphology polygon is in downtown Philadelphia and delimited to the North by I-676 (The Vine Expressway), to the East by 11th Street, to the South by Spruce Street, and to the West by 22nd Street. This is a rectangle measuring one mile by 0.78 miles (1,600 meters by 1,250 meters). Any locations within this polygon not conforming with the definition of Dense Urban morphology, e.g., near the southwest corner of the rectangle, must not be considered as potential indoor test points.

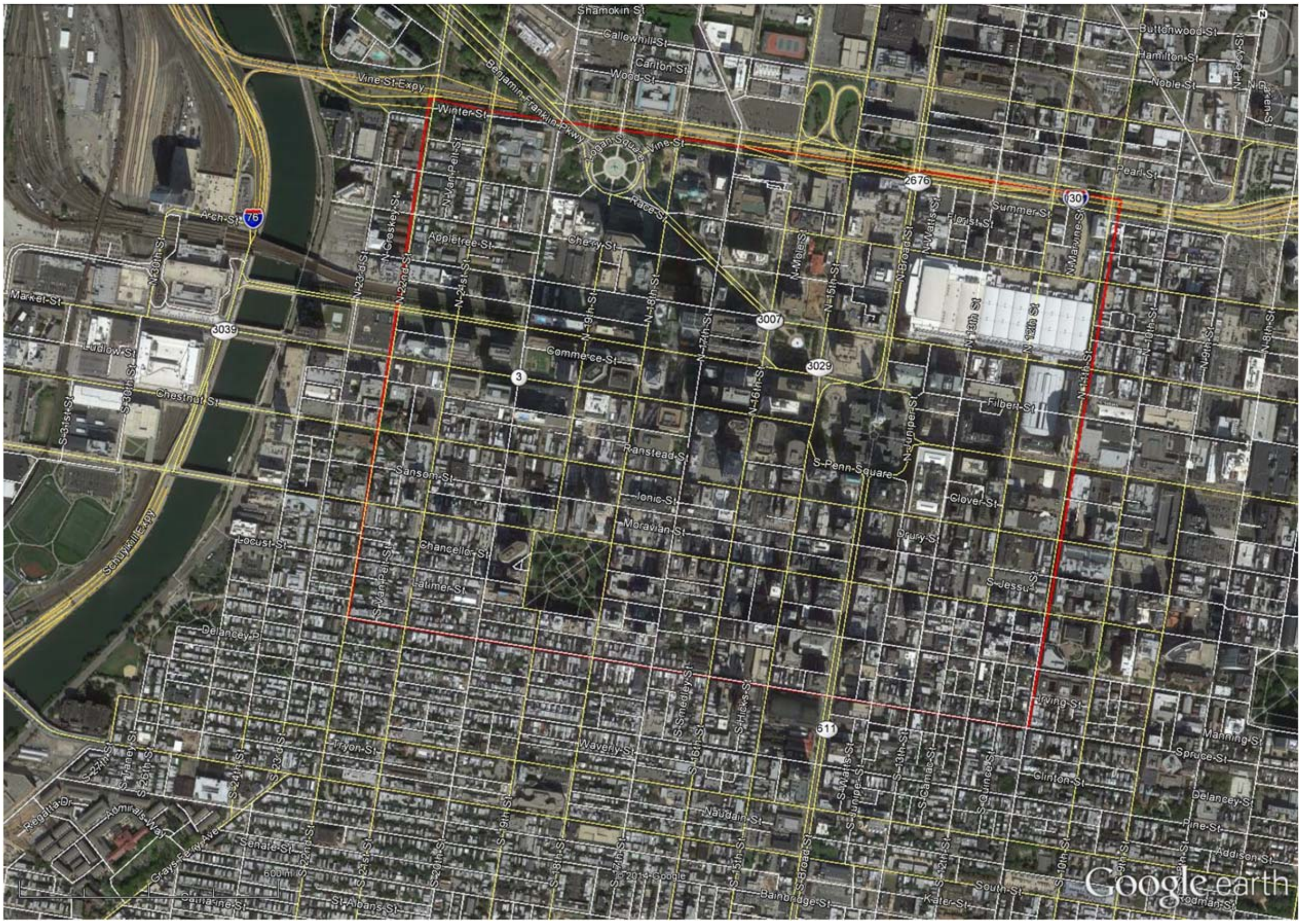

Figure 10.2 - Philadelphia Dense Urban Polygon

This polygon includes public buildings such as City Hall, Reading Terminal, and the Convention Center, as well as the major skyscrapers in the city, such as One Liberty Place, Two Liberty Place, and the Comcast tower. These buildings are iconic for the city of Philadelphia and can be easily identified in a perspective view.

Figure 10.3 - Philadelphia Dense Urban Polygon in Perspective

The following sample test scenarios can be found in the Dense Urban morphology within the Greater Philadelphia regional test bed.

A. Commercial Locations
   i. Many story (more than 10 stories, commercial sky scraper – steel framing with glass and other materials)
   ii. Multi-story (3-10 stories professional office buildings, hospitals, hotels, convention center, large stores e.g., Macy's)
   iii. 1-2 story surrounded by tall buildings: Retail and grocery stores, businesses, restaurants
   iv. Multi-level Parking structures
B. Public building locations can also be found to match the above building sizes. Specific examples include:
   i. Bus and train terminals
   ii. Museums
   iii. City offices
   iv. Post offices
   v. Fire houses
C. Residential
   i. Many story (more than 10 story high rise condominium residences)
   ii. Multi-story (3-10 story condominium residences)

10.1.2 Urban

The Urban morphology in the Northeast U.S. is characterized by high population density, multi-story office and apartment buildings. Other buildings typically found within urban morphologies include post offices, grocery stores, warehouses, factories, shipyards, and piers.

For the Greater Philadelphia regional test bed, the entire city of Philadelphia (minus the Dense Urban Polygon) is classified as Urban. City Parks, such as Fairmount Park and Wissahickon Valley Park and other areas in the north and west peripheries near the political boundary of the county may be classified as suburban, and should be excluded as test locations.

Estimated population: 1.5 million

Population density: 11,292/sq mi (4,360/km²)

Area: 135 sq mi (350 km^2)

Figure 10.4 - Urban Morphology - City of Philadelphia

A significant number of contiguous "Row Homes", which in some cases may be multi-family dwellings can be found in the urban morphology of the Greater Philadelphia regional test bed. Large recognizable venues include the Sports complex (Lincoln Financial Field, Citizen's Bank Park, and Wells Fargo Center), and Philadelphia International Airport terminals.

Figure 10.5 - Row Homes in Philadelphia

The following test scenarios can be found in the urban morphology within the Greater Philadelphia regional test bed.

A. Commercial locations
    i. 1-2 story (commercial – masonry/brick)
    ii. Multi-story (masonry with steel framing)
    iii. Stadiums and Arenas
    iv. Airport terminal
    v. Universities
B. Public Places
    i. SEPTA Train stations
    ii. Philadelphia Fire Dept. (PFD) fire houses
    iii. Philadelphia Police Department (PPD) district and unit offices
    iv. Post offices
C. Residential locations
    i. 1-3 story (single family brick or brick façade)
    ii. 2-3 story (multi-family brick or brick façade—in a relatively dense setting)
    iii. Multi-story (brick or other materials with steel framing)

10.1.3 Suburban

All Philadelphia-surrounding counties in Pennsylvania can be classified as Suburban. For simplicity and cost efficiency, Montgomery County, PA is identified as the target suburban morphology for the Greater Philadelphia regional test bed.

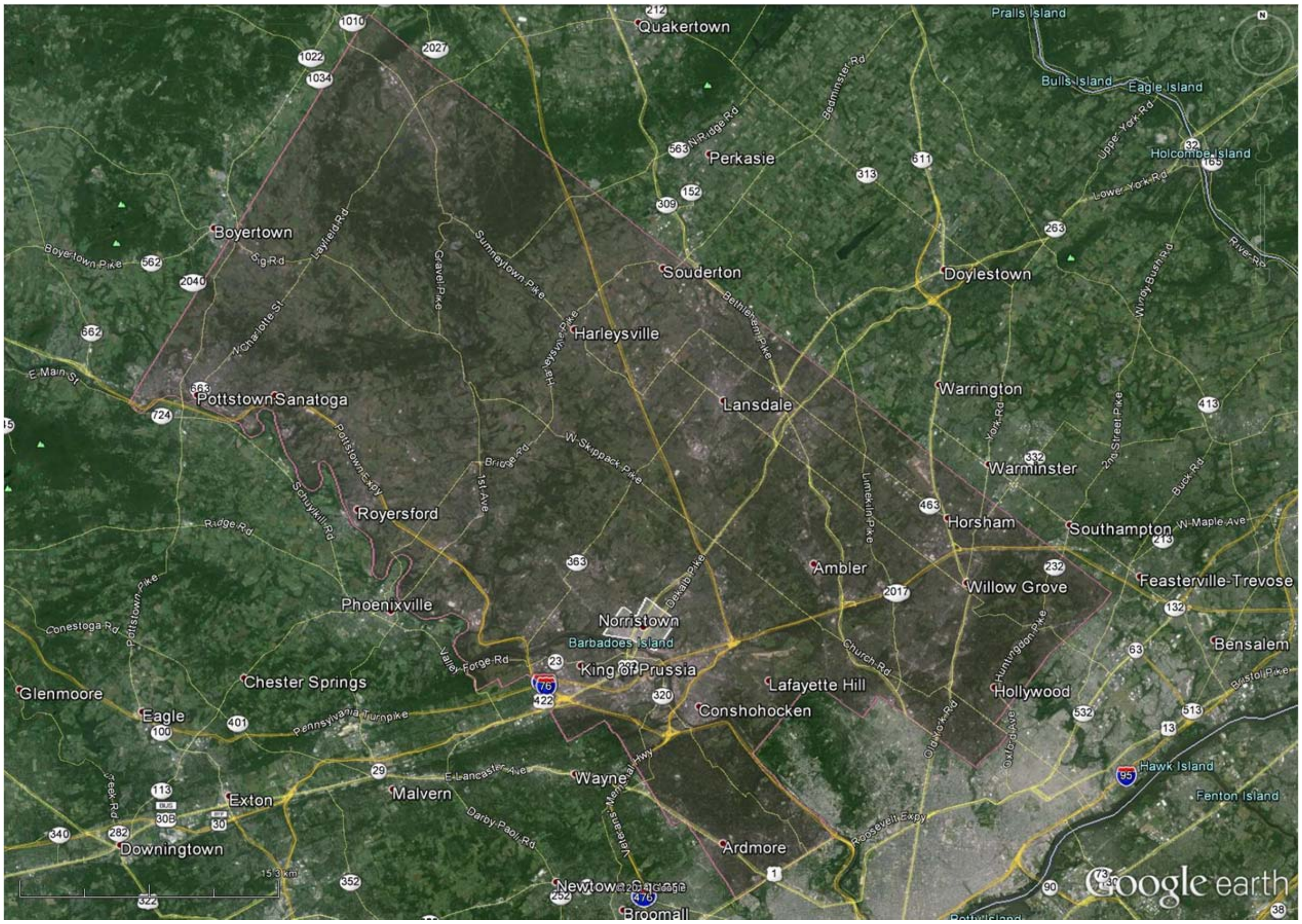

Figure 10.6 - Suburban Morphology – Montgomery County

Montgomery County is largely residential, with lower population density than the city of Philadelphia. Montgomery County exhibits great diversity in the types of residences: from large mansions on wooded lanes to recently built townhome and single family developments to modest single family or multifamily homes. A number of commercial developments exist along the Route 30 corridor, often referred to as "The "Main Line".

Estimated Population: 799,874

Population Density: 1,653/sq mi (638.4/km²)

Area: 483 sq mi (1,251 km^2)

An important exception applies to the Borough of Norristown, which is considered Urban due to the high density of row-home residences. Norristown also houses county offices and courthouses. The following figure depicts the Norristown suburban exclusion polygon, where test call points should not be considered for the suburban case.

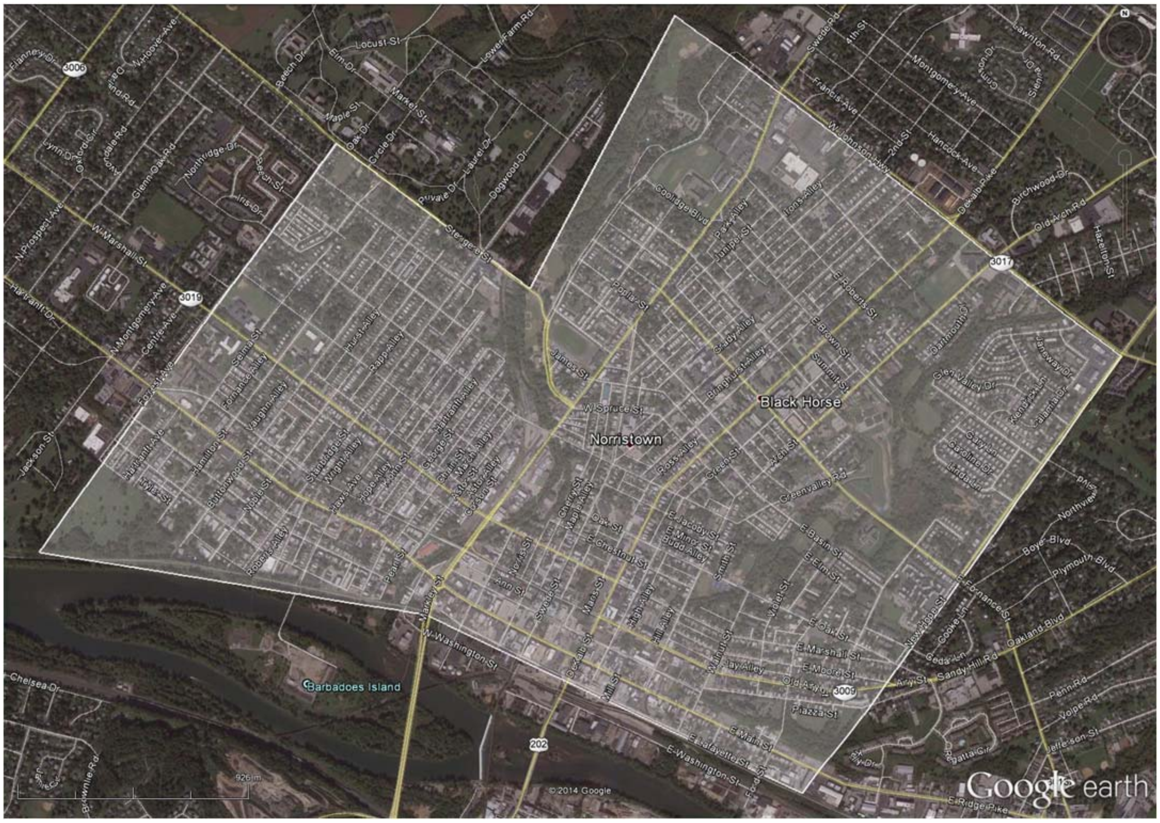

Figure 10.7 - Borough of Norristown Exclusion Polygon

The following test scenarios can be found in the suburban morphology within the Greater Philadelphia regional test bed.

A. Commercial locations
   i. Multi-story (professional buildings, medical centers)
   ii. 1-2 story (retail, business, warehouse, entertainment – brick/masonry, wood framing, or steel framing with wood)
   iii. Office parks
   iv. Large shopping malls
B. Public Places
   i. Township administrative offices
   ii. Township police departments
   iii. Fire houses
   iv. SEPTA train stations
C. Residential locations
   i. 1-2 story (single family – brick, wood with stucco; vinyl, or other siding)
   ii. 1-3 story (multi-family)
   iii. Multi-story apartment buildings

10.1.4 Rural

The rural morphology in the Northeast U.S. is distinguished for being sparsely populated, mostly made up of forests and farmlands and a few isolated residential developments.

The rural morphology in the Greater Philadelphia regional test bed is an irregular polygon between Berks County and Chester County, around French Creek State park.

During detailed test plan development the cell site density in the area should be verified to ensure a low cell site density commensurate with a rural environment.

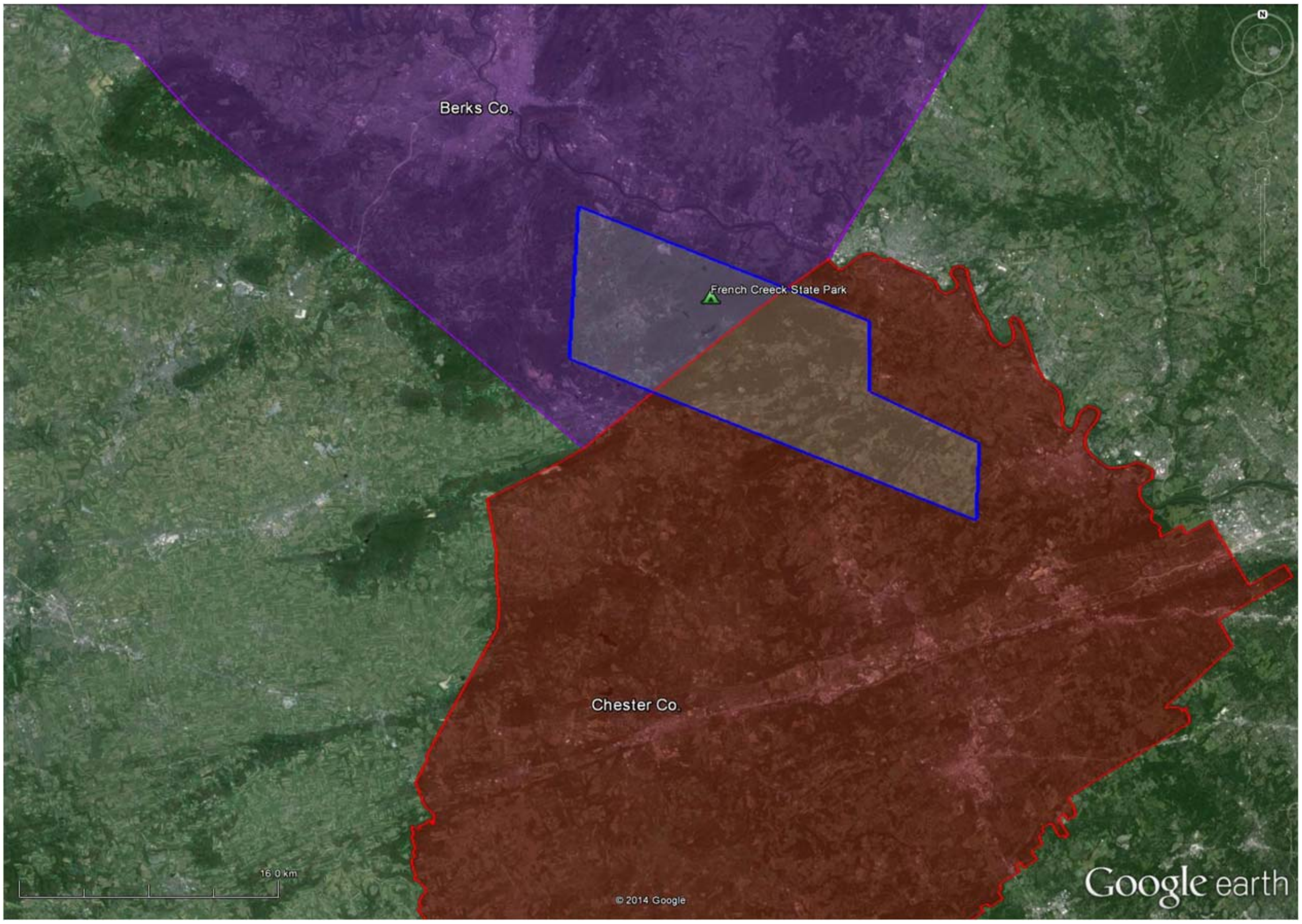

Figure 10.8 - Rural Morphology – Greater Philadelphia Region

The following test scenarios are applicable in the rural morphology within the Greater Philadelphia regional test bed.

A. Residential locations
   i. 1-2 story (single family – wood with Stucco, brick veneer, or vinyl siding)
   ii. 1-2 story (single family – wood with aluminum siding)
   iii. 2-story (single family – stone farmhouse)
B. Commercial locations
   i. 1-2 story (retail, warehouse – wood framing or steel framing with wood)
   ii. 2-3 story (barn, converted barn – tin roof)
C. Government buildings
   i. 2-story brick or masonry

10.2 Greater Philadelphia Test Cases

Dense Urban

I. Commercial

A. High rise building and major commercial center

1. 3-10 story mixed use commercial center surrounded by high rises
    a) *Inside major entrance (>5m from doors)*
    b) *In main hall near middle of building lower level (away from atrium if applicable)*
    c) *Inside interior retail or office space lower floor*
    d) *Inside interior retail or office space upper floor*
2. 11+ story steel/concrete frame w plaster or brick finish
    a) *Outside room with windows lower floor (>3m from window)*
    b) *Outside room with windows upper floor (>3m from window)*
    c) *Building lobby (>3m from entry door)*
    d) *Entry level hallway*
    e) *Upper level hallway (same position above entry level hallway if possible)*
    f) *Interior office or space lower floor (visible from outside office on same floor)*
3. 20+ story steel with glass only exterior
    a) *Outside room with windows lower floor (>3m from window)*
    b) *Outside room with windows upper floor (>3m from window)*
    c) *Building lobby (>3m from entry door)*
    d) *Entry level hallway*
    e) *Upper level hallway (same position above entry level hallway if possible)*
    f) *Interior office or space lower floor (visible from outside office on same floor)*

B. Other commercial structures

1. Multi-level parking structure
    a) *Highest level below roof (interior point)*
    b) *Middle level (>3m from exterior)*
    c) *Ground level (>3m from exterior)*
    d) *Ground level (interior point)*
2. 1-2 story surrounded by tall buildings
    a) *Upper level (inside room)*
    b) *Lower level (outside room)*
    c) *Lower level (inside room)*

C. Public buildings (as alternatives to similar sized commercial structures above)

1. Train Stations (1-2 story building)
    a) *1-2 story open space ticket hall, waiting area*
    b) *Underground or ground level ramps*
2. Fire Stations (1-2 story building)
    a) *Office area*
    b) *Dormitory*
    c) *Engine bay*
3. Police Stations (multi-story)
    a) *Office area*
4. Post Offices (within larger multi-story building)
    a) *Mail holding area*
    b) *Public office*

II. Residential

A. Single Family

1. 2-4 story brick and masonry row home
    a) *Inside room, lower 2 floors*
    b) *Outside room with windows upper floors (>3m from window)*
    c) *Entry level hallway, foyer, etc.*
    d) *Upper level hallway (same position above entry level hallway if possible)*

B. Multi-family

1. 3-10 story steel/concrete frame with wood or plaster finish-- surrounded by taller buildings
    a) *Outside room with windows lower floor (>3m from window)*
    b) *Outside room with windows upper floor (>3m from window)*

   c) *Building lobby (>3m from entry door)*
   d) *Entry level hallway*
   e) *Upper level hallway (same position above entry level hallway if possible)*
2. 11+ story steel/concrete frame with brick or masonry-- surrounded by taller buildings
   a) *Outside room with windows lower floor (>3m from window)*
   b) *Outside room with windows upper floor (>3m from window)*
   c) *Building lobby (>3m from entry door)*
   d) *Entry level hallway*
   e) *Upper level hallway (same position above entry level hallway if possible)*
3. 20+ story steel/concrete frame with plaster or brick finish or glass exterior
   a) *Outside room with windows lower floor (>3m from window)*
   b) *Outside room with windows upper floor (>3m from window)*
   c) *Building lobby (>3m from entry door)*
   d) *Entry level hallway*
   e) *Upper level hallway (same position above entry level hallway if possible)*

Urban

I. Commercial

A. Smaller retail, business (office), warehouse, entertainment

1. 1-story single structure (warehouse type)
   a) *Peripheral room or space with windows (> 3m from window)*
   b) *Interior space near middle of building*
2. 2-story single structure- masonry, brick or brick veneer
   a) *Outside room with windows (>3m from window)*
   b) *Interior office or space lower floor*
   c) *Interior office or space upper floor or level*

B. Larger professional office/major commercial center

1. 3-10 story mixed use commercial center
   a) *Inside major entrance (>5m from doors)*
   b) *In main hall near middle of building lower level (away from atrium if applicable)*
   c) *Inside interior retail or office space lower floor*
   d) *Inside interior retail or office space upper floor*
   e) *Attached parking garage if available (one floor below garage roof)*
2. 11+ story commercial high rise
   a) *Building lobby*
   b) *Attached parking garage if available (one floor below garage roof)*
   c) *Outside office with windows lower floor (>3m from window)*
   d) *Interior office or space lower floor (visible from outside office on same floor)*
   e) *Outside room with windows upper floor (>3m from window)*
   f) *Interior office or space lower floor (visible from outside office on same floor)*

C. Arena

1. Large multiple purpose event venue with multi-level amphitheater seating
   a) *Ticketing area (if indoors)*
   b) *Rest rooms*
   c) *Vending area*
   d) *Seating area, lower levels*
   e) *Seating area, upper levels*

D. Convention hall or center

1. Large multi-purpose event venue, no seating area, single level open space
   a) *Exhibit hall, <5 meters from exterior walls*
   b) *Exhibit hall, >5 meters from exterior walls*
   c) *Lobby level and administrative offices*

E. Airport Terminal

   a) *Ticketing area (typically upper level)*
   b) *Baggage Claim (typically lower level)*
   c) *Boarding gates (if permission can be obtained from airport security)*
   d) *Lower level outside secure area (if permission can be obtained from airport security)*

F. Public buildings (as alternatives to similar sized commercial structures above)

1. Train Stations (1-2 story building)
    - *a) 1-2 story open space ticket hall, waiting area*
    - *b) Underground or ground level ramps*
2. Fire Stations (1-2 story building)
    - *a) Office area*
    - *b) Dormitory*
    - *c) Engine bay*
3. Police Stations (multi-story)
    - a) *Office area*
4. Post Offices (within larger multi-story building)
    - *a) Mail holding area*
    - *b) Public office*

II. Residential

A. Multi-family

1. 2-3 story brick
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Interior room not on top floor (where obtaining ground truth is not impractical)*
    - *d) Building lobby (>3m from entry door)*
2. 4-10 story brick or concrete
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Interior room not on top floor (where obtaining ground truth is not impractical)*
    - *d) Building lobby (>3m from entry door)*
3. 11+ story steel/concrete frame w/wood with glass or other materials on the exterior
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*

<u>Suburban</u>

I. Commercial

A. Multi-story (professional buildings, medical centers, etc.)

1. 1-story single structure (warehouse type with metal roof, if possible)
    - *a) Peripheral room or space with windows (>3m from window)*
    - *b) Interior space near middle of building*
2. 2-story single structure- wood or steel framing, brick/masonry
    - *a) Outside room with windows (>3m from window)*
    - *b) Interior office or space lower floor*
    - *c) Interior office or space upper floor or level*
3. 3-10 story professional building
    - *a) Building lobby*
    - *b) Attached parking garage if available (one floor below garage roof)*
    - *c) Outside office with windows lower floor (>3m from window)*
    - *d) Interior office or space lower floor (visible from outside office on same floor)*
    - *e) Outside room with windows upper floor (>3m from window)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*

B. Office Parks

1. 1-3 story single structure- masonry, brick or brick veneer
    - *a) Outside room with windows (>3m from window)*
    - *b) Interior office or space lower floor*
    - *c) Interior office or space upper floor or level*

C. Large shopping malls

1. 3-4 story mixed use commercial center
    - *a) Inside major entrance (>5m from doors)*

b) *In main hall near middle of building lower level (away from atrium if applicable)*
c) *Inside interior retail or office space lower floor*
d) *Inside interior retail or office space upper floor*

D. Public buildings (as alternatives to similar sized commercial structures above)

1. Township administrative offices and Police Departments (1-2 story building)
   a) *Office Area*
2. Fire Stations (1-2 story building)
   a) *Office area*
   b) *Dormitory*
   c) *Engine bay*
3. Train Stations (1-2 story building)
   a) *1-2 story open space ticket hall, waiting area*
   b) *Underground or ground level ramps*

II. Residential

A. Single family (stand-alone structure)

1. 1-2 story brick or other prevailing construction materials
   a) *1st floor outside room with windows (>3m from window)*
   b) *1st floor inside away from windows (e.g., hallway)*
2. 2-story brick under heavy foliage
   a) *1st floor outside room with windows (>3m from window)*
   b) *1st floor inside away from windows (e.g., hallway)*
3. 2-story brick with metal roof or radiant barrier
   a) *1st floor outside room with windows (>3m from window)*
   b) *1st floor inside away from windows (e.g., hallway)*

B. Multi-family

1. 2-3 story brick or other prevailing construction materials
   a) *Outside room with windows lower floor (>3m from window)*
   b) *Outside room with windows upper floor (>3m from window)*
   c) *Interior room not on top floor*
2. 3+ story brick and/or brick veneer
   a) *Outside room with windows lower floor (>3m from window)*
   b) *Outside room with windows upper floor (>3m from window)*
   c) *Interior room not on top floor (where obtaining ground truth is not impractical)*
   d) *Building lobby (>3m from entry door)*

<u>Rural/Sparse</u>

I. Commercial

A. Agricultural/light industry structure, government building, warehouse, barn

1. 1-story single structure (warehouse or retail)
   a) *Peripheral room or space with windows (>3m from window)*
   b) *Interior space near middle of building*
2. 2-story-high agricultural/light industry building w/metal roof
   a) *Peripheral space or room near outside door or windows (>3m from opening)*
   b) *Interior office or space lower floor*
   c) *Interior office or space upper floor or level*

B. Public buildings (as alternatives to similar sized commercial structures above)

1. 2 story local government building- masonry, brick or brick veneer (county gov., courthouse, etc.)
   a) *Outside room with windows (>3m from window)*
   b) *Interior office or space lower floor*
   c) *Interior office or space upper floor or level*

II. Residential

A. Single family (stand-alone structure)

1. 1-2 story wood (home, barn, work shed) with stucco, brick veneer, or vinyl siding
   a) *1st floor outside room with windows (>3m from window)*
   b) *1st floor inside away from windows (e.g., hallway)*
2. 1-2 story wood frame (home, barn, etc.) with Aluminum siding

   a) *1st floor outside room with windows (>3m from window)*
   b) *1st floor inside away from windows (e.g., hallway)*
3. 2-story stone farmhouse
   a) *1st floor outside room with windows (>3m from window)*
   b) *1st floor inside away from windows (e.g., hallway)*

11 Extrapolation of the Regional Test Bed Results

A number of variables and parameters that can affect indoor location performance for various location technologies of interest are described in section 6. For purposes of extrapolation of regional test bed results, these parameters generally fall into two fundamental categories:

1. Environmental Conditions
2. Location Technology Deployment Options

Similar location performance can be expected between two different geographic areas with similar environmental conditions and the same location technology consistently deployed in both areas. This observation is the fundamental tenet behind the representative test bed concept.

Environmental conditions include variables such as building spacing, height, construction materials, building usage, surrounding morphology (dense urban, urban, suburban, rural), and possibly latitude.

Careful consideration of these environmental variations led to the selection of six regional test beds. Testing across each of these different regional test bed areas will provide sufficient environmental diversity to be reasonably representative of all the normal environmental use cases typically seen from 911 calls made in various indoor locations across the United States.

Other parameters can also be included in the environmental conditions category for the purposes of extrapolation of test bed results. For example, due to the ubiquitous coverage of the GPS satellite constellation (up to 60 degrees latitude), satellite quantity and geometry can be considered reasonably uniform within a specific environment under test, and need not be considered separately as a location technology deployment parameter or option.

For cellular and overlay systems, the typical density and geometry of the macro cell sites and/or beacons need to be accounted for to ensure appropriate extrapolation. Similarly, for Wi-Fi access points, consistent deployment density as reflected in the database should be verified between representative environments and regions to which results are extrapolated to ensure valid performance.

Location technology deployment options include parameters such as quality of assistance information, quality of relevant databases, accuracy of provisioned network data, timing/synchronization accuracy, bandwidth of measured transmission source, specific positioning techniques/algorithms utilized, etc. There are also deployment options unique to a given location method – such as PRS frequency, duration, coordination, and muting for OTDOA, LMU deployment density and handset power-up for U-TDOA, elapsed time since previous database calibration for RF Pattern Matching, and barometer quality and calibration status for barometer-based altitude methods.

To ensure that empirical test results established in a test bed are reflective of performance achievable from a particular location technology under similar environmental conditions in other indoor locations where 911 calls are made, it is imperative that location technology deployment options are consistent between the test bed deployment and areas outside the test bed.

The following table provides a summary of the factors and parameters that are critical to the validity of the extrapolation of regional test bed results for each type of location technology.

AGPS/OTDOA

I. Technology

   A. Content and quality of assistance data
   B. Accuracy of cell site database
   C. Time calibration methods and accuracies

II. Morphology

- ***A. Building density***
- ***B. Building height***
- ***C. Construction type***
- ***D. Building usage (e.g., commercial/residential)***
- ***E. Foliage***
- ***F. Hilly/Rugged Terrain***

III. Network

- ***A. Site density***
- ***B. Site geometry***
    1. Edge cases (such as coast line, string of sites along highways)
- ***C. Inter-frequency boundary***
- ***D. PRS configuration***
- ***E. LTE bandwidth***

U-TDOA

I. Technology

- ***A. LMU deployment density***
- ***B. Accuracy of LMU provisioning (site database)***
- ***C. Software load***

II. Morphology

- ***A. Building density***
- ***B. Building height***
- ***C. Construction type***
- ***D. Building usage (e.g., commercial/residential)***
- ***E. Hilly/Rugged Terrain***

III. Network

- ***A. Site density***
- ***B. Site geometry***
    1. Edge cases (such as coast line, string of sites along highways)
- ***C. Inter-frequency boundary***
- ***D. Bandwidth of cellular uplink***
- ***E. Network features to optimize U-TDOA (e.g., power-up)***

AGPS/AFLT

I. Technology

- ***A. Content and quality of assistance data***
- ***B. Accuracy of cell site database***
- ***C. Time calibration methods and accuracies***

II. Morphology

- ***A. Building density***
- ***B. Building height***
- ***C. Construction type***
- ***D. Building usage (e.g., commercial/residential)***
- ***E. Foliage***
- ***F. Hilly/Rugged Terrain***

III. Network

- ***A. Site density***
- ***B. Site geometry***
    1. Edge cases (such as coast line, string of sites along highways)
- ***C. Cell tower calibration***

<u>AGPS/RTT</u>

I. Technology

- ***A. Content and quality of assistance data***
- ***B. Accuracy of cell site database***
- ***C. Use of one or multiple cell sites in RTT algorithm***

II. Morphology

- ***A. Building density***
- ***B. Building height***
- ***C. Construction type***
- ***D. Building usage (e.g., commercial/residential)***
- ***E. Foliage***
- ***F. Hilly/Rugged Terrain***

III. Network

- ***A. Site density***
  1. Average cell coverage radius
- ***B. Site geometry***
  1. Edge cases (such as coast line, string of sites along highways)
- ***C. Cell tower calibration***

<u>Terrestrial Beacon</u>

I. Technology

- ***A. Bandwidth of beacon downlink***
- ***B. System generation***
- ***C. Accuracy of beacon database***

II. Morphology

- ***A. Building density***
- ***B. Building height***
- ***C. Construction type***
- ***D. Building usage (e.g., commercial/residential)***
- ***E. Foliage***
- ***F. Hilly/Rugged Terrain***

III. Network

- ***A. Beacon site density***
- ***B. Beacon site geometry***
  1. Edge cases (such as coast line, string of sites along highways)

<u>RF Pattern Matching</u>

I. Technology

- ***A. Quality of RF Pattern Matching database***
- ***B. Accuracy of imported network data***

II. Morphology

- ***A. Building density***
- ***B. Building height***
- ***C. Construction type***
- ***D. Building usage (e.g., commercial/residential)***
- ***E. Foliage***
- ***F. Hilly/Rugged Terrain***

III. Network

- ***A. Site density***
  1. Average cell coverage radius
- ***B. Site geometry***
  1. Edge cases (such as coast line, string of sites along highways)
- ***C. Bandwidth of cellular network***
- ***D. Density or presence to short-range cell sites***

Wi-Fi

I. Technology

- ***A. Quantity/Density of surrounding Wi-Fi access points***
- ***B. Quality of Wi-Fi access point database***
    1. Managed versus crowd-sourced
- ***C. Wi-Fi positioning technique used***
    1. Access point technology generation/band

II. Morphology

- ***A. Construction type***
- ***B. Building usage (e.g., commercial/residential)***
- ***C. Number of AP's per floor***

Barometric Pressure Based Altitude

I. Technology

- ***A. Reference pressure distribution density***
- ***B. Accuracy of reference pressure sensor***
- ***C. Accuracy of building altitude database***
- ***D. Device barometric pressure sensor quality***
- ***E. Conditions under which testing is performed***
    1. Storm fronts
    2. Strong winds

II. Morphology

- ***A. Building and environmental design***
    1. Building age
    2. Building sealing
- ***B. Range of temperatures***

12 Conclusion

Due to the pervasive use of wireless devices and their increasing use indoors to call 911, the development of effective methods to test the location accuracy of indoor wireless E911 calls has become a high priority.

Wide scale indoor accuracy testing, e.g., at a local level in many areas, is not feasible due to its high logistical complexity and prohibitive cumulative cost. Furthermore, repeated testing in characteristically similar environments with similar network and location system configurations will not yield added knowledge into network or location technology accuracy performance.

In ATIS-0500022, *Test Plan Input for a Location Technology Test Bed*, ESIF defined a representative testing methodology that was adopted by CSRIC III to provide the FCC with critical indoor location performance data in support of its rule making process. The demonstrated success of the CSRIC III test bed in the Bay Area motivated the extension of its methodology to create a framework of representative testing across the U.S. The basic premise of this methodology is the feasibility of extrapolating the test results derived from a test bed to an area considerably wider than its confines, if certain, well-defined conditions are met.

This document provides detailed recommendations and guidelines for establishing wide scale indoor location performance based on representative testing in a limited number of regional test beds. Six regional test beds are proposed in and/or around six metropolitan areas. Each regional test bed is selected to represent a part of the country with its prevailing characteristics, e.g., Northeast, Pacific Coast, etc. Each test bed is intended to have adequate geographic extent to include the range of environments (morphologies) encountered in that region. Each regional test bed thus represents the network's morphologies, signal coverage, and network technologies associated with E911 location determination and delivery in its region.

Integral to the proposed methodology is the specification of the conditions that must be satisfied to permit extrapolation of the results beyond the boundary of a given test bed area. To this end, this document provides a compilation of a wide range of location technologies, both established and emerging, that could be used indoors and a detailed listing of the parameters the similarity of which has to be satisfied to permit proper extrapolation of the indoor accuracy results. These parameters fall into two broad categories: environmental conditions and location technology deployment options. Parameters in both categories are identified and enumerated for each type of location technology.

Since this document is intended for a broad audience that may be interested in using its guidelines for the purposes of predicting indoor location performance, two specific test bed examples are provided in detail. Those two examples are for two very distinct regions, the Bay Area representing the Pacific Coast Region, and Philadelphia, representing the Northeastern US. The candidate selections of representative test buildings and indoor test scenarios are provided for each of these two test beds. It is seen that a similar technical approach and structure are followed with some reasonable modifications to accommodate the differences between the regions. Application of local knowledge in the detailed definition of a particular test bed is helpful in that regard.

Although the Bay Area test cases provided in this document reflect the CSRIC III testing, in future testing, the selected set of test buildings and test scenarios may be varied to take into account the statistics of prevailing indoor wireless 911 calls in refining the test sample. This may also depend on the specific objective of a test campaign, e.g., technology validation versus compliance testing. These distinctions in application are beyond the scope of the current standard.

Finally, there will always be unusual or unique indoor situations which could be more challenging than the common indoor scenarios used by the majority of wireless callers. This standard does not intend to tackle such special instances, but rather addresses the range of environments and indoor scenarios that are common across the wireless network. Principles found in ATIS-0500013, *Approaches to Wireless E911 Indoor Location Performance Testing*, can be applied in creating an E911 indoor test plan for special circumstances, which are as well beyond the scope of this standard.

Appendix A: Full Matrix of Test Cases (West Region)

The following is fairly comprehensive list of test building types and corresponding test cases that can be adapted and refined for the different regional test beds. Moreover, the eventual subset actually selected to perform a given test campaign (e.g., new technology validation versus compliance testing) may take into account the statistics of prevailing indoor wireless 911 calls in refining the sample of selected test buildings.

Dense Urban

I. Residential

A. Multi-Family

1. 6-8 story steel/concrete frame with wood of plaster finish – surrounded by taller buildings
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*
2. 6-8 story steel/concrete frame with brick or masonry – surrounded by taller buildings
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*
3. 20+ story steel/concrete frame with plaster or brick finish
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*

II. Commercial

A. High rise building and major commercial center

1. 3-4 story mixed use commercial center surrounded by high rises
    - *a) Inside major entrance (>5m from doors)*
    - *b) In main hall near middle of building lower level (away from atrium if applicable)*
    - *c) Inside interior retail or office space lower floor*
    - *d) Inside interior retail or office space upper floor*
2. 20+ story steel/concrete frame w plaster or brick finish
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) level hallway (same position above entry level hallway if possible)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*
3. 20+ story steel with glass only exterior
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*

Urban

I. Residential

A. Multi-family

1. 3-story wood with plaster or stucco
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Interior room not on top floor (where obtaining ground truth is not impractical)*

- *d) Building lobby (>3m from entry door)*

2. 3-story wood with brick veneer
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Interior room not on top floor (where obtaining ground truth is not impractical)*
    - *d) Building lobby (>3m from entry door)*
3. 6-story steel/concrete frame with wood or plaster finish
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*
4. 15-story steel/concrete frame with wood or plaster finish
    - *a) Outside room with windows lower floor (>3m from window)*
    - *b) Outside room with windows upper floor (>3m from window)*
    - *c) Building lobby (>3m from entry door)*
    - *d) Entry level hallway*
    - *e) Upper level hallway (same position above entry level hallway if possible)*

II. Commercial

A. Smaller retail, business (office), warehouse, entertainment

1. 1-story single structure (warehouse type)
    - *a) Peripheral room or space with windows (>3m from window)*
    - *b) Interior space near middle of building*
2. 2-story single structure- wood or steel framing, plaster or wood
    - *a) Outside room with windows (>3m from window)*
    - *b) Interior office or space lower floor*
    - *c) Interior office or space upper floor or level*
3. 2-story single structure- masonry, brick or brick veneer
    - *a) Outside room with windows (>3m from window)*
    - *b) Interior office or space lower floor*
    - *c) Interior office or space upper floor or level*

B. Larger professional office/major commercial center

1. 3-4 story mixed use commercial center
    - *a) Inside major entrance (>5m from doors)*
    - *b) In main hall near middle of building lower level (away from atrium if applicable)*
    - *c) Inside interior retail or office space lower floor*
    - *d) Inside interior retail or office space upper floor*
2. 4-6 story professional building
    - *a) Building lobby*
    - *b) Attached parking garage if available (one floor below garage roof)*
    - *c) Outside office with windows lower floor (>3m from window)*
    - *d) Interior office or space lower floor (visible from outside office on same floor)*
    - *e) Outside room with windows upper floor (>3m from window)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*
3. 15+ story commercial high rise
    - *a) Building lobby*
    - *b) Attached parking garage if available (one floor below garage roof)*
    - *c) Outside office with windows lower floor (>3m from window)*
    - *d) office or space lower floor (visible from outside office on same floor)*
    - *e) Outside room with windows upper floor (>3m from window)*
    - *f) Interior office or space lower floor (visible from outside office on same floor)*

C. Arena

- *a) Specific test cases to be developed*

D. Convention hall or center

- *a) Specific test cases to be developed*

E. Airport Terminal

- *a) Specific test cases to be developed*

Suburban

I. Residential

A. Single family (stand-alone structure)

1. 1-story wood w/ stucco
    a) *1st floor outside room with windows (>3m from window)*
    b) *1st floor inside away from windows (e.g., hallway)*
2. 2-story wood w/ stucco
    a) *1st floor outside room with windows (>3m from window)*
    b) *1st floor inside away from windows (e.g., hallway)*
3. 2-story brick or brick veneer
    a) *1st floor outside room with windows (>3m from window)*
    b) *1st floor inside away from windows (e.g., hallway)*

B. Multi-family

1. 2-story wood w/plaster or stucco
    a) *Outside room with windows lower floor (>3m from window)*
    b) *Outside room with windows upper floor (>3m from window)*
    c) *Interior room not on top floor*
2. 3-story wood w/plaster or stucco
    a) *Outside room with windows lower floor (>3m from window)*
    b) *Outside room with windows upper floor (>3m from window)*
    c) *Interior room not on top floor (where obtaining ground truth is not impractical)*
    d) *Building lobby (>3m from entry door)*
3. 3-story wood w/brick veneer
    a) *Outside room with windows lower floor (>3m from window)*
    b) *Outside room with windows upper floor (>3m from window)*
    c) *Interior room not on top floor (where obtaining ground truth is not impractical)*
    d) *Building lobby (>3m from entry door)*

II. Commercial

A. Smaller retail, business (office), warehouse, entertainment

1. 1-story single structure (warehouse type)
    a) *Peripheral room or space with windows (>3m from window)*
    b) *Interior space near middle of building*
2. 2-story single structure- wood or steel framing, plaster or wood
    a) *Outside room with windows (>3m from window)*
    b) *Interior office or space lower floor*
    c) *Interior office or space upper floor or level*
3. 2-story single structure- masonry, brick or brick veneer
    a) *Outside room with windows (>3m from window)*
    b) *Interior office or space lower floor*
    c) *Interior office or space upper floor or level*

B. Larger professional office/major commercial center/mall

1. 2-3 story major mall
    a) *Inside major entrance (>5m from doors)*
    b) *In main hall near middle of mall lower level (away from atrium if applicable)*
    c) *Inside interior retail space lower floor*
    d) *Inside interior retail space upper floor*
2. 3-4 story mixed use commercial center
    a) *Inside major entrance (>5m from doors)*
    b) *In main hall near middle of building lower level (away from atrium if applicable)*
    c) *Inside interior retail or office space lower floor*
    d) *Inside interior retail or office space upper floor*
3. 4-6 story professional building
    a) *Building lobby*
    b) *Attached parking garage if available (one floor below garage roof)*
    c) *Outside office with windows lower floor (>3m from window)*
    d) *Interior office or space lower floor (visible from outside office on same floor)*
    e) *Outside room with windows upper floor (>3m from window)*
    f) *Interior office or space lower floor (visible from outside office on same floor)*

<u>Rural/Sparse</u>

I. Residential

A. Single family (stand-alone structure)

1. 1-story wood (home, barn, work shed)
    a) *1st floor outside room with windows (>3m from window)*
    b) *1st floor inside away from windows (e.g., hallway)*
2. 2-story wood frame (home, barn, etc.)
    a) *1st floor outside room with windows (>3m from window)*
    b) *1st floor inside away from windows (e.g., hallway)*
3. 2-story brick or brick veneer
    a) *1st floor outside room with windows (>3m from window)*
    b) *1st floor inside away from windows (e.g., hallway)*

II. Commercial

A. Agricultural/light industry structure, government building, warehouse, barn

1. 1-story single structure (warehouse type)
    a) *Peripheral room or space with windows (>3m from window)*
    b) *Interior space near middle of building*
2. 2-story agricultural/light industry building with metal roof
    a) *Peripheral space or room near outside door or windows (>3m from opening)*
    b) *Interior office or space lower floor*
    c) *Interior office or space upper floor or level*
3. 2-story building- masonry, brick or brick veneer (county gov., courthouse, etc.)
    a) *Outside room with windows (>3m from window)*
    b) *Interior office or space lower floor*
    c) *Interior office or space upper floor or level*