March 14, 2012   WORKING GROUP 3
                                        E9-1-1 Location Accuracy

                 Final Report – Outdoor Location Accuracy

The Communications Security, Reliability and Interoperability Council III   **Working Group 3 Outdoor Location Accuracy**

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1   RESULTS IN BRIEF

1.1 Executive Summary

As the communications industry evolves, so does the opportunity to enhance the public's ability to contact emergency services personnel during times of crisis. Public expectation has grown to the point that one assumes public safety personnel will be able to dispatch the appropriate emergency services to any reported event.   This capability is dependent upon public safety receiving the best possible location information available to them.

Working Group 3 (WG3), subgroup on Outdoor Location Accuracy, was charged with:

- Reviewing existing information on outdoor location accuracy testing criteria, procedures, and timeframes and recommending approaches that are realistic, rational and cost-effective:
- Considering alternatives to current FCC Office of Engineering and Technology OET Bulletin No. 71 (OET 71)[1]:
- The development of recommendations on the feasibility of flexible testing criteria and methodologies, and finally:
- Gathering detailed cost data relating to particular testing methodologies from stakeholders to substantiate concerns about potential expense of periodic testing.

This report documents WG3's review of the materials described above and details various methodologies for Outdoor Location Accuracy Testing.

It is the consensus of WG3 that OET 71, issued on April 2000, continues to be a valuable high-level guideline and framework for evaluating compliance for enhanced 9-1-1 location accuracy testing. OET 71 acknowledged within its framework that testing and verification practices would evolve over time and indeed that has been the case.

Since the Bulletin was issued, the Alliance for Telecommunications Industry Solutions (ATIS)[2] Emergency Services Interconnection Forum (ESIF) has produced five (5) standards documents and each of these was reviewed by WG3 (Section 4). These ATIS standards have expanded upon the initial OET 71 framework with advanced processes and procedures that all 911 stakeholders can use to validate the performance of 911 location accuracy. As a consequence of our review of ATIS materials, we suggest the following ATIS Technical Reports, as augmented by recommendations in Section 5, be recognized and used by stakeholders as best practices for outdoor location accuracy:

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[1] < http://www.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet71/oet71.pdf>

[2] < http://www.atis.org

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- ATIS Technical Report 0500001 – High Level Requirements for Accuracy Testing Methodologies
- ATIS Technical Report 0500009 – High Level Requirements for End-to-End Functional Testing.
- ATIS Technical Report 0500011 – Define Topologies & Data Collection Methodology.
- ATIS Technical Report 0500010 – Maintenance Testing
- ATIS Technical Report 0500013 – Approaches To Wireless Indoor Location Performance Testing (referred to in Section 4.7 so as to address concepts that are also relevant to outdoor accuracy)

Our consensus is that ATIS-0500001 generally provides more current and relevant procedures and guidelines than are available in OET 71. WG3 has also provided various methodologies for location accuracy testing within Section 5 of our WG report that define the various methods and provide alternative testing methods. Although there are many valid approaches to location accuracy performance, some of them provide a more cost-effective way to achieve and maintain location accuracy within the wireless service provider's (WSP's) network[3].

Full compliance testing utilizing the empirical testing methodology requires the wireless service provider to test within each County/PSAP gathering statistical data to ensure compliance within the Wireless E911 Location Accuracy Requirements, PS Docket No. 07-114, Second Report and Order, FCC 10-176 (Sept. 23, 2010) ("*Second R&O*")[4] metric. This type of testing ranges in cost from $250 -$1000 per cell site (Section 6). Wireless service providers meet their testing obligations in a number of ways including performing this field testing themselves, utilizing automated means of testing to a location server, outsourcing the work to a third party vendor, or a combination of these. Based on the number of cell sites within the service provider's network, initial testing can be costly.

The WG concurs that ATIS-050001 provides both:
- best practices for conducting Empirical accuracy testing, and
- appropriate guidelines and accepted procedures for use of the predictive testing methodology, as well as proper safeguards in utilizing predictive testing

We recommend that further development and guidance on the various alternative testing methodologies, as defined within this WG3 report, be documented within ATIS-0500010.

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[3] WG3 has decided to use the generic terminology of "Wireless Service Provider" (WSP). In the current context of the document, WSP refers to CMRS providers as defined by the FCC.
[4] http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-10-176A1_Rcd.pdf

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It is also our recommendation for maintenance testing that:

- Key performance indicators (KPIs) should be routinely monitored and archived network-wide, to help determine when system performance has degraded and further testing and system improvements are needed at the local level.
- Enhancements to location technology should be validated in representative environments, to ensure equivalent or improved performance.
- Spot-checking using empirical field-testing should be conducted on an as needed basis, for example, as determined by KPI monitoring or legitimate performance concerns from a PSAP.
- Empirical data for maintenance testing may be collected incrementally, but must conform to the requirements in ATIS-0500010: Maintenance and Testing; Sections 3.2 Useful Life of Data and, Section 3.3. System Under Test.
- Any significant deviations from expected prior performance levels should result in careful investigation and re-testing of the applicable test area.
- WG3 recommends that the alternative maintenance testing methods, as detailed in Section 5 of this WG report, replace the requirement for full compliance testing every two years as is implied in ATIS-0500010.
- We also recommend that wireless service providers provide verification of testing and/or test summary results to the FCC upon request and that those records be maintained for a period of up to 24 months.
- Finally, we recommend that as questions relating to location accuracy arise, WSPs work directly with the County/PSAP or other public safety entities by properly investigating the root cause of potential performance concerns.

The current FCC rules, established in the 2nd R & O, do not clearly mandate a specific Phase 2 yield requirement[5]; rather, current rules establish specific "Phase 2 location accuracy" standards spread over four defined benchmarks at the county-level. Although the WG members generally worked in concert to provide overall objectivity and worked toward best practice resolutions, 'yield' is a subject that we could not find consensus on, and was a continuous point of disagreement . Within the Outdoor Location charter for this WG, yield is not listed as an objective that needs to be discussed or defined. It is mentioned within the scope of the Indoor Accuracy WG.

The subject of location system performance and yield means numerous things to different stakeholders. In an effort to provide visibility into the debate over yield, we have provided highlights from the discussion within Section 7 of this report.

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[5] Phase 2 yield may be defined as the ratio of successful Phase 2 locations over the total number of valid location requests.

No consensus recommendations with regard to yield are contained in this report.

1.1.1 CSRIC III Working Group 3 – Wireless E9-1-1 Location Accuracy Charter

Outdoor Location Accuracy
The Working Group shall develop approaches to outdoor location accuracy testing criteria, procedures, and timeframes that are reasonable and cost-effective, considering alternatives to OET 71. It shall also develop recommendations concerning the feasibility of flexible testing criteria and methodologies, and gather detailed cost data relating to particular testing methodologies from stakeholders to substantiate concerns about potential expense of periodic testing. Report on Outdoor Location Accuracy: Six Months

1.1.2 Structure of the Working Group 3 Outdoor Location Accuracy Report
The document is comprised of 7 sections and 1 appendix as follows:

Section 1:   Results in Brief
Section 2:   Introduction
Section 3:   Objective, Scope, and Methodology
Section 4:   Approaches for Outdoor Location Accuracy Testing
Section 5:   Review of Existing Best Practice Documents
Section 6:   Outdoor Location Accuracy Testing Costs and Timeframes
Section 7:   System Performance and Yield
Appendix A: Acronyms
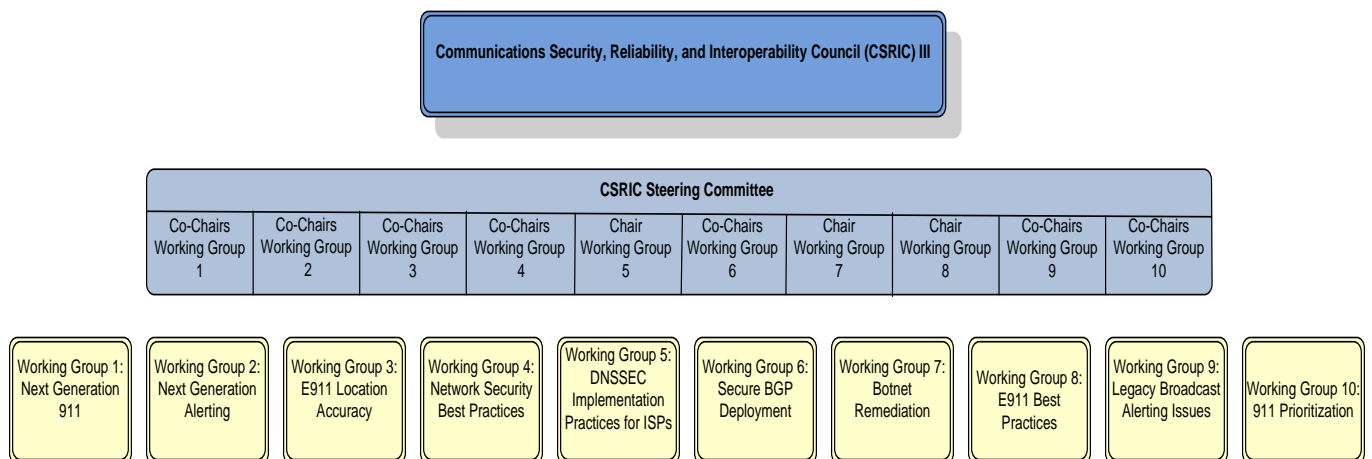
2 INTRODUCTION

2.1 CSRIC III Structure

Figure 1: CSRIC III Organization Chart

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2.2 Working Group 3 Outdoor Sub-Group Team Members

Working Group 3 Co-Chairs
Stephen J. Wisely – APCO International
Richard Craig – Verizon Wireless

Outdoor Location Accuracy Subgroup Co-Leaders
Jeanna M Green- Sprint
Brett Schneider – Bexar Metro 9-1-1 District

Working Group Document Editors:
Jeanna Green – Sprint
Kathy McMahon – APCO International

WG 3 Outdoor Location Accuracy Subgroup consists of the following members:

First Name	Last Name	Organization
Michael	Anderson	Ericsson
Firdaus	Aryana	Telecommunication Systems, Inc.
Wayne	Ballantyne	Motorola Mobility, Inc.
Andrew	Beck	CommScope
Jeb	Benedict	CenturyLink
Donna	Bethea-Murphy	Iridium
Bill	Buchholtz	Texas 911 Alliance
Richard	Craig	Verizon Wireless
Marlys	Davis	King County E9-1-1 Program Office
Khaled	Dessouky	TechnoCom Corporation
Thomas	Dombrowsky	Wiley Rein LLP
Chris	Fischer	NORCOM
Jeanna	Green	Sprint
Roger	Hixson	NENA
Ryan	Jensen	T-Mobile
Marte	Kinder	Time Warner Cable

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First Name	Last Name	Organization
Sandra	Lott	CenturyLink
Mike	Loushine	Applied Communication Sciences
Barry	Martin	Boeing
Kathryn	Martin	Access Partnership
Kathy	McMahon	APCO
Martin	Moody	Metro Emergency Services Board
Jim	Nixon	T-Mobile
Gary	Parsons	NextNav LLC
Ganesh	Pattabiranan	NextNav LLC
Gustavo	Pavon	True Position, Inc.
Raghavendhra	Rao	AT&T
Chuck	Ronshagen	Cassidian Communications
Brett	Schneider	Bexar Metro 9-1-1 Network District
DeWayne	Sennett	ATIS
Norman	Shaw	Polaris Wireless, Inc.
Susan	Sherwood	Verizon Wireless
John	Snapp	Intrado, Inc.
Dorothy	Spears-Dean	Virginia Information Technologies Agency
Bill	Tortoriello	US Cellular
Greg	Turetzky	CSR Technology Inc.
Bruce	Wilson	Qualcomm Inc.
Stephen	Wisely	APCO
Karen	Wong	State of California
Richard Deh-Min	Wu	Nokia Siemens Networks

Table 1 - List of Working Group Members

Additional Contributors:

Ajit Kahaduwe – Nokia Siemens Networks
David Conner – U.S. Cellular

3　OBJECTIVE, SCOPE, AND METHODOLOGY

3.1 Objective

The objective of this report is to present the findings of the CSRIC III Working Group 3 related to outdoor location accuracy testing, focusing on areas identified in the FCC's charter for CSRIC III. These are summarized as:

- ♦ Develop approaches to Outdoor location accuracy testing criteria that are reasonable and cost effective, considering alternatives to OET 71:
- ♦ Develop recommendations concerning the feasibility of flexible testing criteria and methodologies:
- ♦ Gather and present cost data on accuracy testing from stakeholders to substantiate concerns over potential expense of periodic testing.

In the process of tackling the above, explicit objectives also:

- ♦ Address the issue of testing timeframes
- ♦ Evaluate OET 71 in today's context, and how it can be augmented and improved upon
- ♦ Present alternatives for test processes and procedures for E9-1-1 accuracy suitable for use in the current and future time frames

3.2 Scope

Considering the timelines set by the FCC for this working group, this report focuses exclusively on outdoor accuracy testing. Two subsequent reports will address indoor location accuracy and leveraging commercial location based services (LBS), including newer or emerging location technologies. The scope of this report closely reflects the objectives related to outdoor accuracy testing stated above.

To present a complete picture of wireless E9-1-1 accuracy testing methodologies, their evolution, and to address the questions in the stated objectives related to OET 71, Section 4 presents a review of existing best practices documents related to accuracy testing.   It starts with a thorough review of the Bulletin from today's perspective. It then adds a concise synopsis of the various documents related to accuracy testing that were intended to build on OET 71, and that have been developed over the last decade within ESIF.   The area and extent of applicability of each

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document is also identified.

Section 5 presents approaches to outdoor accuracy location testing. It starts by providing a historical context for accuracy testing methodologies. It then presents empirical testing methods gleaned from OET 71 and subsequently articulated more fully by ESIF, especially in ATIS-050001, including its recent updates. It also presents recommendations on empirical testing procedures, e.g., pertaining to test sample size and coverage, that augment the information in those sources. Section 5 then presents alternative testing methods intended to be more cost efficient and flexible, and available once the E9-1-1 system has been verified through empirical testing to operate well and be compliant with FCC requirements. These techniques include predictive testing, incremental testing, monitoring of key performance indicators, monitoring uncertainty trends, and more selective and targeted empirical testing, e.g., for spot-checking, in representative environments, or with reduced sample sizes. Section 5 closes by presenting recommendations on accuracy maintenance testing.

Section 6 presents cost information for various testing methods gathered from working group members and their vendors. This data ranges from the cost of complete accuracy testing and monitoring systems, to manual testing methods, e.g., through contract labor, with per cell or per PSAP price ranges, to some of the costs associated with in-house or hosted data storage solutions in support of location performance indicators and trends monitoring.

Section 7 discusses an area of active debate within Working Group 3 related to the yield of Phase II location systems and its relation to accuracy testing. The salient views within the working group on this issue are presented for the FCC's perusal.

3.3 Methodology

Working Group 3 sub-group on Outdoor location accuracy met every two weeks via conference call(s) to review research and discuss 9-1-1 outdoor location accuracy. The sub-group and ad-hoc structure relied upon members volunteering to embrace additional work in conjunction with participating in the efforts of the full committee.

Text contributions, as completed, were reviewed, edited and approved by the full membership of Working Group 3.

The sub-group conducted over 12 conference calls, and two multi-day face-to-face meetings in Kansas City, Missouri and Richardson, Texas. This effort was challenging given the responsibilities that each member faced in his/her public, private or other profession.

4 REVIEW OF EXISTING BEST PRACTICE DOCUMENTS

4.1 Introduction

In this section, WG3 analyzed established FCC and ATIS documents that pertain to Outdoor Testing methodologies. Specifically, we identify the key recommendations in each one, discuss those which are still applicable, and also highlight those recommendations which are now superseded by technology advances, changes in usage trends, or updated treatments in newer documents.

4.2 Review & Comments on FCC OET 71

OET Bulletin No. 71 was issued by the FCC's Office of Engineering and Technology on April 12, 2000. Its intent was to offer guidelines and suggestions for evaluating compliance with E9-1-1 mandates, rather than establishing mandatory procedures for such evaluation. The Bulletin explicitly states at its outset that other methods and procedures may be acceptable if based on sound engineering and statistical practice. The Bulletin, however, states that compliance with the guidelines in the Bulletin will establish a strong presumption that appropriate means have been applied to ensure compliance with the Commission's rules.

Whereas much of the thrust and content of the Bulletin remains applicable and vital in setting the current guidelines for E9-1-1 wireless location assessment, several of the statements in it reflect the state of knowledge of the wireless industry and E9-1-1 in the year 2000 timeframe. Over the past decade, since the publication of the Bulletin, much evolution in the use of wireless networks and devices has taken place. Significant progress has also been achieved in wireless E9-1-1 and its testing methodologies. The efforts to create methods and guidelines for E9-1-1 accuracy assessment and on-going maintenance have also evolved and are accepted by the various stakeholders in the E9-1-1 arena. This development was promoted by the FCC in OET 71, which states that wireless service providers, equipment manufacturers, public safety, and other interested parties were encouraged to organize and develop standards that may obviate the need for extensive Commission guidelines.

The following paragraphs summarize some of the key contents of the Bulletin and presents comments on them in the context of today's E9-1-1 performance compliance needs, and in light of what has transpired in the E9-1-1 standardization arena.

Both empirical and predictive methods are discussed in the Bulletin, and it encourages the "development of efficient, reliable, simple, cost-effective methods to test and verify" E9-1-1 location accuracy and reliability. Guidelines for the integrity and reliability of empirical testing are provided. This includes basic considerations related to sample test call location selection, measurement precision, a test environment reflective of expected handset use, technology neutrality and statistical confidence in the test results. Certain of these attributes are highlighted here especially where comments are appropriate.

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OET Bulletin No. 71 emphasizes the importance of statistical confidence in the test results, whether empirical or predictive. It explicitly requires that results be obtained with at least a 90% statistical confidence level. The Bulletin offers a technology-neutral candidate statistical approach to demonstrating such confidence in empirical testing. The approach is described in Appendix A of the Bulletin. It uses distribution-free order statistics; i.e., no assumptions are made about the underlying distribution of location error, but it is based on the collection of data at independent test locations (in order to guarantee independent location fixes). This robust statistical approach remains one of those available for use today in testing E9-1-1 accuracy for compliance purposes.

The issue of real world empirical test sample size and its geographical coverage is one that frequently arises but has not been discussed explicitly in OET 71. It has not been addressed in the ATIS documents developed by ESIF thus far either. Recommendations and guidelines for these aspects of empirical test sample size and coverage developed by WG3 are presented in Section 4.

The OET 71 provides general guidance about the selection of random test locations and states a preference for using data from areas where 911 calls are likely to be made, if such information is available. The concept of weighting was further developed by ATIS/ESIF and is reflected in ATIS-0500001 section 9.4. The use of test call weighting to achieve this goal has been adopted by some wireless service providers depending on the nature of their networks and the use of those networks (for example weighting based on wireless 911 call densities, testing where wireless calls are normally located, or possibly using population densities for test call weighting). Those methods are consistent with the possible testing and data analysis approaches discussed in the Bulletin.

The Bulletin also recognizes the inherent uncertainty of radio technology used for wireless location and that location cannot always be reported accurately and may not even be possible in some instances. This fundamental statement holds equally true today, especially as wireless use becomes ubiquitous and wireless user expectations may not reflect the realities of the challenging physical world.

The Bulletin states that only completed calls should be included in test statistics. This continues to be the accepted, standard approach to treating test calls for E9-1-1 systems.

The Bulletin also discusses the tradeoff between getting a location estimate quickly to facilitate public safety but also accurately, which requires more time. It suggests an acceptable time limit for delivering the location estimate of 30 seconds. While this suggestion has not been part of the mandate, it is generally accepted as the de facto standard for maximum latency in E9-1-1 location delivery. OET 71 also suggests that the last location fix in the time window, e.g., within the 30 seconds, can be used to compute the accuracy.

According to the Bulletin, predictive testing methods are permitted "if [they] can be demonstrated to have the necessary robustness and accuracy." Device type acceptance is also mentioned but the Bulletin states that it would be premature (at least at that time) to adopt such an approach and that the relevant performance parameters for such an approach were not identified.

The topic of predictive modeling for E9-1-1 accuracy assessment purposes has been discussed at length within ATIS' ESIF, as discussed above in Section 4 of this report, and described in detail in Section 8 of ATIS-0500001. The use of such validated predictive models to determine the accuracy of E9-1-1 systems in certain benchmarked test areas is consistent with the expressed desire in the Bulletin to achieve test methods that are efficient, reliable and cost effective. WG3 recommends that predictive modeling applied to the testing of E9-1-1 systems follow the guidelines articulated in ATIS-0500001 Section 8 and discussed further in Section 4 above.

For handset type acceptance testing in the current context of E9-1-1, WG3 believes that handset type testing has a viable role to play in reducing the amount of needed field testing by mitigating the need to test multiple handsets in each environment to be tested. However, the relevant and detailed key performance parameters to be met in such tests would need to be identified under varied environments based on empirical test data.

Reflecting its year 2000 time reference, the Bulletin asserts the importance that location systems operate effectively in conditions where 911 calls are made, for example, from within vehicles moving at highway speeds. It further comments that because of increased complexities of testing from moving vehicles, initial testing did not need to include dynamic calls, but such methods should be incorporated into verification and testing protocols as they became refined.

Over the last dozen years, mobile location testing methodologies have evolved to the point that they are now accurate and efficient and, in fact, the preferred wide scale testing approach. The use of Differential GPS[6] is the most common approach to determining ground truth[7] for outdoor testing, which is consistent with the statements regarding ground truth determination and its precision in the Bulletin. OET 71 states that latitude and longitude coordinates should be expressed in tenths of arc-seconds (equivalently 5 significant decimal-degree places), distance errors from "ground truth" be computed to the nearest meter, and all test reports should include a statement of ground truth accuracy.

ATIS-050001 provides guidelines for the necessary ground truth accuracy in mobile test scenarios. WG3 also recommends that in the event that a dispute on absolute ground truth accuracy arises, it could be resolved using stationary test methods or enhanced accuracy mobile

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[6] Differential is defined as a technique in which data from a receiver at a known location (base or reference) is used to correct the data from an unknown location. DGPS is used to increase the accuracy of the resulting position provided by the GPS receiver.

[7] Ground Truth is defined as a geographic location specified in latitude and longitude for the actual location of the test call.

testing techniques (e.g., with more elaborate instrumentation and/or augmentation methods.)

Among the basic principles presented in OET 71 is that reports of compliance testing should clearly define the subject geographical area. Again, reflecting the year 2000 historical context, test areas are described as possibly being as small as a PSAP coverage area or as large as a wireless service provider's entire advertised coverage area (within a metropolitan area or similar region). This reference to larger geographical area has now been superseded by more recent FCC rules which require compliance at either a county or PSAP level. Test data aggregation methods mentioned in the Bulletin by using non-overlapping sub-areas still apply in principle but, more importantly, the principle that compliance areas should not be overlapping remains fundamental today.

Reflecting the Commissions' policy for technical and competitive neutrality, testing and validation methods should be applied in the same manner to all location technologies being used, except where some variation is clearly necessary and fully explained. One example where variations in test methodology may be dependent on the location technology is where the location accuracy has some dependency on the deployment configuration of the network, e.g., A-GPS vs. U-TDOA. For example, deployment reconfiguration or extensive RF re-planning could trigger a need for retest for U-TDOA but not the A-GPS case, or vice-versa.

The Bulletin strives to articulate guidelines for testing E9-1-1 using methods that "accurately represent real world performance." One area where the progress of technology has resulted in significant change in real world experience since the publication of OET 71 in calendar year 2000 is the handset's initial condition.   The Bulletin states that a reasonable starting condition for a handset-based test would be with the handset in its normal off condition for at least 15 minutes, however, it may also be in a stay-warm, low-current drain state if that feature is available. The intended objective is to assure that GPS assistance information or recent history is erased when a new test call is placed.

The most common mode of use for handsets today is the always on, idle condition[8]. In handsets with GPS to support a variety of location based services, the user often turns off the GPS capability until needed to achieve better battery conservation. Accordingly, a warm rather than a cold (e.g. handset completely powered off for a prolonged period) GPS start represents a more realistic test handset initial condition. Note that turning a phone off for 15 minutes may not guarantee that a cold start is achieved, since generally time and other related location information may be retained in the device's non-volatile memory. Software or firmware based procedures that erase GPS assistance data and device history are acceptable for use in testing when available. In any event, the test methodology needs to ensure that prior assistance or position data is not used in subsequent test calls.

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[8] ATIS Technical Report 0500001 – High Level Requirements for Accuracy Testing Methodologies

This important topic of handset initial condition has been discussed in detail within ESIF and the consensus results have been documented in a recent document revision release ATIS-050001. In that document three possible test scenarios are described reflecting the cold, warm and hot GPS device start. The warm start scenario is adopted as the most representative of common wireless device usage today. WG3 recommends that these guidelines be followed and adopted by the FCC as an update to the information in OET 71 on this topic.

Finally, the Bulletin asserts that any empirical testing methodology should include protocols sufficient to test and verify that the system will continue to provide the required level of accuracy in normal operation. The issue of on-going or maintenance testing within ATIS-0500010 contains the consensus recommendations in that regard.

In the context of the E9-1-1 compliance requirements that prevailed around the year 2000, the Bulletin mentions that "a biannual validation of accuracy should ordinarily be sufficient". Much debate has since taken place about the meaning of "biannual," and whether it meant semiannual or every two years, with two years becoming the de facto practical limitation. However, in today's context of accuracy compliance at the county or PSAP level, the implied granularity of the validation necessitates that the most intelligent means available, when using both empirical and alternative test methods, over reasonable time frames, be used to cost effectively achieve on-going validation. This topic is addressed in Section 4 of this report.

There is consensus amongst WG3 members that ATIS-0500001 generally provides more current data than is available in OET 71. Therefore, while OET 71 remains a valid reference, this newer ATIS document is a more up to date source of information on accuracy testing methodologies.

4.3 ATIS Technical Report 0500001 – High Level Requirements for Accuracy Testing Methodologies

Technical Report 0500001, High Level Requirements for Accuracy Testing Methodologies focuses on providing a set of minimum technical requirements for testing location accuracy of a typical network deployment of positioning technologies for wireless E9-1-1 services in order to assess FCC compliance.

CSRIC III Work Group 3 (WG) reviewed the ATIS Technical Report 0500001 and found that the level of detail expressed in this document, augmented with the recommended guidelines on empirical sample sizes and coverage in Section 4, is sufficient to warrant its use as the baseline text for meeting the CSRIC III WG3 Charter that develops approaches to outdoor location accuracy testing criteria and procedures.

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4.4 ATIS Technical Report 0500009 – High Level Requirements for End-to-End Functional Testing.

The ATIS Technical Report 0500009, High Level Requirements for End-to-End Functional Testing, is for use in testing 911 voice path and data path delivery to the designated PSAP. This testing is appropriate for E9-1-1 Phase 1 and Phase 2 service deployments and for testing to ensure that network maintenance activity has not disrupted voice and data path delivery. This technical report is not applicable to location accuracy testing.

4.5 ATIS Technical Report 0500010 – Maintenance Testing

ATIS' Technical Report on Maintenance Testing was first released in 2006. This report was the result of years of discussions on the issue of periodic maintenance testing subsequent to the publishing of OET 71. The report contains the consensus recommendations of the contributing members; including the wireless service provider community, public safety, and the associated technology vendors.

The ATIS Maintenance Testing report, "neither recommends nor imposes a specific test methodology, but rather provides a common frame of reference that individual stakeholders can use to ensure continued accuracy and functionality compliance of Phase 1 or Phase 2 E9-1-1 integrated networks through the inevitable updates and changes that occur over time, and provides a set of minimum requirements for individual test methodologies." The report is broken into two parts, with the first part covering maintenance testing for accuracy and the second covering testing of end-to-end functionality. Included in the report are details on the logistics of testing, including software and hardware requirements as well as definition of the test area. Important issues covered in ATIS-0500010 include:

- Useful life of collected data
- Definition of System Under Test
- Methods to Establish Ground Truth
- Empirical Test Methods in a maintenance context
- Sample Size and Distribution in maintenance situations
- Predictive Testing
- Weighting of Data

CSRIC WG3 finds that this report from ESIF provides a useful technical foundation for maintenance testing as further discussed in section 5.3.

4.6 ATIS Technical Report 0500011 – Define Topologies & Data Collection Methodology.

ATIS Technical Report 0500011 was developed in response to a request from NRIC VII convened by the FCC in 2004. The consensus compromise arrived at by NRIC VII Focus Group 1A was that compliance testing would be done at the state level and that the wireless service

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providers would provide to public safety a one-time report containing representative performance data in various environments.

Four basic wireless use environments are defined in detail in ATIS-0500011 for that purpose:

- Dense Urban
- Urban
- Suburban
- Rural

Although the regulatory framework has since changed, these definitions can still be used today to describe the environments in which the wireless network and location system operate, and in which their location performance is expected to be satisfactory. These definitions can also be used in devising test plans for location system performance assessment and evaluation if such is desired, or in providing representative location system performance data to interested parties.

4.7 ATIS Technical Report 0500013 – Approaches To Wireless E9-1-1 Indoor Location Performance Testing

This ESIF Report on Indoor Location Performance Testing will be covered more fully as part of this group's work on Indoor E9-1-1 Testing Recommendations. Although this report is focused on indoor location testing, a number of important methodologies pertinent to outdoor location testing are included in this report. These include:

- Device Initialization to assure independence between location fixes at the same test location
- Developing a comprehensive test plan
- Ground Truth in challenging environments (e.g. stationary points in an urban canyon)

5 APPROACHES FOR OUTDOOR LOCATION ACCURACY TESTING

5.1 Introduction

OET 71 was issued by the FCC in April of 2000 to provide general, high-level guidelines and suggestions for evaluating compliance with E9-1-1 rules for Automatic Location Information (ALI). It provided a helpful framework and served to initiate the process of developing more detailed methodologies for compliance testing. The key provisions of OET 71 are described further in Section 4 of this report.

OET 71 predicted – "It is likely that testing and verification practices will evolve over time". It continues to encourage the "development of efficient, reliable, simple, cost-effective methods to test and verify ALI accuracy and reliability". These efforts to further develop and improve location test methods continue to the present.

One significant evolution of location performance testing methodologies took place within the

ATIS Emergency Services Interconnection Forum (ESIF) over the course of 18 months between Jan 2003 – June 2004, with broad support of relevant stakeholders, including: public safety representatives, wireless service providers, technology and test vendors, and 911 service providers. The result of this effort – a technical report entitled "High Level Requirements for Accuracy Testing Methodologies (ATIS-0500001) was released in July 2004.

This document utilized OET 71 as a foundation and went on to further develop a common frame of reference that individual stakeholders can use to validate the performance of 911 location technologies, including a minimum set of industry-accepted requirements individual test methodologies should comply with. This document has been and continues to be widely used by wireless service providers, public safety entities, test vendors, and others to guide location accuracy testing.

ESIF recently undertook an effort to review and update ATIS-0500001 to reflect changes in handset use cases – specifically regarding the initial conditions and test cases for A-GPS equipped handsets. This effort resulted in the release of ATIS-0500001 in Nov 2011.

CSRIC WG3's 'Outdoor Location Accuracy' Subgroup reviewed ATIS-0500001 as part of its charter to "develop approaches to outdoor location accuracy testing criteria, procedures…". The consensus within WG3 is that this ESIF document remains relevant and provides helpful direction and proper guidance for conducting location accuracy testing. Specific observations and further recommendations on the use of the ESIF document are provided in Section 4.1.1 of this report.

5.2 Empirical Testing Methods

The most basic and fundamental method to determine the level of performance of a location system is to conduct real-world empirical field testing. While this method is ideal in terms of being highly reliable, it is not necessarily ideal in terms of being efficient, simple, and cost-effective.

Because of the importance of reliably determining initial compliance with FCC accuracy standards, accuracy testing for compliance purposes has typically been restricted to empirical test methods. Best practices for conducting proper empirical accuracy testing are provided in section 7 of ATIS-0500001.

5.2.1 Practical Guidance on Empirical Sample Size and Distribution for Initial or Full Compliance Testing

This section provides additional practical guidance, beyond that contained in ATIS-0500001, on the quantity and distribution of test samples required for initial or full compliance verification through empirical field-testing.

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Whether testing is conducted on network or handset based location networks, an adequate number of test locations or test call attempts must be used to provide for a statistically significant result. The test methodology used for such accuracy testing shall provide adequate and verifiable justification for such test sample and location selections. ATIS 05-00001 states that a "90% confidence level shall be used with a meaningful corresponding confidence interval".

Many location technology systems produce fixes based on a combination of multiple techniques, each having a unique and distinct error distribution. Normal (Gaussian) distributions are sometimes invoked in creating simplifying assumptions to derive the required test call sample size. Such normal distribution assumptions, however, do not apply to all types of location systems and often do not adequately reflect the behavior of a location system in an E9-1-1 environment. In those real world settings, medium to large location errors occur in higher proportions than modeled by a normal (Gaussian) or a Rayleigh distribution.

To illustrate, in a pure GPS system within a benign outdoor setting, the positioning error distribution is a bivariate normal distribution (i.e., normal and independent in latitude and longitude), resulting approximately in a Rayleigh distribution for the positioning error. Simplifications related to this normal behavior could be applied in such a case. A practical GPS-based system used in the context of E9-1-1, however, contains a combination of assisted GPS, various ground-based trilateration techniques, and cell sector based techniques. Cell sector-based or aided techniques do not follow a normal distribution in their positioning errors and are closer to a uniform distribution. Triangulation techniques, inclusive of timing triangulation, may or may not follow a normal behavior. When these other techniques follow a normal distribution, it is often with significantly higher variances than GPS. Additional location techniques, based on signal structure or proximity (e.g., WiFi), may also be or become part of the overall location solution.

In view of this complexity in deployed location systems, and the inability to predict exact system behavior before testing in a given area – as well as the desire to have uniform broadly applicable methods – robust, distribution free and technology-neutral statistical methods are attractive. This is, for example, what has been proffered by the FCC in OET 71 Appendix A, which uses order statistics.

It is recommended that the size of the empirical test sample accommodate the application of a robust statistical test regarding the error percentiles applicable to the compliance of the test area (e.g., the 67th and 90th percentiles). A consequence of this is that an empirical sample cannot be too small (e.g., 100 test calls). The smaller the sample the tighter the order statistics pairs for a given confidence level and the less likely the compliance.

Typical sample sizes appropriate for urban, suburban and some rural counties will normally be considerably larger than such a small sample, thereby causing the order statistics pairs to be close to the 67th and 90th percentiles. A useful rule of thumb for the overall number of test calls is 10 times the number of cell sites in the test area, although there is no exact derivation behind this common engineering selection. It is recommended as a rule of thumb that the minimum sample

size for areas with very few sites be 200 independent test calls to meet the statistical confidence requirements. If a specific distribution of positioning error can be clearly demonstrated that justifies an alternate and possibly smaller sample, it could be considered but careful justification should be provided in that case.

Concomitant with the number of test calls in an empirical sample is the distribution of the test calls to adequately cover the test area. Distance from a serving cell site as well as prevailing cell site density impacts the terrestrial elements of the overall location system and have to be included in the empirical test sample. Different groups of cell sites may have factors (e.g., configuration parameters) that can impact network performance. Thus, another useful rule of thumb is that test calls be initiated on 80% of the cell sectors in the test area. Again, this number is based on reasonable engineering practice rather than mathematical derivation. Both the overall number of test calls in the sample and their distribution across the test area will ensure good statistical representation of prevailing location accuracy.

It should be noted that the statistical formulas used throughout assume independent and random error measurements. Accordingly, test methods that involve repeated static calls with dependence between subsequent location fixes (e.g., due to hot start and/or identical propagation in a short time period) should be avoided since they do not meet the required independence within the test sample.

5.3 Alternative Testing Methods

Wireless service providers have an obligation, following initial compliance with the required accuracy standards, to maintain proper performance of location systems. Given the on-going nature of this obligation and the cost associated with nationwide periodic empirical testing at the county or PSAP level, it is highly desirable to identify alternative methods that meet the goal of being reliable, efficient, simple, and cost-effective.

This goal is in harmony with the Subgroup's charter to "develop approaches to outdoor location accuracy testing criteria, procedures, and timeframes that are reasonable and cost-effective, considering alternatives to the current FCC OET 71", and to "develop recommendations concerning the feasibility of flexible testing criteria and methodologies".

Various alternative testing concepts have previously been developed, including the work done by ESIF in ATIS-0500010 "Maintenance Testing". As suggested by WG3's charter, further development and guidance of alternative testing methods is warranted.

5.3.1 Relevant Alternative Testing Concepts Developed by ESIF

This section provides a summary of alternative testing concepts previously developed by ESIF. These concepts have been reviewed by WG3 and found to be relevant and helpful in developing an alternative testing methodology, following initial or established compliance.

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5.3.1.1 Predictive Testing

One alternative concept is 'predictive testing' which involves the use of predictive tools and models for location accuracy determination to augment empirical methods to reduce the reliance on resource-intensive, repetitive field-testing.

Appropriate guidelines as well as proper safe guards in utilizing predictive testing are provided in ATIS-0500001 Section 8. WG3 concurs that this ATIS document provides the industry accepted procedures for use of predictive testing.

5.3.1.2 Incremental Testing

Methods to automatically collect empirical test data incrementally over time, gradually building a set of accuracy test measurements generated from discrete test calls (which include a ground-truth reference) have been identified and recommended for use by ESIF (see ATIS-0500010: Maintenance Testing Section 7.2). For example, field operations vehicles could be equipped with location collecting equipment.

This method is typically referred to as 'incremental testing'. It does not rely on any randomly uniform test point distribution for data collection. In the event that an area is over-represented in the collected dataset, a random sample may be chosen from collected data for analysis purposes. Considerations must be given to the age of incremental test data, which must not be older than two years, as required by ATIS-0500010: Maintenance Testing Section 3.2 Useful Life of Data, and Section 3.3 System Under Test.

5.3.1.3 Reduced Empirical Data Sample Size

As observed by ESIF in ATIS-0500010 Section 7.3, "Initial empirical compliance testing is done without prior knowledge of whether or not the test area conforms to the mandated accuracy requirement". This may require a sizable sample to establish accuracy performance with the desired level of statistical confidence (as established in OET 71). Subsequent testing, including maintenance testing, may be able to benefit from the knowledge that the system did previously comply, so long as the network and its environment have remained substantially the same since the initial testing.

The result of this observation is that a smaller sample may be possible to achieve the same level of statistical confidence (nominally 90%). This is indeed the case if the location system continues to perform with specified operating parameters within a substantially unchanged environment (relatively the same urban, suburban, or rural environment throughout an existing RF coverage area respectively). These conditions are critical to avoid an adverse affect on the location system performance. An example approach to selecting a reduced sample size in the context of maintenance testing is provided in ATIS-0500010, Section 7.

5.3.2 Additional Alternative Testing & Assessment Methods

This section provides additional alternative testing concepts developed and recommended by

CSRIC WG3. These methods, together with those previously developed by ESIF and referenced above in section 5.3.1, make up a set of alternative testing tools that can be utilized to help meet the goals of section 5.3.

5.3.2.1 Key Performance Indicator Monitoring

Another alternative concept useful in ensuring proper on-going location system performance is to establish a baseline of various key performance indicators (KPI) at the local area during the initial compliance field testing phase, and then monitor the KPI on an on-going basis to identify any changes in trends that would indicate a potential system problem.

Useful KPIs include but may not be limited to:
- Uncertainty Estimate Trends
- Location System Yield Levels
- Location Estimate Latency
- Automated Configuration Database Health Checks
- Inconsistent Results Between Various Location Methods
- Equipment Failure Alarms

As observed by the ESIF Issue 71 "Baseline and Trending of Uncertainty" resolution statement[9] ; "Taken together, these KPIs are very useful in helping determine when system performance has degraded and further testing and system improvements are needed at the local level".

Properly implemented and monitored, KPIs can provide more rapid indication of local system performance problems than periodic empirical field testing – which is dependent on the next scheduled 'test cycle' – while being efficient to implement and maintain operationally.

5.3.2.1.1 Uncertainty Estimate Trends

Wireless Service providers are required to provide an uncertainty value associated with each 911 location estimate, to provide some insight into the quality of the location fix. These uncertainty estimates on a call-by-call basis are not a reliable substitute for empirical location accuracy testing. Uncertainty estimates, when taken on average over time, however, can indicate a _trend_ that may reflect continued proper system operation or system problems.

CSRIC acknowledges that disparate service providers and technologies report confidence and uncertainty values differently. Uncertainty trending is still useful within a single service provider and single technology environment.

The use of uncertainty estimate trending in lieu of on-going empirical testing has been endorsed

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[9] http://www.atis.org/esif/_Com/Docs/Issues/Issue71.doc. A formal letter from ATIS, explaining the resolution statement for ESIF Issue 71, is in the process of being drafted for the FCC.

by the FCC 2nd R & O – "Once a wireless service provider has established baseline confidence and uncertainty levels in a county or PSAP service area, ongoing accuracy shall be monitored based on the trending of uncertainty data and additional testing shall not be required".

5.3.2.1.2 Location System Yield Levels

An unanticipated drop in local yield levels for a given location technology is a clear indicator of location system problems, and serves as a trigger for investigation and resolution.

5.3.2.1.3 Location Estimate Latency

Average local latency values for a given location technology are typically well-behaved and don't normally vary significantly. Increases in average latency can serve as a trigger for investigation.

5.3.2.1.4 Automated Configuration Database Health Checks

Current location technologies depend upon accurate configuration data provisioned in the network. Automated checks of configuration databases are utilized to detect missing, illogical, or improper values, and flag issues for rapid resolution. Automated methods to identify configuration database errors are an important part of any quality maintenance approach.

5.3.2.1.5 Inconsistent Results Between Various Location Methods

Cross checking location estimates from multiple location methods employed on the same 911 call can detect a pattern of inconsistent or illogical results and serve as a trigger for investigation. For example, UTDOA results which are many miles away from the Round Trip Time (RTT) location estimates for some 911 calls in a given area, could flag a likely problem.

5.3.2.1.6 Equipment Failure Alarms

Physical equipment installed in the network necessary for proper location system functionality is typically alarmed for equipment failures. Depending on the location technology and specific equipment utilized, these alarms can indicate various failure modes (for example: loss of GPS/timing, loss of essential network or RF signaling, internal hardware self-test failure, over-temperature condition, power failure, etc). These alarms are typically automatically monitored 24x7 and failures can be quickly remedied.

5.3.2.2 Testing in Representative Environments

Certain location technologies are well suited for collecting and analyzing performance in representative environments, as opposed to continued testing in each and every local area, as they perform similarly in similar environments.

A-GPS is one of these technologies. Once a particular A-GPS handset implementation has been validated through careful testing in the lab and in the field, the only significant performance variation from environment to environment is due to local conditions of sky visibility, signal reflections (multipath), and signal attenuation (foliage). Quality of the assistance information is

an important factor affecting the location latency, secondary location methods, and yield performance. Proper assistance information can be assured through appropriate automated configuration database health checks.

For example, under similar network and environmental conditions, a rural county in Arizona is expected to have statistically comparable A-GPS performance characteristics to a rural county in Nevada. This type of extrapolation has been validated via extensive empirical testing within wireless service provider networks.

Performance of some location technologies, including some network-based methods, is substantially affected by parameters other than sky visibility and signal reflections.   These parameters may include: visibility, density, and geometry of surrounding cell sites, terrain/morphology, signal reflections (multipath), and complexity of RF scattering. The representative environments selected must take into account the underlying location technology of interest, to ensure an adequate mix of real-world conditions are included.

CSRIC recommends that ATIS/ESIF further explore defining the representative usage environments.

5.3.2.3 Empirical Spot-Checking
To maintain some level of periodic empirical field testing as part of on-going maintenance assurance, a systematic method of 'spot-checking' local areas which have previously been tested and shown compliant can be employed. Any significant deviations from expected prior performance levels should result in careful investigation and full re-testing.

5.4 Recommendations on Maintenance Testing
The goal of maintenance testing is to identify an approach to ensure continued optimal performance of E9-1-1 location systems at the local level, following initial compliance verification or prescribed self certification. This method should be simple, efficient, reliable, and cost-effective – yet based on sound engineering principles.

In summary, the following alternative testing methods have been identified for consideration in keeping on-going maintenance efforts reasonable:

1. Predictive Testing
2. Incremental Testing
3. Reduced Empirical Data Sample Size
4. Key Performance Indicator Monitoring
5. Testing in Representative Environments
6. Empirical Spot-Checking

5.4.1 Key Background Observations

It is important to note that alternative maintenance testing methods only apply where County/PSAP compliance has been established via empirical testing. Thus, we approach maintenance of these systems with this prior knowledge.

Empirically collecting statistical significant performance data in each and every county of interest requires considerable effort and resources. Some insight into the magnitude of these costs is provided in Section 6 of this report. Limited resources are best utilized through a systematic method of maintenance which utilizes other available performance indicators and simplifying assumptions, in addition to empirical testing.

5.4.2 Proposed Maintenance Approach

CSRIC WG3 recommends the following approach to on-going maintenance testing following initial County/PSAP-level compliance:

- Key performance indicators should be routinely monitored and archived network-wide, to help determine when system performance has degraded and further testing and system improvements are needed at the local level.

- Enhancements to location technology should be validated in representative environments, to ensure equivalent or improved performance.

- Spot-checking using empirical field-testing should be conducted on an as needed basis, for example, as determined by KPI monitoring or legitimate performance concerns from a PSAP.

- Empirical data for maintenance testing may be collected incrementally, but must conform to the requirements in ATIS-0500010: Maintenance and Testing; Sections 3.2 Useful Life of Data and, Section 3.3. System Under Test.

- Any significant deviations from expected prior performance levels should result in careful investigation and re-testing of the applicable test area.

- CSRIC WG3 recommends that the alternative maintenance testing methods listed above replace the requirement for full compliance testing every two years as would be implied in the ATIS-0500010 "Maintenance Testing" Technical Report Section 3.4. Wireless Service providers have an obligation to provide verification of testing and/or test summary results for up to the previous 24 month period upon FCC request.

- All legitimate performance inquiries from a County/PSAP or other public safety entity shall be properly investigated with full cooperation from the wireless service provider, and any issues resolved in a timely manner.

6 OUTDOOR LOCATION ACCURACY TESTING COSTS AND TIMEFRAMES

WG 3 has been charged with developing approaches to outdoor location accuracy testing that are reasonable and cost-effective. In this section we review at a high level the cost associated with the empirical testing of a wireless service provider's network for 911compliance, and testing by Public Safety for location assurance.

As indicated in Section 5.2, Empirical testing methods are highly reliable, but not necessarily cost effective if applied repeatedly at a PSAP or county level. Deployment of field test resources ranges from $250 to $1000 per cell site[10] depending on the geography, morphology, and in particular prevailing cell site density. The resources required for a Tier I service provider to constantly employ field testing methods to gauge the accuracy of their network's nationwide footprint on a PSAP-level is logistically unfeasible. Similarly, testing in Tier II and Tier III environments is often in the higher portion of the cost per cell site spectrum due to the sparser cell site distribution and increased drive time between cell sites.

In comparison, as discussed in Section 5.2, a program utilizing a combination of Key Performance Indicator (KPI) monitoring, predictive modeling and ongoing network accuracy performance testing can provide an adequate means of gauging overall service provider accuracy performance on a real time and ongoing basis.

9-1-1 Outdoor location accuracy testing has been approached in various ways to achieve compliance. Some wireless service providers chose to initially invest in a location accuracy management performance system, to perform the level of testing required to meet compliance. Those initial costs included: hardware, software development, and labor costs. Dependent upon the service provider and the network or networks monitored, the initial investment cost for such a performance system ranges from $5M to $11M. It may include the ability to monitor location performance throughout the network as well as provide a reporting system, to assist in enhancing the performance of the location networks that provide E9-1-1 Phase II. Generally, the actual performance of the test calls themselves is through handset-equivalent, Location Assurance Devices (LADs) that have been installed or carried in vehicles. Those devices are equipped with a differential GPS receiver for ground truth determination, as well as programmed to generate simulated 9-1-1 calls to the performance system. Such a performance monitoring system allows service providers to verify test calls and generate metrics for FCC compliance for E9-1-1 phase-II. It also enables on-going monitoring of the location networks including location performance

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[10] The costs referenced within Section 6 were obtained thru direct conversations with the following service provider and PSAP stakeholders: AT&T Wireless, Cricket Wireless, Sprint, T-Mobile, US Cellular, Verizon Wireless, CommScope, Bexar Metro 9-1-1 Network District, Capital Area Council of Governments, TX (CAPCOG), Tarrant County 9-1-1 and APCO International. Drive test costs were formulated into a cost by cell site range where applicable.

for commercial LBS.

Monitoring the service provider's network can be done through ongoing and automated scheduled tests. The performance system allows service providers to verify call flow, measure end-to-end latency, assess location accuracy, quickly identify and resolve operational system performance issues and generate reports and metrics for verification of compliance with FCC (Federal Communication Commission) mandates and Commercial LBS performance requirements. This also puts into place the ability to monitor of KPIs discussed above. The data storage and reporting capabilities may vary between in-house systems and hosted data solution and reporting with a vendor. Annual recurring cost to maintain reporting and data storage range between $500K and $1.5M.for a large network.

The other alternative is to engage personnel or contracted services to do the testing within the wireless service provider's network. Based on whether the resources are service provider employees or contracted testing services the $250 to $1000 per cell site cost stated above for PSAP-level testing applies. Some vendors have also taken the approach of a per PSAP testing cost structure that ranges from $50K to $150K per PSAP, regardless of the number of cell sites being tested, and varies depending on whether the testing conducted is for service provider compliance or PSAP accuracy assurance. As a historical example, in 2003 APCO contracted for performance testing in seven diverse PSAP jurisdictions at a cost of $700K to support APCO Project LOCATE[11]. Performance testing included retesting of cell sites in one (1) of the PSAP's.

Performance Testing, as done in the APCO Project LOCATE, study was not accuracy testing for the purpose of assessing compliance with the current Federal Communications Commission (FCC) standards. The purpose of Performance Testing was to assess the delivery of location data from a wireless E9-1-1 call via the existing Wireless service Provider's (WSP) deployed system, through to the PSAP, as captured in the Automatic Location Information (ALI) data display at a workstation. It further sought to document the variance of the actual, delivered location data by measuring the difference between a location data determined by existing baseline map data or other typical survey methods or a differential GPS receiver and the location data actually presented to the PSAP, both initially and upon rebid. The PSAP Performance Testing Process was not intended to confirm or describe accuracy compliance at the PSAP level, but rather provide the PSAP with actual data regarding the usefulness of delivered location data for dispatch purposes.

As demonstrated in the documented APCO Project LOCATE report, testing regimes can be costly and there are multiple ways to provide performance data to agencies, however, all processes must be documented and carefully analyzed.

Another challenge with PSAP-level testing is that in some cases there is a need to incorporate

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[11] APCO Project LOCATE Final Report, February 2007.

both automated testing through a performance system and to send out people to place test calls to generate enough calls to obtain a statistically valid sample for the desired county or PSAP-level reporting.

Based on the size of the service provider's network, the per cell site or per PSAP costs and logistical efforts for testing and maintaining compliance, if applied repeatedly, would become significant obstacles for the service provider and public safety, depending on who is pursuing the testing.

Many public safety entities, concerned with wireless location accuracy and its impact on their ability to locate callers, initiated wireless accuracy assurance programs. These programs range from personnel placing test calls from known points of interest or intersections during their normal course of business, to extensive programs with dedicated field staff equipped with survey-grade GPS equipment. Basic programs are less expensive to implement and provide PSAPs with the means to quickly conduct end-to-end testing by validating both wireless accuracy and 9-1-1 mapping system functionality. Such programs are also used as a training tool to continuously educate PSAP personnel on wireless 9-1-1. Initial start-up expense can be as low as $1500 but can reach $45K depending on the program. Higher end figures include the cost of a vehicle, computer equipment, staff and GPS equipment. Annual recurring costs to include staff, phone subscriptions, differential GPS correction and vehicle fuel and maintenance can easily exceed $40K.

In summary, the expectation should be that once compliance has been achieved, the wireless service providers would be able to maintain the appropriate level of accuracy in their networks by employing a combination of as needed empirical testing, alternate techniques like monitoring of KPIs and trends, and predictive modeling. This approach is discussed in Section 5 of this report.

7 LOCATION SYSTEM PERFORMANCE AND YIELD CONSIDERATIONS

Phase 2 yield may be defined as the ratio of successful Phase 2 locations over the total number of valid location requests.

Valid location requests are those where the call is made from within a service provider's advertised RF coverage area. The duration of the call must last up to 30 seconds before a determination can be made that Phase 2 location has failed. A service provider has up to 30 seconds to compute the Phase 2 location estimate. The test process or PSAP must initiate a properly timed location request to the service provider network to generate a Phase 2 location estimate.

Phase 2 yield can be measured at the service provider network or at the PSAP. There are many issues that a PSAP must consider however if they wish to test for Phase 2 yield. As discussed in

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Section 5 of this report, yield levels are one of the key performance indicators that can be monitored on an on-going basis to assess the health of the location system.

The following opinions submitted to CSRIC WG3 do not represent a consensus of opinion on how yield should be considered when assessing outdoor location accuracy. The contributions reflect distinct and disparate opinions from the WG3 membership.

Opinion #1

The FCC charter statement for WG3 states that, "the working group shall develop approaches to outdoor location accuracy testing criteria …" A group of participants in WG3 maintain that Phase II yield is a critical test criterion that needs to be addressed and included in any meaningful assessment of E9-1-1 accuracy. This position stems from the observation that the yield of current E9-1-1 location systems varies widely, yet in common current practice E9-1-1 testing only considers the location accuracy of Phase II calls. Low Phase II yield that is unaccounted for can have a dramatically deleterious impact on the performance of E9-1-1 accuracy. Accuracy testing that ignores or side-steps this issue can present an inaccurate and misleading picture of the accuracy that will *actually be delivered to the public safety community*. The importance of yield is reflected in OET 71 and the Second R&O through the upper level call percentage requirements that are cited in those guidelines.

The magnitude of the Phase II yield issue cannot be properly evaluated and addressed until Phase II yield results are included in E9-1-1 accuracy testing and are determined with the Phase II accuracy results for any candidate Phase II compliance area. This would either prove the assertion of Phase II yield problems unfounded, or illuminate this issue so that a full understanding and expectations of the real world capability of E9-1-1 is realized by all stakeholders, and appropriate yield targets compatible with the new accuracy requirements in the FCC rules can be developed for both outdoor and indoor settings. The concept of measuring PH-II E9-1-1 system accuracy must either include accounting for the system yield, or must include the reduction in accuracy of test calls that deliver only a PH1 location; to measure E9-1-1 accuracy in any other way would not provide a complete picture of the accuracy as delivered to the PSAP.

The alternate position, that individual call notations for PH-I or PH-II delivered with E9-1-1 calls to PSAPs would adequately capture this behavior, is deficient for several reasons, including the extreme fragmentation of this data and the prevalence of indoor live 911 calls that would obscure the issue. Furthermore, the notion of a "test bed" to evaluate yield would only delay identification of the magnitude of this issue and would in no way improve the value of the data over including yield in accuracy testing nation-wide. The concept of a test-bed is usually considered in terms of cost and complexity reduction to evaluate new technology. In this case, there is no real cost or complexity savings to justify the test-bed approach.

Thus, this group of WG3 participants recommends that Phase II yield be included in E9-1-1

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accuracy testing and its result be retained with the computed Phase II accuracy and provided to public safety when inquiries into E9-1-1 system performance are made.

Opinion #2

The topic of 'Phase 2 yield' has arisen during several discussions within the CSRIC III Work Group 3 effort. By definition, a Phase 1 result provides "the location of the cell site or base station receiving a 911 call". Phase 1 results are 'static' in nature, drawing upon cell site configuration data provisioned in the network. A Phase 2 result provides an estimate of the 911 caller's location, using network or handset-based methods.

Phase 2 location estimates are location technology-specific and heavily dependent on the environment in which each 911 call is placed. Factors affecting the ability for a specific location technology to provide an accurate location include: surrounding terrain, forestation or other factors affecting sky or cell site visibility; density and geometry of surrounding cell sites; signal reflections (multipath); and complexity of RF scattering. In some instances, a Phase 2 location result is not possible, and only a Phase 1 result is provided to the PSAP.

The current county-level compliance agreement as established in the FCC rules 2nd *R & O* does not mandate a specific Phase 2 yield requirement, but rather establishes specific "Phase 2 location accuracy" standards spread over four defined benchmarks. Wireless service providers are well down the path of testing and analyzing accuracy in every county in which they have deployed E9-1-1 Phase 2 services. Adding a new yield requirement at this point in the process would threaten the service providers' ability to comply with currently available location technologies in the timeframe required by the rules. In addition, Section 5 of this Report gives comprehensive guidance to wireless service providers on how to properly and efficiently manage location technology performance at the local level. This methodology includes monitoring of key system performance indicators – such as location system yield levels, uncertainty estimate trends, location estimate latency, configuration database health checks, equipment failure alarms, and inconsistent results between various location methods.

It is also noted that interested PSAPs already have access to the Phase 1 / Phase 2 result mix for their 911 calls. PSAPs looking for increased system performance visibility can collect and analyze Phase 2 yield information locally; utilizing the parameters they already receive for each call. This process should be kept separate from accuracy compliance. Additionally, the represented wireless service providers have all emphasized their willingness to work with individual PSAPs regarding local location system performance concerns.

The CSRIC III WG3 "Outdoor Location Accuracy" Subgroup's charter does not mention the term 'yield'. In fact, this Subgroup's charter is to identify ways to simplify outdoor location accuracy testing criteria. Yield is mentioned in the "Indoor Location Accuracy" Subgroup charter, in the context of evaluating new location technologies that potentially can be used to improve location performance in indoor environments. Relevant existing and proposed location

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technologies will be carefully studied in challenging real-world conditions, through the use of a common, neutral test bed. It would be appropriate to consider yield as a criteria for assessing these technologies with respect to indoor location performance. It is hoped that this effort will help identify opportunities to improve the availability of high-accuracy (Phase 2) location estimates in the future – and set the stage for any new recommendations. It is imperative that we first go through the test bed process to clearly determine what performance improvements may (or may not) be both technically and economically feasible, and the timeframe in which these new technologies might be available for actual implementation, prior to any recommendations for new rules.

Opinion #3

The inability of a wireless service provider to achieve Phase II data in a given area should not be arbitrarily dismissed. A low yield adversely impacts the PSAP's ability to locate individuals in distress and could indicate problems with a service provider's location positioning system. It is Public Safety's consensus that service providers should account for and provide yield results in a separate report to the FCC upon request.

Public safety understands that E9-1-1 location accuracy is measured against Phase II data. It would be helpful however for the FCC to clarify their assumptions in the Second R&O as to how Phase I results should or should not be taken into consideration during location accuracy compliance testing.

Appendix A

Acronyms

Acronym	Definition
A-GPS	Assisted-Global Positioning System
ALI	Automatic Location Information
APCO	Association of Public Safety Communications Officials
AT&T	American Telephone and Telegraph
ATIS	Alliance for Telecommunications Industry Solutions
CSRIC	Communications Security, Reliability and Interoperability Council
E9-1-1	Enhanced 9-1-1
ESIF	Emergency Services Interconnection Forum
FCC	Federal Communications Commission
GPS	Global Positioning System
KPI	Key Performance Indicator
LAD	Location Assurance Device
LBS	Location Based Services
LOCATE	Locate Our Citizens At Times of Emergency
NENA	National Emergency Numbering Association
NRIC	Network Reliability and Interoperability Council
NSN	Nokia Siemens Networks
OET 71	Office of Engineering and Technology Bulletin No. 71
PSAP	Public Safety Answering Point
RF	Radio Frequency
RTT	Round Trip Time
U-TDOA	Uplink Time Difference of Arrival
WG3	Working Group 3
WiFi	Wireless Fidelity
WSP/SP	Wireless Service Provider/Service Provider