June 2014

WORKING GROUP 1
Next Generation 911

Final Report
Specification for Indoor Location Accuracy Test Bed

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1 Results in Brief

1.1 Executive Summary

CSRIC IV Work Group 1 Subgroup 3 was charged by the FCC to provide guidance to the Commission on establishing a permanent entity to design, develop, and manage an ongoing public test bed for indoor location technologies. The purpose of this Test Bed would be to evaluate candidate indoor location technologies for E911, to develop accuracy benchmarks and other key performance indicators, and to continue to inform Commission policy and rulemaking. The guidance contained in this report is summarized below:

- **<u>Technology Categories</u>** which the Indoor Location Accuracy Test Bed would be expected to support include:
  - Current and near-term technologies – those either currently in use or in the process of being deployed
  - Near-term special use-case technologies – those which will require some unique provisions (e.g., localized infrastructure, calibration, etc.) in the Test Bed & methodology, compared to the wide-coverage technologies above, and therefore should be studied separately from macro network methods
  - Future technologies of interest – those for which the Test Bed will need to consider flexibility in order to accommodate future E911 relevant location technologies

- **<u>Test Methodology</u>**
  The consensus approach arrived at is to adopt, in full or in large part, the CSRIC III test methodology for near term use, and then to extend this approach to better adapt it to indoor localization technologies which may be tested for E911 purposes in a number of years. The testing process developed and implemented in the CSRIC III testing in San Francisco is expected to improve in time as refinements are made, and as feedback from all stakeholders is incorporated into the process. Topics such as increasing the number of test points within each building and dynamic testing along a route within a building are considered potential avenues to explore. Although a consensus on test methodology was achieved, a dissenting opinion remained (provided in Section 9). One factor driving this consideration is the potential growth of the permanent Test Bed from an indoor location technology exploration and qualification platform into a compliance platform.

- **<u>Management Framework</u>**
  It is recommended that a two tier organization structure be created: a 'Test Bed Program Manager' and a 'Test Administrator-Executor'. In addition, the Test Bed Program Manager would receive technical input from a small, focused Technical Advisory Committee representing the various stakeholders.

- **<u>Funding Mechanisms</u>**
  The guidance to the Commission regarding Test Bed funding is as follows:
  - Federal agencies pursue funding to support the fixed costs of the Test Bed, and the Commission manages the test bed in coordination with the National 911 Program Office. Fixed costs cover the Test Bed Program Manager, who is selected by competitive bid for a 2-year appointment.
  - Costs for each test cycle are borne by test participants, cover (primarily) the Test

Executor, and commitment to pay their portion of the expenses is a prerequisite to test participation. Participants indicate whether they desire qualification-level testing or compliance-level testing.

- **Logistical Processes**
  To ensure that test bed resources are appropriately utilized, a candidate indoor location technology should be already commercially available, or at least in an active prototyping phase (i.e., prototypes available for testing). In an active prototyping phase, there should be published literature describing the operational principles of the technology. A candidate technology that is claimed viable mainly via simulation, with limited demonstrations in a lab-only environment, would not likely be considered ready for the test bed.

2 Introduction

The Communications Security, Reliability, and Interoperability Council was charged by the FCC to provide guidance to the Commission on establishing a permanent entity to design, develop, and manage an ongoing public test bed for indoor location technologies. The purpose of this Test Bed would be to evaluate candidate indoor location technologies for E911, to develop accuracy benchmarks and other key performance indicators, and to continue to inform Commission policy and rulemaking. The charter for CSRIC IV – Working Group 1 – Subgroup 3 was as follows:

> "In its Indoor Location Test Bed Report, CSRIC III WG3 recommended that the Commission charter future stages of the test bed under the auspices of future CSRIC working groups in order to continue the assessment of current and evolving location technologies. CSRIC III WG3 found that "several cycles of testing, at regular intervals, are needed to support the rate of technology development" and that "a test bed management structure with contractual authority that extends beyond [CSRIC] cycles will encourage ongoing technology development." The Working Group, therefore, will examine the requirements to establish a permanent entity to design, develop, and manage an ongoing public test bed for indoor location technologies that can provide the FCC with regular comprehensive, unbiased, and actionable data on the efficacy of location technologies. The Working Group will consider chartering requirements, including prerequisites for impartial test bed administration and maintenance of data confidentiality; types of entities that could assume the role as test bed administrators; technical requirements; scope and scale of necessary facilities and locations; permanent or contracted human resources to manage the test bed; start-up and ongoing cost requirements to maintain the test bed on an ongoing basis; and other considerations necessary to establishing an independent testing administrator."

The current document contains the guidance of Subgroup 3, reached over the course of approximately 6 months of collaboration among subgroup members in a series of bi-weekly conference calls, a face-to-face meeting in Washington, D.C., numerous break-out meetings and teleconferences, and extensive email correspondence.

2.1 CSRIC Structure

Communications Security, Reliability, and Interoperability Council (CSRIC) IV									
CSRIC Steering Committee									
Chair or Co-Chairs: Working Group 1	Chair or Co-Chairs: Working Group 2	Chair or Co-Chairs: Working Group 3	Chair or Co-Chairs: Working Group 4	Chair or Co-Chairs: Working Group 5	Chair or Co-Chairs: Working Group 6	Chair or Co-Chairs: Working Group 7	Chair or Co-Chairs: Working Group 8	Chair or Co-Chairs: Working Group 9	Chair or Co-Chairs: Working Group 10
Working Group 1: Next Generation 911	Working Group 2: Wireless Emergency Alerts	Working Group 3: EAS	Working Group 4: Cybersecurity Best Practices Working	Working Group 5: Server-Based DDoS Attacks	Working Group 6: Long-Term Core Internet Protocol Improvements	Working Group 7: Legacy Best Practice Updates	Working Group 8: Submarine Cable Landing Sites	Working Group 9: Infrastructure Sharing During Emergencies	Working Group 10: CPE Powering

Table 1 - Working Group Structure

2.2 Working Group 1 Subgroup 3 Team Members

Working Group 1 Subgroup 3 consists of the active members listed below. Active members are those who have attended at least 3 subgroup conference calls or the face-to-face meeting, or who have contributed text or mark-ups to the final report.

Name	Company
David De Lorenzo, Chair	Polaris Wireless
Bruce Cox	NextNav
Bruce Wilson	Qualcomm
Cheri Lynn Rockwell	Butte County
David Conner	US Cellular
Eric Hagerson	T-Mobile
Ganesh Pattabiraman	NextNav
Greg Turetzky	Intel Corporation
Gustavo Pavon	TruePosition
Jeanna M. Green	Sprint Corporation
Jerry Panagrossi	InvisiTrack
Jim Winegarden	Century Link
Kara Thielen	Viaero
Khaled Dessouky	TechnoCom Corporation
Kirk Burroughs	Qualcomm
Martin Moody	Metro Emergency Services Board
Matthew Gerst	CITA – The Wireless Association
Michael Loushine	Applied Communication Sciences
Nader Moayeri	NIST
Raghavendhra Rao	AT&T
Rashidus Mia	TruePosition
Richard Craig	Verizon
Robert Rhoads	DHS
Roger Hixson	NENA
Roger Marshall	TeleCommunication Systems
Russ Markhovsky	InvisiTrack
Ryan Jensen	T-Mobile
Scott Luallin	Intrado
Steve Leese	APCO
Susan Sherwood	Verizon
Terri Brooks	TruePosition

Wayne Ballantyne	Motorola Mobility LLC
Wink Infinger	Florida 9-1-1 State Coordinator

Table 2 - List of Working Group Members

3 Technologies that the Indoor Location Accuracy Test Bed Should Support

This section provides guidance to the Commission regarding technologies which the Indoor Location Accuracy Test Bed would be expected to support on day-one, and describes the likely evolution of the test bed required to support anticipated or novel location technologies.

Technology Categories:

1. Current and near-term technologies
2. Near-term special use-case technologies
3. Future technologies of interest

3.1 Current and Near-term Technologies

The following list of technologies has been selected as these are either currently in use or in the process of being deployed. Several have not yet been through the Test Bed process, while several participated in the CSRIC III indoor location accuracy trial. A clear path to E911 (i.e., standards & certification) is part of determining which technologies are "current or near-term". The intent is to be inclusive – if there are technologies that are near-term available, then they would be included in this category

- A-GPS + GLONASS combination
- OTDOA
- UTDOA
- Wi-Fi Based Positioning[1]
- Active Position Tracking / MEMS Sensors[2] (We need to modify our test procedure to enable this type of location method to allow inclusion in the Test Bed)

[1] In the case of Wi-Fi proximity – there is a keen interest on the part of the FCC and others (including Public Safety) to explore using this commercial-based method for E911 purposes.
[2] In the case of Active Position Tracking – there was a vendor who was unable to participate in the prior Test Bed because the test procedure did not tolerate their unique approach to positioning. There is a renewed interest from the FCC, Public Safety, and Congress to better understand how Active Position Tracking (as currently used by commercial-based vendors, for example) could be applied to benefit E911. Clearly there are privacy issues that would need to be addressed before adoption of such an approach, and the current CSRIC Test Bed methodology would need to be extended to cover this approach.

- Altitude by way of Barometric Pressure Sensor in the Handset[3] (as a stand-alone service)

- A-GPS + AFLT (participated in CSRIC III trial)

- Metropolitan Beacon System (participated in CSRIC III trial)

- RF Pattern Matching (participated in CSRIC III trial)

3.2 Near-term Special Use-case Technologies

These special use-cases will require some unique provisions (e.g., localized infrastructure, calibration, etc.) in the Test Bed & methodology, compared to the wide-coverage technologies above, and therefore should be studied separately from macro network methods.

- In-building DAS Deployments (currently in use)

- Small Cells, Femto Cells, etc. (currently in use and increasing in quantity over time; includes non-call time or pre-provisioned location; e.g., cell lookup)

- Bluetooth Positioning

3.3 Future Technologies of Interest

The Test Bed's policies and procedures will need to incorporate flexibility in order to accommodate future E911 relevant location technologies.

- Any technology provider who feels their product will materially improve E911 location performance and is ready for formal public scrutiny

4 Types of Tests for the Indoor Location Accuracy Test Bed

This section provides guidance to the Commission regarding Indoor Location Accuracy Test Bed mission scope and capabilities: the costs, benefits, and tradeoffs inherent in selecting what types of tests could be supported, the scope of testing, which technologies could be tested, the types of indoor environments, regional vs. nationwide, etc.

The guidelines proposed in this section build on the "Indoor Location Test Plan" approved by CSRIC III, which was the basis for testing a number of indoor wireless E911 technologies in the San Francisco Bay Area in late 2012. A number of recommendations are proffered in this section to address the near and longer term expected needs of indoor location testing.

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[3] In the case of Altitude using a Barometric Pressure Sensor in the handset – 3rd parties are beginning to offer this separate service using existing infrastructure for atmospheric pressure calibration, as opposed to the method tested in the prior Test Bed. Given the interest in altitude estimates from public safety, this approach should be studied further.

The guiding principle has been to recommend a plan that enables a reasonably thorough characterization of the performance of various location technologies under test while being cognizant of cost and logistical complexity. The consensus approach arrived at is to adopt, in full or in large part, the CSRIC III test methodology for near term use, and then to extend this approach to better adapt it to indoor localization technologies which may be tested for E911 purposes in a number of years.

The majority of E911 solutions available today rely on wireless communications with cell towers or beacons that are located from a fraction of a mile to a few miles away from the handset initiating the indoor E911 call. Therefore, testing in various topographies / representative areas, morphologies and deployments will be necessary. ATIS ESIF has recommended a set of 5 + 1 regional test beds to capture the variations in topography, morphology and building styles and construction materials across the country. (The "+1" is exclusively the dense urban morphology in Manhattan.) The driver regarding the number of test bed areas is the extent to which the obtained results could be extrapolated from a certain test area to a wide region well beyond it, or more generally, to indoor wireless use scenarios that are found elsewhere in the nation.

The testing process developed and implemented in the CSRIC III testing in San Francisco is expected to improve in time as refinements are made, and as feedback from all stakeholders is incorporated into the process. Topics such as increasing the number of test points within each building and dynamic testing along a route within a building are considered potential avenues to explore. Although a consensus on test methodology was achieved, a dissenting opinion remained (additional material is provided in Section 9). One factor driving this consideration is the potential growth of the permanent Test Bed from an indoor location technology exploration and qualification platform into a compliance platform.

The "Indoor Location Test Plan" approved and executed by CSRIC III represented the first formalized, multi-party, public indoor location accuracy trial for E911-relevant mobile location technologies. Test protocol design for that trial was an involved process which relied on industry best-practices, published standards, and the many years' experience of the various participants. The Commission should realize that test protocol design for a *permanent* Indoor Location Accuracy Test Bed could evolve as technology advances.

4.1 Near-Term Considerations for the Test Bed

We recommend that for the near term the basic CSRIC III test plan be adopted by CSRIC IV:

1. Use the morphology classifications defined by ESIF and adopted by CSRIC III, i.e., perform indoor testing in dense urban, urban, suburban, and rural areas (as applicable in a given test bed area).
2. Test with enough buildings and distinct building types in each morphology to characterize indoor location performance in that morphology.
3. Test multiple devices from each vendor (two to four devices were used in CSRIC III).
4. Use a warm start regime for the test calls (or events), where test device memory from a prior fix is not relied upon in generating the current fix.
5. As in CSRIC III, test for and report on horizontal and vertical accuracy (when available), time to first fix, spread of the location fixes about the ground truth location of the test

point, and reliability of the reported uncertainty. Other less quantitative factors can be assessed as well in light of the experience in testing the technology in the test bed, however this would be outside the scope of the test procedure itself. Such evaluation factors may include: practicality and suitability for E911, maturity, robustness, extensibility and the like. Reporting on such evaluation criteria would be presented separately from the quantitative test report.

6. Specific test parameters may differ somewhat from one test bed area to another and even over time in the same test bed. These parameters include the specific number of buildings per morphology, number of test points per building, number of location fixes per test point, and so on. However, the broad parameters of the CSRIC III test plan should be followed in the near term.
7. Start with retesting in the San Francisco Bay Area (similar to CSRIC III). Next, extend to the Northeast (Philadelphia and its surroundings including the "+1" dense urban environment in Manhattan, NYC) then to the other test bed regions in an order influenced by opportunity.
8. Ensure a management structure and vendor agnostic funding structure exists to oversee the test bed and execute the test plan in the short term. (Similar to a CSRIC like body or other such neutral entity.)

4.2 Longer-Term Considerations for the Test Bed

In the longer term we recommend the following revisions/extensions to the scope of the test plan used by CSRIC III:

1. Phone use is becoming more "always on, always position aware":

   This usage change suggests that we develop procedures to allow the proper testing of technologies that benefit from or rely upon the historical track of the device. More than one localization solution is possible. As one possible solution, a handset calculated position or an available position from an LBS application may be inserted into the beginning of an E911 call flow. In another, location related information may be exchanged periodically with the network or infrastructure or location computations may be periodically triggered. It is anticipated that technically oriented forums, such as ATIS's ESIF ESM subcommittee, will address the details of such test methodologies and develop recommendations over the next year or so.

2. Small indoor cells and Wi-Fi APs used for location, both have small coverage areas, covering just one building or a portion of a building. The variability of spatial accuracy within a given building goes up significantly with in-building small footprint emitters, as compared to outdoor emitters spreading their signal more uniformly throughout a building.

   As more small cells are deployed, we expect to develop modified test procedures that are more suited to localization technologies that rely on presence of networking and localization infrastructure in the building that facilitates localization and tracking. These include methods where a larger number of test points are spread uniformly throughout a given test building. In that case, the number of test calls per test point may be much smaller than in the standard methodology used in CSRIC III (and adopted here for the near term). A statistical study may be needed to examine the mathematical tradeoff between the number of test points and test calls, depending on the memory characteristics of the location technology under test. Use of a mix of the standard methodology and this adapted methodology to capture dependence on specific building details versus morphology/surrounding environment factors would be recommended. An expanded set of technical evaluation parameters, such as those identified in the Committee Draft ISO/IEC 18305, "Test and evaluation of localization and tracking systems", may be included, for example, to describe the fraction of the building in which location coverage is available. To the extent that some of these localization techniques may be deployed exclusively inside a building and independent of the outside world, they may not need to be tested repeatedly in different morphologies in different test bed areas. Under such conditions, testing them in different buildings in possibly two areas may suffice.

3. If some future location technique is a candidate for indoor E911 use and it contains key elements that can be affected by motion (e.g., IMUs), a degree of motion will need to be incorporated into the modified test procedure. The effort performed by NIST in the context of the ISO/IEC 18305 could be a useful source of information in this regard.

4. A management framework and funding mechanisms for a permanent test bed would need to be established along the guidelines discussed in the document.

5 Management Framework for the Indoor Location Accuracy Test Bed

This section provides guidance to the Commission regarding management and the expected utilization of the test bed, how many companies or entities are likely to request access to the test bed, the potential duty cycle of test activities, etc.

5.1 Background

Based on the success of CSRIC Work Group III, and the real world lessons learned from it, the FCC has chartered CSRIC IV Working Group 1 to develop recommendations for a permanent test bed framework that can provide the FCC and the various E911 stakeholders with regular, comprehensive, unbiased and actionable data on the efficacy of location technologies used indoors.

The envisioned framework includes the entities that perform, on an on-going basis, both the complex administrative and technical tasks entailed in indoor testing of multiple location technologies and solutions, which may operate on a variety of wireless networks, in disparate regions of the country. Many of the related challenges experienced and learned during the CSRIC III testing guide the recommendations on test bed structure provided below.

This section proposes a framework for the management and execution of the test bed.

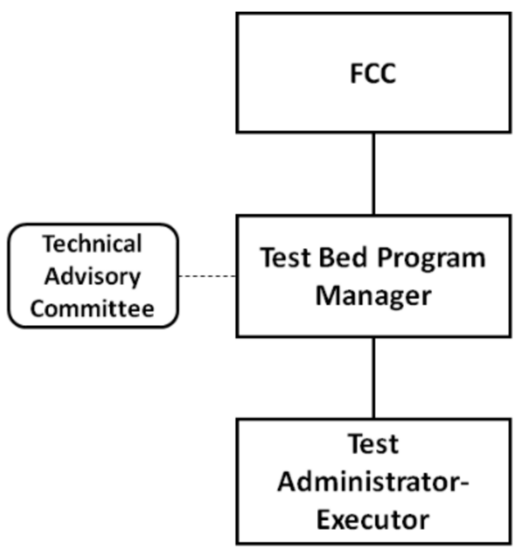
5.2 Objective

The objective of the test bed is to ensure that the performance of new and revisions to existing location technologies can be tested in an unbiased and timely manner under typical 911 conditions. The results of these tests would help the regulatory bodies (FCC), wireless carriers, and public safety groups come to an understanding of the art of the possible related to indoor location as it evolves.

5.3 Structural Framework for the Test Bed

The success of the test bed relies on providing valid, unbiased data in a timely manner to the various stakeholders. Additionally, two sets of challenges: (1) administrative and contractual and (2) technical and operational, were encountered as explained in Section 8 (on lessons learned) of TechnoCom's test report to CSRIC III WG3. Hence, to best achieve the goals of the test bed, it is recommended that a two tier organization structure be created. A 'Test Bed Program Manager' and a 'Test Administrator-Executor'. In addition, the Test Bed Program Manager would receive technical input from a small, focused Technical Advisory Committee representing the various stakeholders.

The rationale for this tiered structure is that it: (a) ensures the administrative/contractual and technical challenges are handled by the right organizations, properly equipped to best deal with those distinct challenges, (b) creates a separation of the entity wanting to test (either vendor or carrier) from the entity executing the test, thus ensuring the independence and efficiency of the Test Administrator-Executor, and (c) provides a means for on-going technical oversight as the E911 and location technology landscape gradually evolve, and consequently the test bed's technical requirements and details would need adjustment or refinement.



5.4 Roles and Responsibilities

5.4.1 Test Bed Program Manager

The role of the 'Test Bed Program Manager' is to be the primary interface between the FCC, the Test Bed Administrator-Executor, the vendor or vendors who want to test their technology in the test bed, the wireless carriers participating in the test bed or monitoring it, public safety, and local points of contact in the test bed areas.

The Manager should be a neutral party and a legal entity with contracting capabilities. Its responsibilities will be as follows:

With Test Bed Administrator-Executor: Hire and manage the Test Administrator-Executor, provide program management and budgetary oversight for the testing program, review the test plan and provide programmatic oversight to ensure the test plan and any variations to the plan fit the intent of the test bed and socialized with the various stakeholders and the Technical Advisory Committee.

With Vendor desiring to test: Ensure compliance of the technology to be tested with entry criteria for the test bed, enter into contracts with them, work with the technical Test Administrator-Executor to ensure readiness of the technology and its supporting interfaces for testing. Manage flow of funding contributions and deliverable results.

With Participating Wireless carriers: Enter into contracts with the participating wireless carriers, manage the flow of data to and from their organizations and ensure timely availability of the required interfaces to their networks (if required). Manage flow of funding contributions and deliverable results as appropriate.

With the FCC: Provide the FCC and other authorized entities with the test results and the parameters of the tests.

With the Technical Advisory Committee: Consult with the Technical Advisory Committee to obtain concurrence in the event of technical or related programmatic changes to the test bed that may occur over time, e.g., changes to test plan, test methodology, test area boundaries, outputs, etc.

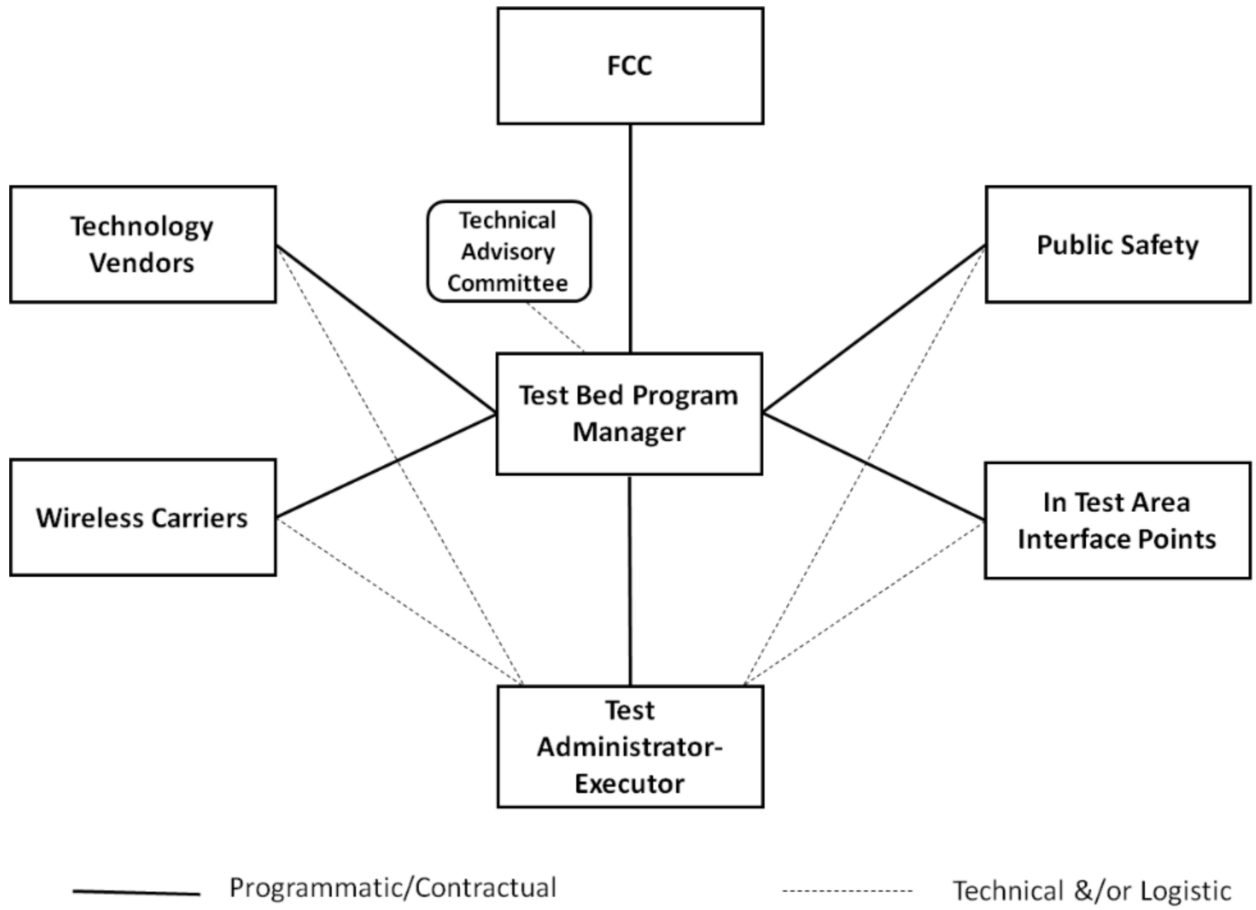
With Public Safety, Municipalities, and Local Points of Contact: Work with public safety entities, both national and local in different cities and test areas, to ensure and facilitate access to buildings. Work with technical Test Administrator-Executor to manage the set of candidate buildings targeted for testing. Mange changes to the test bed, particularly in schedule and scope (as needed in consultation with the Technical Advisory Committee).

The relationships and interfaces of the Test Bed Program Manager as well as the other entities involved in the test bed framework are illustrated below. In essence the characteristics of such a Test Bed Program Manager are that they:

- Possess the Project Management skills, contractual organization, and manpower to execute their part of such a project and be a catalyst to its efficient and smooth operation

- Be an unbiased party to the outcome of the results

- Possess sufficient technical skills to interface with the Technical Advisory Committee and Test Administrator-Executor to insure compliance of the test plan with the test bed objectives as the details of the test bed evolve over time, (e.g., changes in morphology or boundary selections in one or more test regions).



5.4.2 Technical Advisory Committee

The Technical Advisory Committee is intended to provide a focused representation of the stakeholder groups that provides on-going technical guidance and oversight for the indoor test bed process. Since the wireless industry is dynamic, location technologies evolve, and indoor testing is logistically complex and subject to external factors that may not be easy to control (e.g., access to certain buildings, availability of certain interfaces, etc.) the Technical Advisory Committee's chief responsibility is to ensure that the goals of the test bed are being met, even in the event of implementation changes that may have to take place, put in place by the be Test Bed Program Manager and the Test Administrator-Executor. Review and endorsement by the Technical Advisory Committee of major modifications or exceptions, if and when they occur, would serve to strengthen the credibility of the test outcomes.

During CSRIC III, members among its WG3 informally played the role of the Technical Advisory Committee, interfacing directly with the test administrator. During the lifetime of CSRIC IV it is possible that certain members among its WG1 subtask 3 could assume this role as well. In a more permanent arrangement that goes beyond a specific CSRIC commission, this technical committee would be comprised of a relatively small number of technical representatives (less than 10) with a balanced representation from among the stakeholder groups. The members would volunteer to serve in this capacity with concurrence from the various stakeholders. Some of those members could be drawn from other similar Industry committees, such as the ESIF ESM subcommittee from ATIS. The key qualification for membership is intimate experience with E911 and the CSRIC III and CSRIC IV proceedings as well as strong familiarity with and a good understanding of the applicable indoor test methodologies.

Examples of matters the Technical Advisory Committee would provide input on to both the Test Bed Program Manager and Test Administrator-Executor include test bed variations (e.g., number of test bed areas, technologies simultaneously under test) and basic, high level test plan changes (specific test morphologies, mix of types of test buildings to be used, overall number of test points, acceptable test initial conditions, etc.).

5.4.3 Test Administrator-Executor

The indoor Test Administrator-Executor plays a key role in the indoor test bed and is critical to its successful operation. The test Administrator-Executor needs to possess the independence, credibility and proven experience to be able to meet the expected rigorous demands of the indoor test bed, including technical interfacing with a significant number of disparate organizations that could be participating in or providing inputs to the test bed, managing complex logistical challenges, and handling evolving and competing technologies often in complex network arrangements.

Although the responsibilities of the Test Administrator-Executor can be viewed to fall into two broad areas: Technical/Operational and Administrative/Contractual, the emphasis is on the technical/operational responsibilities as the envisioned role of the Test Bed Program Manager should alleviate a significant administrative/contractual load that would otherwise be placed on the Test Administrator-Executor (which is what took place during CSRIC III, and from which we have learned). The elements of the Test Administrator-Executor role include:

1. **Detailed Test Plan Development**

   The Test Administrator-Executor is responsible for developing a detailed test plan tailored to the specific location technologies under test during any given phase of the indoor testing. This detailed plan should be based on a high level plan outlined within CSRIC IV WG1 or agreed to by it (or by the Technical Advisory Committee as its cognizant successor) and inputs submitted by the location vendors to be tested, relayed by the Test Bed Program Manager. This test plan would identify the critical elements pertaining to the technologies under test, e.g., the test equipment, its configuration, its connectivity and use mode. It would also describe the interfaces to the wireless networks used (as applicable) and how the test calls are triggered, test data collected, and any unique test processes to be followed in the field.

2. **Test Building and Location Selection**

   The Test Administrator-Executor will review candidate test buildings and provide a list of them to the Test Bed Program Manager. The Test Bed Program Manager will provide administrative feedback on those candidates, based on interactions with public safety and local contacts. This feedback will be used by the Test Administrator-Executor in the final building selections step, which should ensure balance in the test, attention to the specific RF environments, and available building plans, and their physical and logistical access factors identified by the Test Bed Program Manager. The test Administrator-Executor is likely to need to add the building owners/managers to its liability insurance policy. In certain circumstances, they may need to sign a building access agreement, if not provided by the Test Bed Program Manager. Upon final building selection, knowledgeable technical staff from the Test Administrator-Executor with good understanding of basic wireless location physics will then determine the specific test points within each test building. The test points are to be documented carefully by the Test Administrator-Executor to ensure that the ground truth survey team surveys the specific points intended, and to maintain those records for future reference.

3. Ground Truth Determination

The Test Administrator-Executor will select, contract with and oversee the performance of the professional survey team and review their deliverable ground truths for accuracy and consistency with the defined test points.

4. Review of Location Technology Vendors' Readiness and Integration with Wireless Networks

The Test Administrator-Executor will interface with the selected location technology vendors to review the test configuration and test process for their technology and its state of readiness for inclusion in the testing. The Test Administrator-Executor will also interface with the wireless service providers through whose networks some of these location systems may be tested. The Test Administrator-Executor's engineers are responsible for ensuring that the processes established by the location technology vendors for automated relay of the location fix logs from their systems are properly defined. Those logs would be either transferred directly from the location system platform or from within a wireless carrier's network (in the case of an overlay) to the data repository servers of the Test Administrator-Executor. The Test Administrator-Executor should flag to the Test Bed Program Manager (and in turn, and to the extent necessary, the Technical Advisory Committee) any identified sources of integration risks that could significantly impact test integrity, schedule or budget.

5. Field Test Preparation

The Test Administrator-Executor is responsible for developing the appropriate portable test fixtures capable of housing location technologies to be concurrently tested indoors. (Issues such as battery life, control of the test units, and proper separation of devices should be taken into account while keeping size and weight of the test fixtures manageable so as not to be a detriment to building access.) The Test Administrator-Executor is to also work with the individual location technology vendors to ensure that the test units are made available by the vendors in a timely manner and that agreement is reached on their automated test protocols, and that those protocols are indeed consistent with the spirit of the collectively agreed to test plan. The Test Administrator-Executor also needs to make its field engineers available to be trained on those test protocols by the location vendors. Finally the Test Administrator-Executor is to monitor dry run testing by the selected indoor location technology vendors to ensure that their systems under test are yielding their results in the expected formats and frequencies and that all test interfaces and protocols are working as intended prior to the start of the actual indoor testing. The Test Administrator-Executor should keep the Test Bed Program Manager apprised of any issues in the test preparatory steps.

6. **Actual Field Testing**

   The Test Administrator-Executor will provide the field test team and their supporting back-office engineering to implement the test steps defined for each technology in the detailed test plan. The Test Administrator-Executor's project manager(s) will coordinate the access of the field team to the different buildings. In the event of access issues or unforeseen operational problems, the Test Administrator-Executor would interface with the Test Bed Program Manager to facilitate issue resolution or necessary changes. The field team is to carefully log the start and end times for the test calls at each test point and to note any issues that may have arisen during the testing. At the end of each day of testing they need to upload to the back-office analysis team the daily logs from the field testing activities of that day. The back-office engineering team should then perform preliminary sanity checks on the day's operations and collected data.

7. **Data Handling, Analysis and Reporting**

   The Test Administrator-Executor will establish the data repository server to receive and maintain the test data. It will be responsible for correlating and analyzing the gathered field data and would start that concurrently with the collection of field data. The Test Administrator-Executor will then compile the results and assemble a detailed report to submit to the Test Bed Program Manager. The Test Bed Program Manager will then make the report available to the FCC (required), Public Safety entities (required), participating Carriers (required) and other stakeholders approved by the vendor.

   The typical types of data that will be gathered, analyzed and included in the report will include location accuracy, yield, latency, reported uncertainty, location spreads, and other possible parameters as may be identified in the strawman test plan formulated by CSRIC or the Technical Advisory Committee and agreed to by the affected stakeholders and relayed by the Test Bed Program Manager. The Test Administrator-Executor will create the required FTP sites for sharing the common or the confidential raw data with the respective companies per the NDA requirements. The Test Administrator-Executor needs to sign any necessary non-disclosure agreements with the indoor testing participants and will safeguard, maintain or compartmentalize the confidential data per those agreements.

5.5 Test Administrator-Executor Competencies and Qualifications

Consistent with the above role the Test Administrator-Executor should possess certain competencies and qualifications. The Test Administrator-Executor should have:

1. A business focus on wireless location and its testing approached from a provider-agnostic or neutral perspective, with an established track record in that business area.
2. Strong technical background in wireless location and E911 with extensive experience in performing in-depth field testing for wireless location, especially in an E911 context. Familiarity with the various wireless air interfaces and the methods in which location

technologies are either included or overlaid on those air interfaces for E911 purposes.

3. Prior experience testing E911 systems in the field.
4. Intimate knowledge of the industry accepted E911 wireless location test methodologies (e.g., from ATIS), and in particular indoor wireless testing methodologies.
5. Strong system engineering experience with knowledge of how wireless location systems work and the expected effects of propagation and multipath on their performance.
6. In-house technology and/or processes that aid in the efficient handling and processing of large amounts of test data and the generation of accessible outputs. Also have the supporting IT infrastructure to receive, maintain and as necessary separate or compartmentalize the test data.
7. Existing working relationships with various players in the wireless location and/or E911 area.
8. A history of financial stability and insurance coverage appropriate for the requirements associated with indoor access and testing.
9. Preferably, some involvement in CSRIC, which aids in having a good appreciation of the contrasting perspectives within the broad group of stakeholders and an understanding of the relationships among the test bed participants and its beneficiaries.

6 Funding Mechanisms for the Indoor Location Accuracy Test Bed

This section provides guidance to the Commission regarding funding models for the Indoor Location Accuracy Test Bed.

Operating expenses can be divided into fixed costs for a permanent Test Bed plus costs specifically associated with conduct of each test cycle. Expenses will need to support (a) the Test Bed Program Manager (i.e., the legal and administrative agent), (b) the Test Executor who conducts the tests, and (c) potential lease, long-term equipment rental, and maintenance fees; it is presumed that the Technical Advisory Committee operates *pro bono* [refer to Section 6, Management Framework for the Indoor Location Accuracy Test Bed].

The Test Bed may start in one geographic region, but will likely extend to be in a number of geographic regions. Some of the facilities may be private or commercial establishments (hotels, malls, office buildings), and some facilities may be owned/managed by federal, state, or local governments or by national laboratories. However, between test cycles, there will probably not be significant facility-specific expenses; for example, it is possible that the Program Manager may enter into occasional low-cost long-term arrangements for building access in order to facilitate indoor testing under mutually-agreeable terms and conditions. Fixed costs are likely to focus on the Program Manager in order to maintain organizational continuity and to provide a single point-of-contact for various interested stakeholders.

It is possible that the Test Bed will be expected not only to support indoor location accuracy tests which will evaluate various technology solutions and inform Commission rulemaking, but also to provide demonstration of compliance from CMRS providers in regards to Commission E911 mandated performance. Participants who conduct tests towards the first objectives will likely expect a somewhat different level of test thoroughness vis-à-vis compliance testing (e.g., more geographically limited testing); participants who may seek to demonstrate compliance likely will expect heightened scrutiny of the results and therefore more extensive (and consequently more expensive) testing.

Considerations that will impact the Commission's decision on funding (and cost recovery) include:

- Ensure the neutrality and impartiality of the Test Bed, including impartiality of the Program Manager and the Test Executor.
- Maintain stability of the Test Bed and meet payment obligations for regularly-occurring and fixed-cost expenses between test events.
- Ensure fairness to all test participants, so that financial barriers do not keep promising technologies from evaluation and that "deep-pocketed" entities do not feel that they are shouldering an excessive portion of the Test Bed financial burden.
- Provide flexibility so that test scope and expense can accommodate protocols which either (1) qualify a particular technology or (2) demonstrate compliance for a deployed system by a CMRS provider.

Funding could come from government sources (appropriations), private industry (fees), or a public/private partnership. For private industry participants, funding could be tiered based on test objectives.

During the early years of the Test Bed (perhaps 2014-2016), it is likely that technology qualification/evaluation would predominate, and many vendors may be interested in participating to demonstrate and raise awareness of their solutions. In later years (2016+), compliance testing by CMRS providers could be the dominant objective; although the Commission acknowledges that not all compliance testing would be required to occur via the Test Bed, progressive improvement in technologies for indoor location likely will create continuing demand for testing. At some point in time (perhaps approx. post-2019) when Indoor Location Accuracy Standards are mature, demand for testing in the Test Bed may become lighter. Thus, in the early years, a twice per year test cycle may be warranted, and the first such event could be expected to have significant pent-up demand (the most recent testing having concluded in 2013). In later years, fewer test events and participants are possible, leading possibly to yearly or bi-yearly testing, meaning funding may be split between fewer entities and fixed costs required to maintain the Test Bed may predominate. However, with the longer period between formal test cycles, the funding mechanism in place (mostly private and part public) should still accommodate ad hoc requests to test new technologies that become ready for evaluation or qualification in the interim.

Given the considerations outlined above, the guidance to the Commission regarding Test Bed funding is as follows:

- <u>*Federal agencies pursue funding to support the fixed costs of the Test Bed*</u>, and the Commission manages the test bed in coordination with the National 911 Program Office. Fixed costs cover the Test Bed Program Manager, who is selected by competitive bid for a 2-year appointment.
- <u>*Costs for each test cycle are borne by test participants*</u>, cover (primarily) the Test Executor, and commitment to pay their portion of the expenses is a prerequisite to test participation. Participants indicate whether they desire qualification-level testing or compliance-level testing. The Test Executor for each test cycle is selected by competitive bid, and their budget proposal for each of the qualification-level and compliance-level testing is shared equally by all participants in the tests of each type. There is the possibility that some participants may withdraw prior to conduct of tests,

which would change the cost-share portions for those participants who chose to proceed; the possibility and outcome of this situation would be explained to all potential participants during the planning phases proceeding a test cycle.

7 Logistical Process of Conducting an Indoor Location Accuracy Test

This section provides guidance to the Commission regarding the process whereby an indoor location accuracy test is conducted: its planning, conduct, data analysis, and reporting. It also describes registration requirements and documentation submissions that a candidate indoor location technology needs to comply with to participate in the test bed process.

To ensure that test bed resources are appropriately utilized, a candidate indoor location technology should be already commercially available, or at least in an active prototyping phase (i.e., prototypes available for testing). In an active prototyping phase, there should be published literature describing the operational principles of the technology. There should already have been numerous field trials in varying morphologies demonstrating the viability of the technology. A candidate technology that is claimed viable mainly via simulation, with limited demonstrations in a lab-only environment, would not likely be considered ready for the test bed.

7.1 Registration Requirements

This section identifies the “registration requirements” for candidate technologies that are submitted to the test bed for evaluation. The original charter for CSRIC IV WG1 by the FCC directed the definition of the test bed towards a broad evaluation of available and emerging technologies that can benefit indoor wireless E911. No specific emphasis was placed on their degree of commercial maturity or adoption in commercial networks in E911 configurations. The registration requirements or criteria described in this section have been formulated to be consistent with this context and should be interpreted accordingly.

It should be noted, however, that during the time span of CSRIC IV, the FCC released its FNPRM addressing the accuracy requirements for indoor wireless E911 and its potential compliance methods that may use a test bed approach. Although the detailed testing protocols for technology evaluation and accuracy compliance might not be dissimilar, entrance criteria to a test bed for evaluation purposes versus regulatory compliance would be quite different. Not only could the management and funding mechanisms for those efforts be different, but also the location technology submitted for compliance testing would have to meet a more stringent threshold, defined in terms of commercial maturity, technical standardization, deployment in wireless service providers’ networks, field trials completed with published results, etc. To reiterate, the emphasis in the requirements below is on technology evaluation for indoor wireless E911 and not on establishment of compliance with any mandates.

Below we enumerate the various aspects of any new location technology which shall be described by the location technology vendors in order to register candidate technologies for inclusion in indoor testing. In general, this is very similar to what was requested of location technology vendors who participated in the CSRIC III test bed, as well as vendors who did not participate but were discussed in the report “Leveraging LBS and Emerging Location Technologies for Indoor Wireless E9-1-1” Specifically, the following guidelines are proposed.

A Candidate Technology Test Form must be completed by a location technology vendor for each indoor location technology (each, a *candidate technology*) that the vendor wishes to submit for testing. This Form shall include the following descriptive information:

i. Commercial Availability
    i. What is the commercial state of the candidate technology?
        1. Commercially released with one or more commercial deployments
        2. Commercially released with no commercial deployments
        3. Prototype in live field testing
        4. Prototype in simulation testing (pre-field testing)
    ii. Provide references or links to any published literature describing the operational principles of the technology and the field trials completed in various morphologies demonstrating the viability of the technology.
ii. Network Deployment Requirements
    i. Describe the impact of the candidate technology to the wireless network; e.g., no impact at all; software/firmware upgrade; hardware upgrade, enhancement or modification; etc.
    ii. Describe the impact of the candidate technology on a wireless network's voice and data services.
    iii. Describe the network dependencies of the candidate technology, including baseband protocol requirements and version(s), operating frequency requirements and/or boundary limits, transceiver antenna location, geometry, and density requirements, and other Radio Access Network (RAN) concerns.
    iv. Describe any dependencies on the deployment and/or use of additional RAN, satellite, or other systems for commercial use of the candidate technology.
    v. Describe, to the extent permissible by any NDAs, working relationships already established between the candidate technology provider and any US wireless carriers.
iii. User Equipment (UE) Deployment Requirements
    i. Describe the impact of the candidate technology to the UE; e.g., no impact at all; software/firmware upgrade; hardware upgrade, enhancement or modification, power consumption impact, etc.
    ii. If additional hardware is required, describe, if known, any plans to integrate this hardware with other existing chip sets.
    iii. Regarding power consumption, the vendor shall describe the expected power consumption when an actual E911 location fix is being obtained and any background power that may be needed, steady-state, in order to later achieve better TTFF or accuracy when an actual E911 location fix is attempted.[4]
iv. Morphologies Tested
    i. Describe the various morphologies tested to date; e.g., rural, urban, dense urban (urban canyon), building structures and compositions, complexity

[4] For example, in the CSRIC III report "Emerging Location Technologies for Indoor Wireless E9-1-1" report, the LEO SATELLITE-BASED POSITIONING technology offered by Boeing required background power.

of indoor environments, etc.

v. Standards Compliance
   i. Describe the candidate technology's compliance with existing standards; e.g., 3GPP, 3GPP2, 802.11, OMA/SUPL, ATIS/ESIF, etc.
   ii. Describe the candidate technology's timeline for achieving compliance with relevant industry standards.

vi. Interface Utilization
   i. Describe the wireless network interfaces utilized by the candidate technology and any changes required thereto for commercial deployment.

vii. PSAP Integration
   i. Describe the interfacing of the candidate technology with existing PSAP systems and infrastructure.

7.2 Outputs of Indoor Location Accuracy Tests

The following material describes outputs of test activities and how results are standardized and shared with the outside parties and interested stakeholders:

1. Each location technology vendor wishing to participate in the test bed process has the responsibility to coordinate with a wireless service provider (to the extent necessary) to host their technology over the wireless network and provide any required network interface or access to other relevant information. Any impact to the wireless service provider's network must be reasonably limited to allow rapid integration of the technology-under-test and timely test execution.
2. Detailed test results (call-level test data) for a particular technology-under-test are distributed only to the location technology vendor, the host wireless service provider (as an incentive for providing support for the location vendor) and to the test bed vendor for analysis and preparation of the test report.
3. Summary test results from all technologies tested are made public through the release of the formal test report. Summary test results include quantities such as various accuracy performance levels/cumulative distribution functions, yield figures, latency figures, uncertainty estimate performance, etc.

One key tenet of the test bed process is that any vendor offering their technology for inclusion in the test bed – agrees that their performance, as measured and analyzed, will be included in the report. The last opportunity in time for a vendor to "back out" of the test process is just prior to the start of test execution. Once beyond that point – withdrawal from the test process is not allowed. The test bed process is intended to explore and document actual performance levels achieved by a given technology – whether or not those performance results are in-line with vendor claims/expectations. This approach is necessary to achieve the overall goal of supplying the commission, public safety, wireless service providers, and other interested stake holders with real-world performance insights for a given technology of interest.

8 Stakeholders

This section provides guidance to the Commission regarding the organizations and agents who will expect to interact with the Indoor Location Accuracy Test Bed.

- FCC
  - Effectively balance the need of the public with the technological capabilities of the industry

- National 911 Program Office
  - Help coordinate the efforts of states, technology providers, public safety officials, and 911 authorities on IP-enabled 911 and Next Generation 911.

- Wireless Carriers
  - Achieve a cost effective fulfillment of the accuracy requirements imposed on them

- Public Safety Agencies & Organizations
  - Save lives effectively with a reliable implementation of dispatch procedures, using the positions delivered by the carriers

- Location Technology Vendors and Device OEMs
  - Provide cost effective technology to improve public safety and save lives

- Infrastructure Vendors
  - Sell complex but reliable networking equipment and database maintenance systems to effectively manage large amounts of data
  - ESME & PSAP & CAD system vendors – consume location data from the carrier's front-end location platform

- Test Service Providers
  - Provide cost effective, transparent comparison of differing location technologies to support government mandate decisions, carrier budget decisions and location technology vendor improvements to their technology

- Standards and Metrology Oversight Bodies
  - Participate in identification and evaluation of candidate indoor location technologies; assist in test site selection and test plan preparation; ensure appropriate conduct of tests with meaningful and defensible results

9 Additional Considerations on Test Methodology

Developing test methodologies is an involved process. The following opinion submitted to CSRIC IV WG1 is distinct from the consensus approach described in Section 4.

Opinion #1

NIST is concerned that the size of the data set used in the San Francisco tests might have been too small. To be specific, a total of only 75 test points in 19 buildings were used to characterize indoor E911 location accuracy and time to first fix in four morphologies. The uncertainty in any statistical inference would be high when the data set is small. Instead of using only 2-6 test points per building, per CSRIC III guidelines, NIST recommends using at least 20-60. Better yet, the well-established techniques of "Design of Experiments" should be used to simultaneously determine the number of buildings to use in each morphology, the number of test points in each building, the number of test calls to make at each test point, and perhaps even the number of handsets to test from each vendor. Using only 2-6 test points in a building ignores the spatial diversity across a building of the wireless signals used for E911 localization functionality[5].

There has to be a sound basis for selecting the above test parameters. NIST recommends that an experimental study be carried out to measure the effects on statistical uncertainty when the above parameters are varied. The findings of such a study should guide the procedures to be used in the next round of CSRIC tests as opposed to simply adopting the CSRIC III procedures.

10 Conclusions

As described in this report, the technologies for wireless indoor location determination continue to evolve. Likewise, the experimental protocols for testing these technologies will undergo change. Finally, regulations and public expectations regarding wireless calling and E911 are not going to remain fixed. Therefore, the Commission may wish to re-visit the guidance in this document at an ongoing basis, as part of the process of overseeing the conduct of indoor location accuracy tests and the management, funding, and evaluation of a permanent Indoor Location Accuracy Test Bed.

11 Acronyms

3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2
AFLT	Advanced Forward Link Trilateration
A-GPS	Assisted GPS
AP	[Wi-Fi] Access Point
ATIS	Alliance for Telecommunications Industry Solutions
CAD	Computer Aided Dispatch
CSRIC	Communications Security, Reliability, and Interoperability Council
DAS	Distributed Antenna System
E911	Enhanced 9-1-1
ESIF	Emergency Services Interconnection Forum
ESM	Emergency Services & Methodologies
ESME	Emergency Services Messaging Interface
FCC	Federal Communications Commission
FNPRM	Further Notice of Proposed Rulemaking
GLONASS	Globalnaya navigatsionnaya sputnikovaya sistema [Russian GNSS]
GNSS	Global Navigation Satellite System
GPS	The NAVSTAR Global Positioning System
GSM	Global System for Mobile Communications
IEC	International Electrotechnical Commission
IMU	Inertial Measurement Unit

[5] Regarding the second bullet in Section 4.2, we agree that the “slow-fading” component varies slowly when localization is based on outdoor emitters that are possibly miles away. The same cannot be said though about the “fast-fading” component that can vary a lot over a fraction of a wavelength.

IP	Internet Protocol
ISO	International Organization for Standardization
LBS	Location Based Services
LEO	Low Earth Orbit
LTE	Long-Term Evolution
MEMS	Microelectromechanical Systems
NDA	Non-Disclosure Agreement
NIST	National Institute of Standards and Technology
NYC	New York City
OMA	Open Mobile Alliance
OTDOA	Observed Time Difference Of Arrival
PSAP	Public-Safety Answering Point
RAN	Radio Access Network
RF	Radio Frequency
SUPL	Secure User Plane Location
TTFF	Time to First Fix
UE	User Equipment
UTDOA	Uplink-Time Difference of Arrival
WG	Work Group