BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, DC 20554

In the Matter of	)	
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Wireless E911 Location Accuracy Requirements	)	PS Docket No. 07-114
	)	
	)	

COMMENTS OF TELECOMMUNICATION SYSTEMS, INC.

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SUMMARY

Establishing criteria for Indoor Location Accuracy is challenging. Few technologies have been tested with rigor, and no single technology has been identified to work across all test morphologies. Even identifying the location accuracy required for indoor emergency calls needs further analysis.

TeleCommunication Systems, Inc. (TCS) believes that the Federal Communications Commission's (FCC, or Commission) ultimate goal should be to encourage the adoption of location technologies by wireless carriers such that a Dispatchable Location of the caller would be provided to the Public Safety Answering Point (PSAP) telecommunicator. Different morphologies will create different location accuracy requirements. This is already evident. The outdoor location accuracy requirement of 50m horizontal distance may work on a highway, but it is insufficient in a high-rise, where a vertical component is required. Similarly, a 50m horizontal accuracy with no vertical accuracy requirement may be sufficient in a single-family subdivision, but insufficient in a townhouse complex, where 20m accuracy may be required to identify the correct Dispatchable Location. In short, various morphologies will require various indoor location accuracy requirements, and the current single-requirement approach of demonstrating accuracy within a Geographic Compliance Area may not yield the ultimate desired result of producing Dispatchable Locations.

In addition, demonstrating that location accuracy is met within a test bed may not ultimately serve Public Safety's need for Dispatchable Locations within the Geographic Compliance Areas they serve. Ultimately, the Commission will likely receive pressure for wireless carriers to test indoor location accuracy within each Geographic Compliance Area, and this future requirement could prove to be a costly exercise.

TCS believes that the introduction of an Indoor Location Accuracy requirement prompts the need to create a twofold set of goals that lead to the desired result of providing Dispatchable Locations for each wireless emergency call. First, a series of Location Accuracy goals can be created for various morphologies and demonstrated in a test bed to show that one or more location technologies can be used to achieve the desired Location Accuracy goal; and second, a single Measured Location goal can be created, defined by horizontal and vertical uncertainty components, which would be measured through the analysis of the aggregation of actual emergency calls generated within the Geographic Compliance Area over regular time intervals.

TCS will provide key definitions to the terms needed to understand this approach, will provide greater detail to explain this bifurcated wireless Location Accuracy approach, and will broadly discuss the technologies currently under consideration.

Many of the location technologies under consideration have had and will continue to have significant improvements. The GPS technologies that are primarily being used today to provide the wireless location of a caller are expanding to include other satellite constellations, which will improve the outdoor and indoor accuracy of those technologies. The LTE standards have incorporated the ability to convey multiple location determinations and will incorporate Observed Time Difference of Arrival (OTDOA) as part of the standard architecture. And new technologies are emerging – primarily beacons, small cells, and Wi-Fi – that could produce excellent indoor location results but which require deployment efforts, as in the case of beacons and small cells, or which require verification techniques, in the case of Wi-Fi. If wireless carriers are ultimately responsible for location accuracy results, then understanding the span of control (SoC) for these various technologies will be important. Ultimately, the conclusion is that the location technologies, though promising, need further analysis, and the cost and

implementation time frames of these issues are not areas that TCS can directly address. However, the test beds that the Commission has already established via Communications Security, Reliability and Interoperability Council (CSRIC) III and the planned efforts in CSRIC IV could prove to be the needed foundation for establishing Location Accuracy goals for specific morphologies, validating the technologies that meet those goals, and establishing the baseline calibration of uncertainty values produced by these technologies.

Determining whether calls come from indoor or outdoor environments appears especially problematic, and TCS believes that a bifurcated approach deals with this situation by focusing on challenging morphologies in test beds and then measuring uncertainty values from actual 9-1-1 calls to determine when technology needs to be deployed in certain geographic areas.

TCS has long supported the use of commercial location technologies for public safety requirements. Deploying different location technology for commercial vs. emergency uses creates an environment in which the lesser-used emergency technologies risk becoming obsolete and expensive to maintain. Roaming issues must be overcome in both environments; solving this issue in commercial location technology architectures will have the added benefit of solving this same issue in emergency call situations.

But using commercial technologies requires that privacy issues be addressed, and it will be necessary to bypass personal settings that block or disable the use of location technology. This can be done with the addition of emergency settings in the commercially used location protocols.

To provide an environment in which various location technologies can be tested in different emergency call morphologies, test beds will need to be created and maintained. TCS believes that such test beds will be the most cost-effective method of determining location

accuracy compliance. By demonstrating the ability for location technologies to meet the Location Accuracy goals in the test bed and generating correlation to uncertainty values, it will be possible to avoid costly testing in Geographic Compliance Areas. Administrative procedures can be created to support the continued use of these test beds at significant cost savings to all involved.

Location analytics can be used to show goal compliance within each Geographic Compliance Area. Because uncertainty values on each call will be correlated with Location Accuracy, it will be possible to use information gathered from actual emergency calls to determine how well the wireless location technology is achieving compliance goals within each Geographic Compliance Area. Geospatial location analytics can identify areas of high location uncertainty, thereby identifying the need for new location technologies to be deployed in the particular Geographic Compliance Area. Perhaps most important, the PSAP telecommunicator will have a greater trust of the location data being presented and will be able to ascertain whether a Dispatchable Location has been achieved. By focusing more on the location analytics from a given Geographic Compliance Area, we can consistently and systematically improve the wireless location accuracy within each Geographic Compliance Area.

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COMMENTS OF TELECOMMUNICATION SYSTEMS, INC.

TeleCommunication Systems, Inc. (TCS) hereby submits these comments in response to the Third Further Notice of Proposed Rulemaking (Notice) released by the Federal Communications Commission (FCC, or the Commission) in the above-referenced proceedings. In the Notice, the Commission asks vital questions regarding the delivery of accurate location information to Public Safety Answering Points (PSAPs) for wireless 9-1-1 calls placed from indoors. The Commission also seeks comment on the provision of vertical location information (z-axis or elevation) and Location Accuracy standards consistent with the evolving capabilities of indoor location technology and increased deployment of in-building communications infrastructure.

A. Introduction

TCS' experience in Enhanced 9-1-1 (E9-1-1) began when it pioneered the first U.S. wireless E9-1-1 solution in 1997, and continues through recent deployments of some of the first true Next Generation 9-1-1 (NG9-1-1) systems in Iowa, Texas, and Tennessee. TCS also continually pioneers and improves the methods by which U.S. PSAPs receive a mobile caller's location during calls for emergency assistance. Today, TCS supports half of all U.S. wireless

and nomadic Voice over Internet Protocol (VoIP) E9-1-1 calls. Its award-winning wireline, wireless, and VoIP E9-1-1 products, together with its E9-1-1 solutions, serve more than 140 million wireless and IP-enabled devices. As the only non-carrier TL 9000-certified company that supports E9-1-1 services, TCS provides highly reliable solutions that ensure a subscriber's emergency call routes to the appropriate PSAP and that the caller's location information is automatically delivered. Identified by research analysts as the global leader in precise location systems, TCS actively leverages its industry-leading location infrastructure to provide updated Phase II location information to PSAPs in order to provide life-saving resources quickly for each emergency mobile caller. TCS provides location infrastructure for both emergency (E9-1-1) and commercial location solutions, making TCS a national expert in location technology. TCS offers the following comments in response to specific questions posed by the Commission in Sections III and IV of its Notice.

B. Determining a Regulatory Compliance Approach

As the Commission considers the incorporation of indoor location requirements for 9-1-1 calls, TCS believes that we will cross a critical threshold that will require a different approach to how we measure regulatory compliance.

Public Safety is interested in receiving a "Dispatchable Location" for every call. If the call taker does not have enough trust in the location fix of the call (i.e., the uncertainty level is too high), then the call taker needs to get information from the caller before dispatching emergency services. But if the uncertainty of the location fix of the call is within a reasonable margin, the call taker should have enough assurance to dispatch emergency services. Therefore, getting a Dispatchable Location is the critical requirement for each emergency call. For an outdoor

environment, 50m horizontal uncertainty seems to be sufficient because line-of-sight typically allows an emergency responder to find a caller at this distance (e.g., on a highway or in an open field). Unfortunately, this distance could be too great in an indoor environment, especially if this extends into the z-axis. Being on the wrong floor of a building can cause critical time delays. For certain indoor environments, 20m horizontal and 3m vertical would likely be sufficient. But on any given call, the call taker will not know if the call is coming from an indoor or outdoor location. This leaves three viable approaches for location regulatory compliance:

1. Have one common requirement that is more stringent for all environments and which would be tested in each geographic compliance area;
2. Be able to determine whether a call is coming from an indoor or outdoor location and apply separate compliance requirements for each environment within each geographic compliance area; or
3. Find some method for which the assurance of the location of the caller can be determined on any call, regardless of indoor or outdoor location, and use this assurance level to measure compliance within each geographic area.

Requiring a more stringent location requirement for all environments could prove to be a costly endeavor and might not yield significant performance improvements because actual 9-1-1 calls might not be coming from these more difficult morphologies. Similarly, performing accuracy testing for indoor locations, following the approach of "drive testing" that is used to conduct outdoor Location Accuracy testing, would likely create a heavy burden on each wireless operator and, again, might not yield significant performance improvements because we are testing simulated, not actual, 9-1-1 calls.

Trying to determine whether a call is coming from an indoor or outdoor environment is problematic, perhaps even impossible, especially if we need to establish different goals for different indoor environments (e.g., what works well in a warehouse may work poorly in a high-rise apartment complex).

For these reasons, TCS recommends that the Commission give strong consideration to the third approach, by which the assurance of the location of the caller is determined and aggregated to measure compliance within the geographic compliance area (currently, the county level). This approach will be far less costly to implement, will use call information from actual 9-1-1 calls, and (perhaps most important) will begin to establish an understanding by the call taker of the assurance of the Dispatchable Location fix for each call. This in turn will build trust in the system and immediate recognition when the location fix of the caller is not sufficient for dispatch and other means of location determination (e.g., verbal interrogation of the caller or listening for audial background cues) are required. Shortly, we will discuss a bifurcated approach to regulatory compliance, but first we believe it will be helpful to provide some background and useful definitions.

C. Establishing Common Definitions

Determining the location of any phone, wireline or wireless, is governed by the nature of the access network through which the phone is connected to the network. In wireline telephony, a phone is physically connected to the network by a circuit and the termination point is well known in the form of a civic address, usually validated against a Master Street Address Guide (MSAG) so that these addresses, when presented during a 9-1-1 call, can be found in an MSAG database. When an emergency call originates from a wireline phone, the originating circuit is effectively mapped to an address and can be supplied to the PSAP in a textual format. In this

case, the location is presented as a validated street address and allows the first responders to locate the caller at the address presented.

The inherent design of wireless phones means that, unlike wireline phones, the location associated with a wireless phone is NOT immutable and is normally tied to a specific point in time. Because wireless phones use electromagnetic signals to access the network, the location determination process is governed by the physics of electromagnetic signal propagation. It is a statistical process, and the challenges associated with this process are well known (multipath, measurement error, measurement precision, etc.). The end result of this process is a Geodetic Location (latitude, longitude, and altitude) with an area of uncertainty that is computed at a certain Confidence level. By their nature, wireless networks will calculate a Geodetic Location, though certainly a more coarse location determination can be provided that is associated with the wireless access point (e.g., tower, small cell, femtocell, or Wi-Fi access point) of the call.

In a wireless environment, providing PSAPs with a Dispatchable Location can occur in one of several fashions. The Geodetic Location that is computed can be mapped to a civic address using an external Geographic Information System (GIS). This is an approximate process, and the uncertainty associated with the Geodetic Location is carried over and to some extent amplified by the mapping to determine a civic address. Alternatively, the civic address can be determined through proximity detection techniques. For example, if the mobile were able to hear a low-powered beacon source (e.g., a Wi-Fi access point, Bluetooth beacon, or femto/small cell) whose precise location was known as a civic address, then a location server can reasonably conclude, by virtue of the fact that the mobile can hear this source, that the known civic address of the beacon source is the location of the mobile. The challenge associated with this method is that known beacon sources are not always available. Even when they are, they are

notoriously hard to manage. They are not always owned by the operator or by an entity with which the network operator has a trust relationship.

Location Accuracy is the comparison of a determined Geodetic Location, using a particular location technology, to a known location. These comparisons are usually compiled through ground-truth testing. Location Accuracy would be used to determine how well a particular location technology works in a specific morphology and could be demonstrated in a test bed, much like what Communications Security, Reliability and Interoperability Council (CSRIC) III demonstrated and CSRIC IV now anticipates.

A Measured Location is the combination of a Geodetic Location and the horizontal and vertical uncertainty values associated with the determined location. These uncertainty values are error estimates that are used to create a shape around the Geodetic Location, within which the actual location of the caller is expected to be found given a certain probability, which is expressed as a percentage and defined as the Confidence value of the Measured Location. For instance, a location technology may provide an estimate of a 95 percent probability that the caller is in an oblate ellipsoid of 50-meter radius and 6-meter vertical height (+/- 3 meters), which translates into a 34,416-cubic-meter space around the point described by a latitude, longitude, and altitude. For the purposes of this discussion we will conduct in this response, TCS proposes that a fixed Confidence level be established (in the above example, the Confidence value was 95 percent, the horizontal uncertainty was 50 meters, and the vertical uncertainty was 3 meters).

TCS will use the term “Dispatchable Location” to indicate a civic address or Geodetic Location which provides a Measured Location that produces a reasonable level of assurance to

the call taker that the first responder will be able to locate the caller quickly enough to provide life-saving emergency services.

Accuracy testing should ensure that the technology (or aggregated technologies used within a Commercial Mobile Radio Service (CMRS) provider's location solution) is tuned such that all components of the Measured Location are within tolerances and the shape encompasses the actual location of the device (within the expressed Confidence value). Call takers need to be able to trust that all the components of the estimate can be utilized to locate the device/caller. Furthermore, in Measured Locations, the target Confidence influences the horizontal and vertical uncertainties. TCS recommends that all location technologies report their Measured Locations with a standardized Confidence value. Three Confidence values are typically discussed: 67 percent, 90 percent, and 95 percent. Because of the mathematical nature of these calculations, it is possible to formulaically modify uncertainty calculations from location technologies that use Confidence values different from the standardized Confidence value. A reported Confidence value of 95 percent or higher is what is recommended for use in representing location information per IETF RFC 5491, the mechanism that is foundational to NG9-1-1 as defined by the NENA 08-003 standard.

Over the years, public safety organizations have asked the Commission to establish specific geographic levels within which location regulatory compliance requirements would be measured. TCS will use the term Geographic Compliance Area to represent this concept. However, as we will explain in greater detail, rather than continuing the practice of Location Accuracy testing within these Geographic Compliance Areas, TCS recommends that Measured Locations within the Geographic Compliance Areas would be aggregated and analyzed, and

regulatory compliance would be determined by validating that the aggregated Measured Locations fall within regulatory guidelines.

As was mentioned earlier, location information for wireline 9-1-1 calls, including VoIP 9-1-1 calls, is provided as a civic address. For a mobile emergency call, we can have two major types of representation of the location of a caller: a textual representation (e.g., MSAG-validated street address) or a Measured Location (latitude, longitude, and altitude with an expression of location uncertainty, horizontal and vertical, calculated from a common and predetermined Confidence value). TCS will be using the term Composite Location to refer to the combination of these data elements that would be delivered to Public Safety with each 9-1-1 call. In particular, in addition to the Measured Location of the call, the textual representation would provide a MSAG-validated or civic street address and/or could present supplemental information that would provide additional detail useful for establishing a Dispatchable Location of the caller (e.g., floor number, room number, stairway designation, hallway identifier, etc.).

Techniques for conveying this supplemental information are currently described in existing protocol standards as well as NG9-1-1 standards. NG9-1-1 networks are designed to carry both Geodetic Locations and civic/MSAG-validated addresses, though work may still be needed for PSAP customer premises equipment (CPE) to display all of the information that can be conveyed.

Mobile-originated emergency calls today rely on initial, Coarse Location (e.g., cell tower) for routing and Measured Location for dispatch. While an initial Coarse Location is immediately available from the network and useful to route the call to the appropriate PSAP, an

enhanced Measured Location is useful to dispatch emergency service resources to the caller requesting help.

D. TCS Recommends a Bifurcated Regulatory Compliance Approach

Because location regulatory compliance for both indoor and outdoor environments is now under consideration, TCS believes that a bifurcated approach to regulatory compliance should be considered. Location Accuracy of particular location technologies should be independently established, and Measured Locations from each actual emergency call should be aggregated from each specific Geographic Compliance Area to determine whether the location technologies in use in any particular geography are providing sufficiently small uncertainty measurements as to be deemed compliant for that particular geography. Essentially, we should have Location Accuracy goals and Measured Location goals.

The Commission has already established Location Accuracy goals for outdoor calls and has determined different goals for different deployed technologies. Currently, demonstrating proof of compliance has required drive testing in each Geographic Compliance Area. If we continue to take this single focus on Location Accuracy compliance, TCS believes that the wireless operators will ultimately be forced to provide indoor location testing within each Geographic Compliance Area in order to demonstrate compliance. This could be a very costly approach, deriving little benefit because testing is conducted from simulated 9-1-1 call locations, not from actual 9-1-1 call locations. And, because such testing will be periodic and probably infrequent, seasonal variation or changes to the radio frequency (RF) footprint or physical landscape could create location inaccuracies that would go undetected for long periods of time.

Instead, TCS recommends the following bifurcated approach:

1. Location Accuracy goals for specific location technologies would be determined **in a test bed** and validated within a specific set of morphologies against specific Commission goals; and
2. Measured Location goals for actual 9-1-1 calls within a specified time frame would be collected across each Geographic Compliance Area, and uncertainty values would be aggregated and compared with specified Commission goals.

To determine Location Accuracy of a given location technology, the Commission should establish a test bed with an appropriate number of morphologies for which Location Accuracy measurements could be gathered, ultimately to determine how well various location technologies work in those morphologies. Examples of recommended morphologies to test include: open-sky outdoor environment (such as on a highway), forested outdoor environment, urban canyon, business warehouse, single-family residential structures, multistory commercial structures (work or school campus, single office building with two or fewer stories), multistory (greater than two-story) high-rise commercial structures, multistory residential structures (hotel, apartment, or townhouse complex of two or fewer stories), and multistory (greater than three-story) high-rise residential structures. The Commission need not specify a different goal for each morphology – many of the morphologies mentioned above might best share the same accuracy goals.

The Commission could establish specific goals for each morphology with the intent that a Dispatchable Location can be determined within that morphology. Because of the unique nature of each morphology, it would be perfectly reasonable to have different requirements for different morphologies. As we mentioned earlier, it might be reasonable to assume that a 50m horizontal

uncertainty might be sufficient to establish a Dispatchable Location for an outdoor highway morphology, but a 20m horizontal uncertainty might be required to establish a Dispatchable Location for a position inside a two-story office building.

We encourage the Commission to incorporate the results from the anticipated CSRIC IV test bed into any proposed Location Accuracy metrics or timelines for implementation.

Six criteria would be established as Commission Location Accuracy goals for each morphology:

1. A horizontal Location Accuracy, expressed in meters;
2. A vertical Location Accuracy, expressed in meters;
3. A percentage of calls which must fall within a less strict accuracy criteria;
4. A percentage of calls which must fall within a more strict accuracy criteria;
5. A first time frame by which goals for the above-mentioned criteria must be met; and
6. A second time frame by which a final set of goals for the above-mentioned criteria must be met.

By way of example, the Commission could set the following goals for an indoor two-story office building:

- To be met by December 31, 2017: 50m Horizontal, 10m Vertical Accuracy for 67 percent of calls tested; and 100m Horizontal, 15m Vertical Accuracy for 80 percent of calls tested.
- To be met by December 31, 2020: 20m Horizontal, 3m Vertical Accuracy for 75 percent of calls tested; and 40m Horizontal, 5m Vertical Accuracy for 90 percent of calls tested.

We support the ATIS definitions for indoor accuracy testing approaches that support the CSRIC IV test bed effort and believe that the CSRIC III and CSRIC IV test beds can serve as models for the test beds recommended in this response.

Besides testing location technologies to determine if they meet the regulatory compliance criteria associated within each morphology, the test bed would also perform a very important function of determining the correlation between uncertainty values and accuracy results of the location technology tested in each morphology. It is expected that there would be a direct correlation between uncertainty and accuracy for each location technology. This correlation would serve as a calibration baseline for aggregated Measured Location calculations, which serves as TCS' recommendation for the second part of the regulatory compliance criteria.

Six criteria would be established as Commission Measured Location goals, to be applied against each Geographic Compliance Area:

1. A horizontal location uncertainty, expressed in meters;
2. A vertical location uncertainty, expressed in meters;
3. A percentage of calls which must fall within a less strict accuracy criteria;
4. A percentage of calls which must fall within a more strict accuracy criteria;
5. A first time frame by which goals for the above-mentioned criteria must be met; and
6. A second time frame by which a final set of goals for the above-mentioned criteria must be met.

By way of example, the Commission could set the following Measured Location goals:

- To be met by December 31, 2017: 50m horizontal, 10m vertical uncertainty for 67 percent of calls tested; and 100m horizontal, 15m vertical uncertainty for 80 percent of calls gathered.
- To be met by December 31, 2020: 40m horizontal, 5m vertical uncertainty for 75 percent of calls tested; and 80m horizontal, 10m vertical uncertainty for 90 percent of calls gathered.

As mentioned earlier, a single Confidence value should be established for all location technologies; it would be used to determine horizontal and vertical uncertainty values for each 9-1-1 call, as well as to determine ground truth deviation for Location Accuracy testing. In addition, a time frame for collecting data would need to be established that defines the "calls gathered" above. TCS recommends monthly data gathering, allowing trend analysis to be performed and seasonal variation adjustments to be calculated. Measured Locations that contain horizontal and vertical uncertainty values can be collected on every call and analyzed across specific Geographic Compliance Areas (currently, county-level). Such data collection and analysis could be conducted far more frequently than testing is conducted today. If the compiled Measured Location measurements for a given compliance geography meet the location uncertainty compliance goals, that Geographic Compliance Area would be deemed compliant. If the location uncertainty compliance goals are not met, then aggregated Measured Location information would need to be analyzed and recalibration (Location Accuracy) testing might be required to determine if the location technology has drifted or if calls placed from that particular geography are coming from morphologies that are inherently difficult for the specific location technologies deployed. When the location technology is first tested in a given Geographic

Compliance Area, a calibrated baseline can be established at specific ground truth test points within the area. Periodically, calibration (via ground truth tests) should be conducted in each Geographic Compliance Area and compared with these initial values in order to verify that the systems are functioning properly. TCS believes that this approach will greatly reduce the cost of testing, put more focus on geographic areas for which actual 9-1-1 calls are failing to meet compliance criteria, and identify the severity of the challenge in that particular area. TCS also believes that this will encourage greater trust between mandated operators and public safety officials, as well as apply greater focus on actual 9-1-1 calls and the appropriate use of particular location technologies.

It might be possible to establish a single and immediate goal for Measured Location measurements for current Geographic Compliance Areas. As call trends occur and more calls come from more challenging morphologies, analysis should be able to detect such trends and apply more appropriate location solutions to those particular geographies. This approach will move toward an environment in which location technologies will be better understood and trusted by call takers, geographic areas can have more regular and structured analysis, and problem areas can be more rapidly addressed. When problems are found, data entry errors can be corrected, location technology can be repaired, or new location technology can be applied or installed to address the changes in call mix (e.g., more calls coming from indoors).

In preparation for establishing the appropriate uncertainty values related to Measured Location goals that would serve as the basis for regulatory compliance, TCS believes that further analysis of existing empirical wireless 9-1-1 calling data should be undertaken. This would also allow the Commission to more comprehensively understand which environments are more prone to location information insufficient for the needs of Public Safety. We believe that existing

wireless 9-1-1 call records provide the most complete, up-to-date, and readily available sample set for emergency call data. We believe there is a need to evaluate geographies first on a macro scale (states, counties) in order to identify areas producing adequate results. We suggest reported horizontal uncertainty values as a strong initial indicator.

Initial impressions of this approach may appear to significantly diverge from current approaches. However, we believe that the industry broadly, and the CSRIC environments specifically, are already performing the tests and calculations we are recommending. CSRIC III performed specific Location Accuracy tests of particular location technologies in a broad set of identified indoor morphologies. And the industry has been collecting huge amounts of data for outdoor morphologies. To date, however, there has not been an aggressive effort to draw correlations between Location Accuracy and system-reported horizontal/vertical uncertainty. To allow a more efficient method of determining geographic area compliance that could ultimately incorporate indoor location scenarios, this correlation would need to be studied. TCS has conducted brief analyses of uncertainty data over the past seven years and believes that strong correlations exist, based upon the geospatial mapping of thousands of data points across specific geographic areas, typically at the county level. But a more rigorous effort should be undertaken to provide this correlation so that compliance can be determined from it and public safety officials can begin to have greater assurance that the wireless location information they currently receive is trustworthy.

E. Descriptions of Location Technology

The CMRS providers currently have sole responsibility for wireless Location Accuracy. To meet Location Accuracy requirements, they generally rely on location technology that uses control plane methods and avoid user plane methods. The primary reason is the impression that

user plane methods can be "spoofed" by criminals or others. It is important to point out that several of the methods being evaluated and listed in this Notice are currently user-plane based. The Span of Control (SoC) that a CMRS provider has with regard to ensuring Location Accuracy for emergency services is an important consideration. A CMRS has a high SoC for macro-cell techniques. A CMRS provider has limited SoC for noncarrier "learned" Wi-Fi access points scanned using drive or crowd-sourcing techniques. The CMRS provider can perform reasonability checks that assess whether a user plane-calculated position is within the radius of the serving cell site that is calculated through the control plane, but this does not imply that the location is sufficiently accurate. It will be prudent to have operators deploy location techniques where they, or an otherwise responsible entity, can establish a high level of assurance that the Measured Location is within the required metrics. Below is a table of most of the location techniques under consideration, highlighting SoC issues.

Location Method	**Span of Control (SoC)**	**Location Standards Basis**
A-GNSS	CMRS provider has direct SoC.	Control plane supported.
LTE OTDOA Macro Cells	CMRS provider has direct SoC.	Control plane supported.
LTE OTDOA Small Cells	CMRS provider may have limited direct control over the initial deployment and the type of small cells, some of which may be moved after initial deployment.	Control plane supported.
U-TDOA	CMRS provider has direct SoC.	Control plane supported.
RF Pattern Matching	CMRS provider has direct SoC.	Control plane supported.
Terrestrial Beacons	The CMRS provider would rely on a responsible entity to deploy and provision terrestrial beacons.	Control plane supported.
Wi-Fi based on Access Points (APs) provisioned at a known X,Y,Z	The CMRS provider may have limited or derived control over the initial deployment, and APs may be moved after initial deployment, requiring	Control plane is not available.

	techniques for detecting such events. Certain deployments can be considered as having a responsible entity that provisions the initial X,Y,Z and updates positions if an AP has been detected as having been moved.	
Wi-Fi based on APs X,Y,Z learned by drive testing or crowd sourcing	The CMRS provider has limited SoC. Determining how to generate a level of reliable location of such APs will require further study.	Control plane is not available.
Bluetooth beacons provisioned at a known X,Y,Z	The CMRS provider may have limited control over the initial deployment, and beacons may be moved after initial deployment, requiring techniques for detecting such events.	Control plane is not available.
Bluetooth beacons X,Y,Z learned by drive testing or crowd sourcing	The CMRS provider has limited SoC. Determining how to generate a level of reliable location of such beacons will require further study.	Control plane is not available.

Location calculation based on provisioned small cells for a given building will enable the floor to be determined with a high level of accuracy. Trilateration methods based on small cells will enable room/suite location. The civic location for a building/floor/suite can be provisioned as part of a small cell deployment. Typically for these deployments, map information is available, as maps are used to ensure coverage. The main issue for this method is the high level of initial and ongoing data provisioning required. This is feasible for large buildings in cities, but may not be applicable for rural areas. The use of a specific building's RF infrastructure, be it cellular or Wi-Fi based, will need to be analyzed. The provisioning and accuracy requirement for a building to provide commercial service could vary more widely than if used for 9-1-1 service.

A caller's specific address, or civic location, can be delivered in some cases if supplied to an access network through a pre-call provisioning process or derived – though with varying

degrees of trustworthiness – through mapping techniques such as reverse geocoding. We believe that location information should be conveyed in its raw form, allowing Public Safety to perform any transformation techniques on the delivered location information. Determining a caller's floor level has similar challenges. In some scenarios, attributing a specific floor level (textual description) to measurement systems may be possible if coordinated with radio antenna placement and controlled signal propagation. When associations of floor level information are included with measured altitude, it is our recommendation that both be supplied to the PSAP. Similar requirements should apply to suite/room number information. For these reasons, TCS recommends that Measured Location be delivered to Public Safety on each 9-1-1 call.

Locating a mobile device that is indoors is feasible using current location technologies. However, whether the level of yield and accuracy needed to cover an entire PSAP/county level, as is being proposed by the Commission, is technically and economically feasible remains an open question.

Any Commission mandates should be based on location methods where the CMRS provider's SoC is established to a defined level of acceptability or the indirect SoC is established by a responsible entity. Only control plane location methods currently meet this criteria, so other promising location techniques will require further assessment to establish a level of acceptability. In-building coverage of A-GNSS is described in the Notice and is not addressed in our comments. To improve indoor positioning with a high level of CMRS provider SoC, methods should be based on Long Term Evolution (LTE) Observed Time Difference of Arrival (OTDOA) minimally, and should include solutions that improve LTE OTDOA such as small cells and terrestrial beacons. Augmenting baseline location technology to include both small cells and

terrestrial beacons, for example, will improve indoor Location Accuracy, but will have to be balanced by the time it will take to deploy these solutions nationwide.

We point out that there is no single identified technology which by itself can meet the proposed mandate in all network topographical areas, or morphologies. Furthermore, CSRIC testing has not identified a technology in each of the morphologies that will meet the accuracy proposed. Once a set of technologies can be demonstrated at CSRIC, showing that 3 meters accuracy can be achieved across all the morphological test beds and that those technologies can realistically be applied across a CMRS provider's coverage footprint, then estimates of the feasibility for a CMRS provider to deploy in the three-year time period could be determined.

Variations in the capabilities of the handsets, availability and density of beacon sources, terrain morphologies, and commercial/business reasons imply that operators will likely have to deploy a mix of location technologies. The solution set will likely include Assisted-GNSS (A-GPS, A-GLONASS), A-GNSS+OTDOA, terrestrial beacon-based systems, small cells, RF fingerprinting, location measurement unit (LMU)-based technologies, Wi-Fi, and hybrids of the various technologies. For CMRS providers and location technology vendors, the challenge is to engineer the overall system to meet a target accuracy and yield over the measurement area. We would encourage that any calls that last 10 seconds or less be excluded from the yield percentage compliance.

When a mobile originates an emergency call, the location server in the CMRS network that is tasked with locating that mobile does not have a priori knowledge of the location morphology of the environment of the mobile other than the serving cell tower to which it is connected. Because it has no knowledge of whether a mobile is indoors or outdoors, the location

server cannot bias its location technology selection to pick an "indoor location technology" in some cases and an "outdoor location technology" in others. There are some exceptions to this general rule – for instance, when the cell of origin is a small cell that the operator knows is deployed indoors.

While on the subject of small cells, it is worthy to note that small cells differ in important ways from Distributed Antenna Systems (DAS). Although both small cells and DAS may be used to provide coverage in areas where the macro cellular network is unable to do so, the key difference between the two is that small cells have unique Cell Global Identifiers (CGIs) which are visible to the core switching network. DAS/repeaters, on the other hand, are entirely subsumed by the Radio Access Network (RAN) and share their identity with the macro network under whose overall umbrella coverage area they are deployed. From the user equipment (UE) and core network's perspective, the existence of DAS/repeaters is transparent.

This has critical implications for location. When a UE connects from a small cell with limited coverage area (e.g., a femtocell), the unique identify of the serving small cell means that the location of the mobile can be tied to the known location of the small cell. Small cells, like any other cell in the network, may be provisioned as part of the operator's base station almanac. This is not possible in the case of DAS networks.

We note that DAS and repeaters have the potential to disrupt the accuracy of location methods. As noted in our earlier response, DAS and repeaters are deployed in a manner that is transparent to the core network. Their location and indeed their very presence in the chain of communication between the network and the handset is unknown from the core network's point of view. The presence of DAS and repeaters in the chain of communication affects location

technologies in two ways: disruption of timing-based location techniques and lowering of the uplink transmit power of mobiles, which can affect RF fingerprinting and uplink measurement-based location methods.

On the other hand, small cells are managed as extensions, and perhaps smaller cousins, to the macro technologies that support E9-1-1 services today. However, even small cells introduce issues because of the way operators must manage the location of small cells and keep their base station almanac up to date. Some small cells, such as femtocells, may be deployed by a subscriber and connected to the operator's network via the public internet. Because these femtocells are not nominally owned by the operator, their location may change (e.g., a subscriber may change residences). A process is needed by which the operator's small cell gateway is always kept up to date with the current location of the small cell so that the operator may reflect this in its base station almanac. Some small cell vendors have implemented GPS chips in such small cells to automate this process. Typically, a small cell does not become active until it has been able to determine its location via autonomous GPS; the location is then reported to the small cell gateway as the current location of the small cell. Operators may then reflect this update in their base station almanac.

The availability of these various methods for location determination will naturally create additional complexities in the location servers that integrate these various technologies. Generally, the location server makes a location technology decision based on requested quality of service (Geodetic Location and time to fix), handset capability (e.g., whether the target mobile is GPS or GLONASS capable), cell of origin, availability of beacon sources in that particular cell, and operator configurations. For instance, a mobile may be calling from a cell where it is known that terrestrial beacon sources are available in sufficient densities; however, the mobile

itself may be a legacy mobile that may be incapable of using these signal sources, so terrestrial beacon-based location may not be feasible in that particular instance. In another example, the coverage area of the serving cell could be one where the density of network base stations may be more plentiful than a third-party terrestrial beacon's source, making a combination of A-GNSS and OTDOA the preferable technology for that particular cell. The result of the decision-making process could be that the location server decides to execute more than one location technology simultaneously (e.g., A-GPS and A-GLONASS may be attempted and the results hybridized). When more than one technology is successful, the location with the smallest uncertainty at a normalized Confidence level is returned as the location.

In order to have a robust solution for improved indoor location, the E9-1-1 system will need to move toward a hybrid approach that uses cellular-controlled access points such as macro and small cells, as well as noncellular-controlled access points such as Wi-Fi. The location of non-CRMS access points such as Wi-Fi are readily available today from databases that are continuously collected by agents on cellular phones that associate the location of the phone with a Wi-Fi media access control (MAC) address. TCS currently uses the location of more than 38 million Wi-Fi access points to assist in the location of users for commercial location-based services (LBS) applications, along with Cell ID and assisted GNSS. Enterprise Wi-Fi deployments can be registered in a database as to specific floor location and possibly room location to provide even more granular accuracy. TCS believes that the inclusion of "trusted" Wi-Fi and other specialized location beacon access points should be part of the E9-1-1 system going forward.

In cases where Wi-Fi networks or other beacon sources are deployed and managed by institutions and enterprises, an operator's location server in the cellular network could potentially

leverage the capabilities of the enterprise system to provide a more accurate location. For example, when an emergency call originates on the cellular network, the location server in the cellular operator's network could query the handset for a list of Wi-Fi access points or beacons audible to the handset in its current neighborhood. The location server could then map these access points to a known institutional or enterprise network and query that network for a more precise location.

Several Wi-Fi network providers whose systems are deployed primarily indoors (e.g., a large campus environment) do offer custom (non-standards-based) application program interfaces (APIs) through which external LBS may query for the location of a specific Wi-Fi radio that may be in the coverage area of that particular network. This capability can be leveraged to support the location of a mobile that has made an emergency call from the vicinity of such a Wi-Fi network. Some additional standards capabilities may need to be developed in order for this architecture to work end-to-end.

The CSRIC III Indoor Location Test Bed (WG3) activity of 2012 provides a good benchmark of how individual location technologies perform as stand-alone entities. While the results offer encouragement, it remains to be seen how these technologies could be woven into an overall multi-technology location system that can meet the mandate in both indoor and outdoor morphologies, over a PSAP/county area with diverse terrain, and for a large subscriber base with varying handset capabilities. The most promising technology demonstrated in the test bed (NextNav's Metropolitan Beacon System) is not yet commercially available for evaluation and requires integration into the chipset. How widely available NextNav's terrestrial beacons will be in areas across the United States remains to be seen. Furthermore, altitude information requires handsets to be equipped with calibrated barometric pressure sensors, which may not be

available in all handsets. Even when barometric pressure measurements are available, the location server's ability to retrieve them is limited by current protocol definitions. This implies that location may have to be computed on the handset in the short term until protocol enhancements are in place to support computation on the server. This makes A-GNSS the only viable short-term technology to compute altitude.

A-GNSS methods do have the capability to produce reliable altitude information. Where A-GNSS is more likely to succeed – in suburban and rural areas, for example – altitude information may already be possible.

During an emergency call, if a handset indicates that it is GNSS-capable, the location servers attempt to provide an A-GNSS-based location. If there is a failure, the location server may fall back to alternate solutions. Because this capability is already in place, we do not think that a strengthening of the E9-1-1 Phase II mandate is needed at this time. Tightening the mandate will not result in any material difference in the way the network behaves with respect to attempting A-GNSS-based location.

Time to First Fix (TTFF) is an issue specifically with GNSS-based techniques. The dominant component of the latency in this technique has to do with a mobile's acquisition of satellite signals. Network location servers are able to assist the mobile with satellite assistance information which narrows the signal search window in the time and frequency domain. This speeds up signal acquisition significantly, although it may still take a mobile 15 to 25 seconds at the high end in order to return a location or pseudo-range measurements. The average TTFF for an A-GPS location solution is well within the 30-second window, typically 12 to 15 seconds.

TTFF is a significant issue for GNSS-based location because satellite signal acquisition takes time and is the dominant component of latency. The higher bandwidth capability of an LTE network may lower the time that it takes for the network to push GNSS assistance data to the handset. However, the overall effect on TTFF is likely to be minimal because satellite acquisition times are independent of the cellular network bandwidth.

For other technologies, TTFF is not a significant issue. We note that the term "small cell" is a generic term which may include cells with limited coverage and capacity limits. There are many types of small cells, ranging from femtocell (very limited indoor coverage area, usually residential) to metro cell (big office and neighborhood). When a mobile is connected from a small cell with a small coverage area (e.g., a femtocell), it is possible that high accuracy location can be fulfilled via a database dip into the base station almanac, returning the position of the base station. In these instances, high accuracy location can be provided with very low latency (subseconds). With metro cells, Enhanced Cell ID or trilateration (e.g., OTDOA) may be used to provide finer location, usually with a medium level of latency (a few seconds).

Many of the location technologies described are only used in commercial settings. TCS has long held the philosophy that emergency services should utilize commercial solutions as much as possible. Generally, the commercial marketplace has found strong interest in location-based solutions and has driven the innovation of location technologies. Because of the life-and-death nature of emergency services, the need for greater reliability and trustworthiness is expected and can typically be provided through georedundant architectures and greater levels of security testing. This will generally reduce the costs of emergency systems and provide the added benefit of allowing emergency location technologies to follow similar upgrade paths as commercial technologies will enjoy, keeping emergency solutions from obsolescence.

In conclusion, further studies would be required before we can assert with a high level of assurance that the proposed mandate is achievable technically and economically.

F. Indoor vs. Outdoor Call Determination

As mentioned earlier, a cellular network generally cannot identify a call as an indoor location call. One possible exception would occur in cases where the serving cell is known to be deployed in an indoor location and has an area of coverage that does not extend beyond the indoor area.

TCS believes no exclusions can be made for indoor location requirements, as all 9-1-1 calls should be treated the same way. TCS processes more than 200,000 wireless E9-1-1 calls per day, and we have no certain way of knowing whether a call is from an indoor or outdoor location. While test beds can be set up to test the accuracy of indoor calls with specific technologies, the real world will have an unknown percentage of indoor and outdoor calls, with each call having its own horizontal and vertical uncertainty. The industry goal should be to convey the horizontal and vertical uncertainty with every E9-1-1 call and to steadily decrease these uncertainty levels going forward.

In most cases, the network can only determine a Geodetic Location with an associated area of uncertainty. This fundamental capability is inherent to wireless networks and is unlikely to change in the near future. Whether this Geodetic Location is indoors or outdoors generally only can be determined by external means, such as comparing the determined location to a GIS or other equivalent technique.

Nonetheless, it is reasonable that for locations reported that use certain types of techniques or that include a certain combination of location determination using a variety of

location technologies, that some broad assumptions about the caller's actual location (e.g., indoor vs. outdoor) can be made. Therefore, we believe that extending existing standards to support multiple locations with detailed additional data will make it possible for NG9-1-1 PSAPs to benefit from having visibility into this supportive location detail.

Additional technical information provided to the PSAP is not always perceived as a good thing, as PSAP telecommunicators already have their hands full while handling critical emergency communications. However, we believe that indicative technical information such as location technology type used as well as Confidence and uncertainty relating to Measured Locations is important data. Even if some PSAPs don't see an immediate use for this technical data, other PSAPs already do. Further, Confidence and uncertainty values given for an A-GPS estimate of a mobile voice call may present an important distinction from similar Confidence and uncertainty values provided for a small cell deployment, which may give the telecommunicator enough information to decide to request updated information in order to more accurately locate the emergency caller. We recommend that all available information be delivered toward the PSAP, and we encourage PSAPs to upgrade their hardware and software to NG9-1-1 in order to present the data.

We encourage the Commission to provide incentives for PSAPs to move toward NG9-1-1, which supports conveyance and presentation of z-axis/altitude information. CMRS provider 9-1-1 systems can convey z-axis information to NG9-1-1 Legacy Network Gateways (LNGs) for conveyance through Emergency Services IP networks (ESInets) to NG9-1-1 call-handling systems. In addition, we suggest that the z-axis information be applied to Short Message Service (SMS) text-to-911 standards. The SMS text-to-911 platforms can be used as a real-world proof-of-concept without impacting wireless voice E9-1-1 systems. This approach

ensures that CMRS provider modifications to propagate z-axis information are used as soon as possible. There are well over 6,000 PSAPs in the U.S. and it will take time to update them, even the newer NG9-1-1 deployments, to present and then fully utilize z-axis/altitude information.

Conversely, we believe that accuracy requirements do not negatively affect current NG9-1-1 standards. From a location perspective, the key enhancement that NG9-1-1 offers is the ability to pass Composite Location, including both the civic and Geodetic Location, either by value PIDF-LO for static/nomadic service providers or by reference, using a location URI for static/nomadic/mobile service providers, within the call setup message (e.g., SIP INVITE).

As we consider the vast amounts of data that could potentially be passed to the PSAP, we support sending the standardized 3-D shape for each Measured Location to the PSAP for display. Though this is a future-leaning concept, we believe it to be one that could be successfully utilized given proper explanation and qualifications to Public Safety. We discourage the practice of mandatorily "dumbing down" data in order to achieve a normalized view. With inclusion of the z-axis component to location, uncertainty values for x/y-axis and z-axis most likely would be presented separately, given the proposed target accuracy requirement metrics are done this way.

Beyond the traditional CoS text descriptor that is currently used to map from a several-location technology type to one of a few text values (e.g., WPH1, WPH2), it is feasible to provide to the PSAP the actual location technology values used to clarify the type of location determined. In 3GPP networks, this protocol facilitates the ability to carry the positioning technology information from the serving location engine (where the location is computed) to the operator's location gateway. Further, this positioning technology information is conveyed to the existing PSAP/ Automatic Location Identification (ALI) system. Some data extensions may be

needed to the J-STD-036 standard for the E2/ESP interface to be able to pass on this information to ALI systems. In addition, ALI-to-PSAP interfaces (e.g., extended ALI format) may need some text filter modifications, which is typically a simple change but often is custom/unique for each PSAP or group of PSAPs in a jurisdictional area.

We note several additional challenges to this proposal. Current protocols used for determining location for emergency calls (defined by 3GPP) do not yet support the acquisition of Wi-Fi access points detectable by a handset. In addition, conveyance of location is limited. For example, the E2/ESP interface between the operator's wireless network and the PSAP/ALI system (E2) currently does not support the conveyance of more than one Geodetic Location to the PSAP – highlighting standards development changes that would be needed.

Because a location server in a wireless network is rarely aware that a mobile is indoors, the location determination process will typically be the same for an indoor or outdoor call location. For example, for A-GNSS-based location the Measured Location is determined from the number of satellites audible, the dilution of precision of these satellites, the quality of the measurement made by the handset, etc. This is true regardless of whether the mobile's true location is indoors or outdoors. Hence, we don't anticipate the uncertainty value calculation process to be different for indoor vs. outdoor calls.

G. Roaming Issues

For circuit-switched wireless emergency calls, handling location for roaming customers has not been an issue. Typically, a subscriber connects to the radio access network in the visited carrier's network. The emergency call origination is handled by the serving Mobile Switching Center (MSC) in the visited network and the call is routed to a PSAP based on cell of origin.

The location servers deployed in the visited network are tasked with determining the initial and updated location for the call. This model has held not only for roamers, but also for SIMless/unregistered callers.

As networks move to Voice over Long Term Evolution (VoLTE), we anticipate that all emergency calls (routing and location) will either be handled by the visited network or through a location roaming scenario.

In some cases, such as interim SMS text-to-911 roaming, location roaming will be required to provide coarse and enhanced location.

H. Privacy

Location used for E9-1-1 should not require a user to "opt-in," regardless of the nature of the location server utilized. If a CMRS provider elects to augment emergency location services with commercial LBS, the commercial LBS APIs must be able to indicate that the use of the query is for emergency purposes. Popular commercial location query APIs, such as the Open Mobile Alliance (OMA) Mobile Location Protocol (MLP), often support specific query APIs or indicators in a query to designate the location request is for emergency purposes. If commercial LBS systems that typically gather and share location information that requires user "opt-in" per FCC privacy requirements are used, then we believe that these same commercial LBS systems should exclude data that was attained for emergency purposes.

This does not imply that CMRS providers and their agents cannot collect E9-1-1 call or location data for reporting, analysis, and improvement of location and emergency services in general, but rather that data should not be intermixed with the gathered commercial data sets that are used for commercial purposes.

When utilizing commercial LBS platforms external to the CMRS provider, care must be taken to ensure the trustworthiness of the reported location. In commercial LBS platforms and device-based operating system API calls, the location request is generally performed by the user or by entities the user has granted permission to retrieve his location. Spoofed location is rarely viewed as a large concern because the user may be intentionally spoofing or blurring his location (perhaps for legitimate purposes). Generally, commercial LBS systems are concerned more about unauthorized snooping and access to location.

For emergency services, the situation is quite different. Not only is there concern about unauthorized use and access of emergency location, but the consumers of the location (emergency routing, PSAP operators, call dispatchers, and first responders) need to know that the location is trustworthy. As such, for location systems outside a CMRS provider's control or those which can be directly influenced by the user/owner of the device, care must be taken to ensure that the location has not been spoofed and provided location is coincident with location estimates derived from CMRS-controlled infrastructure (e.g., Cell ID based, enhanced Cell ID, TDOA/OTDOA/UTDOA/AFLT). If the only location estimate that is available is from services outside CMRS provider's control, it is recommended that this situation be conveyed to the emergency location consumers in case special treatment is necessary.

It is for this reason that TCS typically separates location solutions into "network-centric" and "device-based" solutions. Network-centric location solutions typically use control plane architectures and are under the SoC of the CMRS provider. This makes the location information inherently more trustworthy.

Privacy issues also create a unique problem for 9-1-1 scenarios in which there is a desire to use commercial LBS solutions. In emergency-based location systems, any privacy settings are overridden and location technology (such as GPS) in the handset can be turned on, even if the user has disabled location techniques for commercial applications. Ultimately, emergency services tacitly assume that the user has "opted in" when dialing 9-1-1 and wants the emergency response team to locate the user.

At the current time, this particular override challenge has not been solved for emergency services that use commercial LBS infrastructure. For example, text-to-911 currently uses commercial LBS infrastructure to deliver the texter's location, and the location information cannot be delivered if the user has enabled certain privacy settings or turned off the location capabilities of the device. In this scenario, in order to provide a Dispatchable Location to the PSAP, there is a need to override the user's privacy settings. Given that this is currently being done for emergency voice calls, TCS believes it should be possible to override commercial privacy settings for 9-1-1 use. However, it will likely require cooperation from handset and device manufacturers. In this commercial LBS scenario, it can be reasonably argued that requesting a 9-1-1 interface for the purpose of reporting an emergency also creates a tacit agreement that the user has "opted in" to revealing his location for the purpose of allowing an emergency response. The user, however, has a reasonable expectation that neither his location information nor any details of the nature of the call (e.g., the type of emergency, the extent of injuries, etc.) would be divulged to third parties other than those being asked to render assistance.

I. Test Bed Methodologies

As described earlier, TCS believes that Location Accuracy should be thoroughly tested in a test bed environment with multiple morphologies. The rules developed by the Commission

should provide a set of Measured Locations, including Geodetic Location and uncertainty calculations at a specified and uniform Confidence level, and compare them to known position testing points. This will ensure that all reported components of a Measured Location are within the tolerances of the Location Accuracy requirements for E9-1-1. The test bed administrator can specify the administrative and operational requirements for CMRS providers and location providers to test their overall solution. We believe that the test bed administrator should work cooperatively with relevant standards organizations (e.g., ATIS) to develop an acceptable approach to testing and reporting.

The following test bed administrative issues should be considered:

1. An evaluation of the test bed should be allocated to a commercial vendor, standards entity, or government entity. The players in this ecosystem are currently participating in labs defined by standards organizations and government labs (e.g., FirstNet). Minimizing cost should be a primary goal.
2. Any award to a commercial vendor should be re-bid on a periodic basis.

The Notice lists four morphologies: dense urban, urban, suburban, and rural. Earlier, we identified a broader set of possible morphologies because of potentially large variations between various indoor call scenarios. Clearly, this will require further study, and we support the use of CSRIC IV to identify the relevant morphologies for actual requirement determination. TCS also believes that the compliance approach we have described allows for the addition of new morphologies that might prove problematic in particular Geographic Compliance Areas and which impact a CMRS provider's ability to meet uncertainty compliance within that area. However, multiple morphologies raise other issues that need to be considered, including:

- A regional CMRS provider may only have a subset of the morphologies in its environment, so CMRS testing guidance should only have to test the appropriate subsets.
- Testing multiple morphologies with multiple location techniques may present a high cost burden, especially for smaller CMRS providers.
- The morphologies may be transitive. If a technology or CMRS provider passes testing in the more difficult dense urban morphology, there may be a valid assumption that the solution will work in many other morphologies.
- Multistory buildings are of particular concern. These buildings may appear in any of the four morphologies and explain why we suggested a larger number of morphologies than described in the Notice.
- It must be decided if the test bed exists for proving location techniques by location vendors or for CMRS providers to prove compliance. A location technique may pass the compliance tests. If one or more CMRS providers incorporate that particular location technique, will it imply the CMRS provider is compliant?

TCS believes that the recommended approach has the potential benefit of reducing cost to CMRS providers, location vendors, and location service providers. Location techniques that are successful in one or more of the morphologies could be adopted by one or more CMRS providers without the need to retest. If a location vendor or a CMRS provider can prove conformance in the harshest environments, then the easier environments could be deemed conformant without the need to retest.

Several promising indoor location techniques – such as barometric pressure, small cells, and A-GNSS techniques with highly sensitive antennas deployed stand-alone or within small cells – are highly dependent on the environment in which they are deployed. Barometric

pressure in one five-story building may vary dramatically from a five-story building in another area. Observed pressure readings can be affected by building pressure gradients, especially in stairwells and elevators. The test bed and compliance measurements will need to be flexible to accommodate location techniques that are affected by their environment.

J. Location Analytics

We encourage the Commission to first promote the development and implementation of periodic reporting of Measured Location statistics through the use of more reporting analytics tools. This will reduce the reporting that relies on more costly drive testing, and such tools can be automated to produce results more frequently.

Based on actual 9-1-1 call statistics, TCS does not believe that there has been a market failure in the provision of E9-1-1 information for wireless calls originating indoors. On the contrary, TCS believes the wireless carriers, the public safety jurisdictions, and the vendors serving both entities have all made significant progress based on market motivation to keep pace with the increases in wireless 9-1-1 calling from all locations and in all environments, indoors and outdoors. Call data does show that calling patterns have "spread out." Whereas in the past calls were very frequently placed from roadways (and therefore outdoor environments), many more calls today are found to be off the roadways, and many of these are likely indoors. This has increased horizontal uncertainty values seen over time, but the average horizontal uncertainties recorded still seem to indicate that current Location Accuracy guidelines are generally being achieved. However, a more rigorous review of the available data is warranted and might give more specific insights into trends. There will always be examples of individual failures of the location technology to meet the needs of specific calls. It is important to build our

assessments on the broadest possible analysis so that specific problems are not exaggerated, but to also ensure that correctable problems receive proper attention.

TCS supports carrying forward the restrictions on publicizing the raw data, as this has commercial and competitive implications for vendors of location technologies as well as CMRS providers. The raw data gives insight into the performance profile of a vendor's location system in various terrain morphologies and should therefore be considered proprietary information.

CONCLUSION

In summary, TCS believes that there is compelling evidence that Indoor Location Accuracy goals need to be created, but that applying such goals to individual Geographic Compliance Areas will be very difficult. It may not even be possible to distinguish between indoor and outdoor emergency calls. For this reason, TCS believes that a different approach would be appropriate, one which establishes Location Accuracy goals for various outdoor and indoor call morphologies, but which determines compliance via Measured Locations of actual emergency calls in each Geographic Compliance Area. This will require less testing, will be based upon data from actual emergency calls, will identify the needs of each Geographic Compliance Area, and will give greater focus to the uncertainty information being provided on each call so that a PSAP telecommunicator can determine whether a Dispatchable Location has been obtained. This is not a radical departure from the Commission's current mandates and activities. Because of the existing CSRIC III and anticipated CSRIC IV test beds, the Commission has already established environments in which location accuracy for specific morphologies can be defined, and location technologies can be tested in those morphologies. The existing outdoor location accuracy requirements could serve as the foundational basis for a single Measured Location goal, and 3-D data, including z-axis measured position and vertical

uncertainty, could now be collected across each Geographic Compliance Area to determine the level of challenge to those specific areas. Though TCS does not believe that enough information has yet been gathered to establish the ultimate Location Accuracy or Measured Location goals, the foundations have been laid and information can be gathered. Whether voluntary compliance is sufficient or further mandated compliance is ultimately required can be determined over a time frame of further analysis and testing.

Respectfully submitted,

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