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From: <rjohnson@swri.org>
To: K5DOM.K5PO1(RECKERT)
Date: Tue, Oct 26, 1999 11:03 AM
Subject: ET Docket No. 99-300

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Bob,

Attached is our response to Public Notice DA 99-2130 in WordPerfect format. We have included a color figure, and if that proves to be a problem let me know.

If we can provide any additional information, please advise.

Regards,

Dr. Richard (Dick) Johnson
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SIGNAL EXPLOITATION AND GEOLOCATION DIVISION

October 25, 1999
Reference: ET Docket No. 99-300

Federal Communication Commission
445 Twelfth St., S.W.
Washington, DC 20554

Ladies and Gentlemen:

Reference your Public Notice DA99-2130 soliciting comment on methods for verifying compliance with E911 accuracy standards. Southwest Research Institute (SwRI) has been involved in the research and development of radiolocation systems for various military and law enforcement agencies for over 40 years. An important part of our work has been in the test and evaluation of system performance to verify compliance in meeting operational requirements. Based on our extensive expertise and experience, we are proposing procedures and offering comment on compliance verification for E911 Automatic Location Identification (ALI) system performance.

SwRI is proposing that the compliance verification process be composed of a five step process: (1) definition of a 2-D grid coordinate system over the wireless service area and assignment of circular error probabilities (CEP) at each intersecting grid point, (2) preliminary experimental validation of the CEP percentages and adjustment of measurement error variances in the location prediction model so that the theoretical and experimental data agree, (3) identification of selected intersecting grid points for experimental compliance testing using random sampling over the entire wireless service area, (4) perform repeated trial experiments at each selected intersecting grid point and record data, and (5) analyze data for accuracy compliance and evaluate ALI system response time.

A fundamental concept in our proposed approach is the characterization of either network or handset-based ALI system performance through the use of CEP contours for dual-ring error bounds. Figure 1 illustrates the coverage of a wireless service area employing a 2-D grid system. At each intersecting grid point, CEP contours for dual-ring error bounds are defined. Theoretical predictions using the CEP statistical model based on expected measurement errors provide us with the percentage of 9-1-1 calls that will be contained within a prescribed error bound. For example, an error bound of 100 meters should contain 67% or more of all fix estimates (represented by the plus marks). Thus, the theoretical CEP prediction results in an percentage value for each grid intersection. The theoretical percentage is experimentally validated by locating a mobile transmitter at the grid intersection and placing repeated 9-1-1 calls. A scatter plot of the results of this experiment would resemble the illustration shown in Figure 1. A circle of 100 meters is drawn about

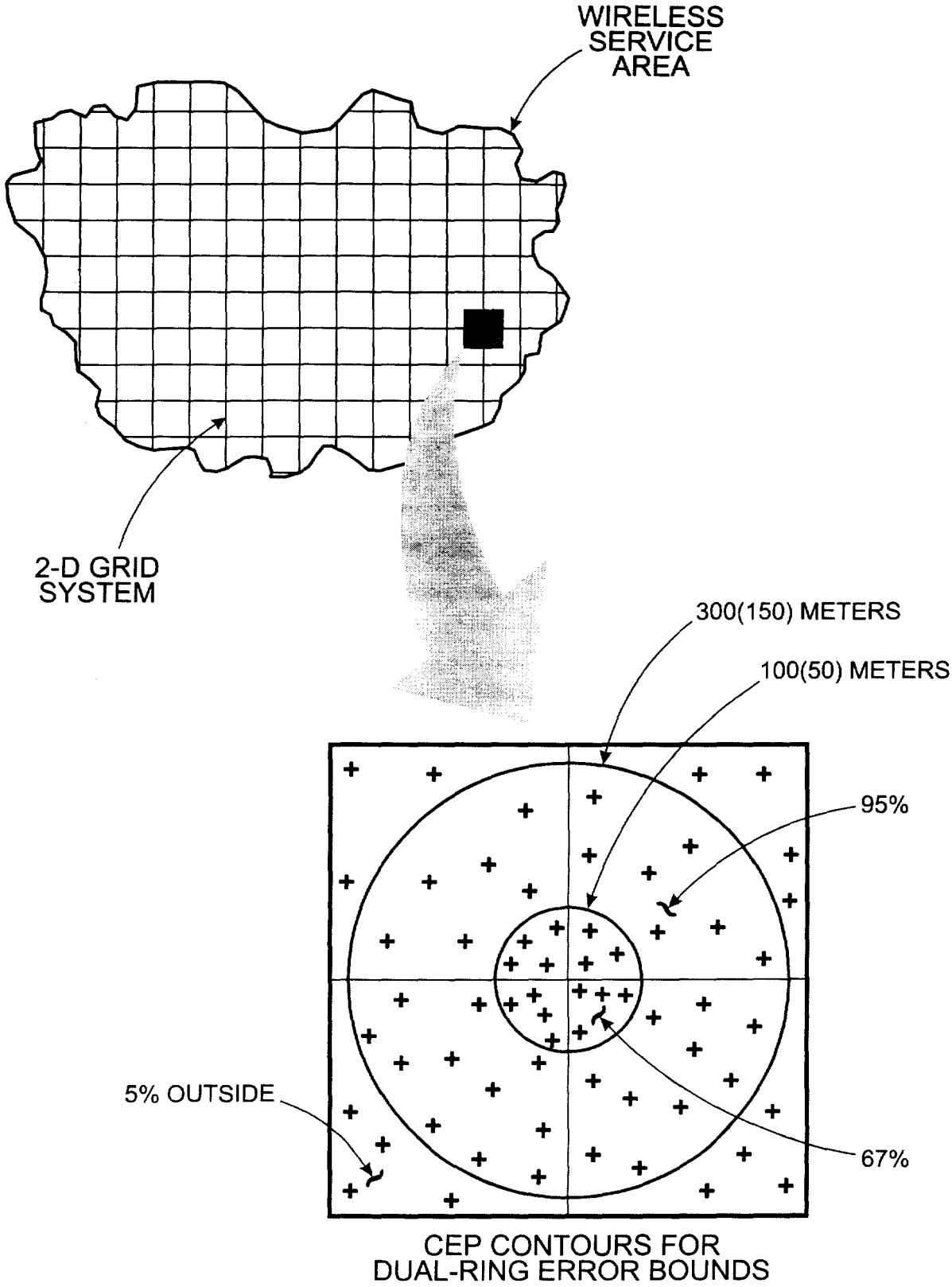

Figure 1. CEP Theoretical and Experimental Circular Error Bounds

the grid intersection, and this circle should contain 67% or more of all location estimates. Also the experimental percentage should closely agree with the theoretically predicted percentage. It is anticipated that the accuracy performance at each and every grid intersection will not meet the FCC standard. Some points may be less than 67% and some points may be significantly greater than 67%; however, the objective of the compliance verification process is to determine whether or not the average percentage over all grid intersections is 67%, or greater.

In the first step, the definition of a grid system over the wireless service area should be dependent on the average or nominal spacing between cell towers and the rate of change of the CEP contours. A suggested value for grid spacing would be of the order of 1/10 cell site separation, but no closer than 600 or 300 meters depending upon network or handset based ALI systems. At each intersecting grid point CEP percentages are computed for error bounds of 100 and 300 (or 50 and 150) meters. At each grid point, the CEP is used to predict the percentage of calls from that location which would be contained within an error bound of 100 meters. A typical CEP contour plot for 100 meters error bound is shown in Figure 2. The service region is the metropolitan San Antonio area. The red areas are regions of compliance where 75-100% of calls are within 100 meters error bound. The yellow areas are marginal in performance. Ideally, at each intersecting grid point the CEP would predict that 67% or more calls are bounded by 100 meters error and 95% or more are bounded by 300 meters. However, this will not be the case and the objective of the compliance verification process is to determine whether or not the averaged percentage over all intersecting grid points in the wireless service region satisfies the accuracy requirement. The CEP is crucially important for the experimental design aspect of the compliance verification process. For example, the CEP percentages are used to predict the number of samples required at each intersecting grid point, and to predict the number of points to be sampled over the entire wireless service area.

The second step of the compliance verification process involves a preliminary drive test to validate the CEP percentages at representative intersecting grid points. The CEP model is based on expected measurement error variances, and the preliminary drive test will provide experimental data so that the model can be adjusted as necessary. The CEP percentage estimates are based on two prediction software codes which may be separate or combined. The first is a propagation prediction code that estimates radio horizon, multipath delay spread, angular spread, GPS timing errors, etc. These parameters are used to define the error variances for location accuracy estimates. The second software code required is the location prediction code that estimates location error based on the expected measurement error variances. The output is percentage of calls that will be contained within a prescribed error bound (i.e. 100 meters) from a specified intersecting grid point. Empirically, this is the equivalent of a repeated trials experiment where a number of 9-1-1 calls are placed from a fixed location. If the resulting location estimates are displayed on a scatter plot and a circle of 100 meters is drawn about the centroid, then the percentage of calls contained in the circle should be equal to the estimated CEP percentage. SwRI proposes that the software propagation and

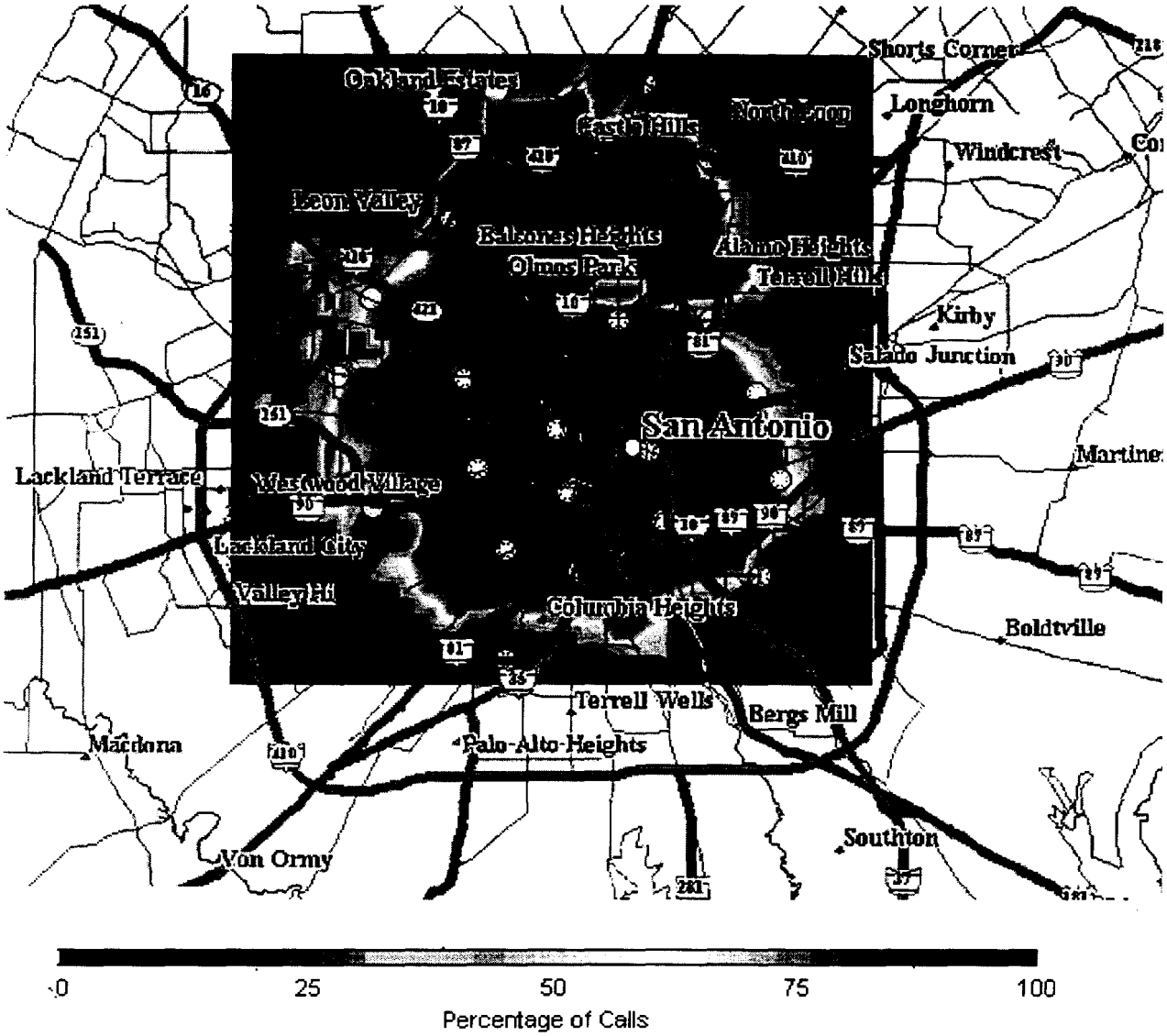

Figure 2. Percentage of Calls Having an Error Bound of 100 Meters for a TDOA Network-Based System in Metropolitan San Antonio, Texas

location prediction codes not be "standardized," but selected by the various parties involved in the verification process. Part of the compliance verification process involves the experimental validation of the CEP location accuracy predictions, so that there is a system of checks and balances. Stated another way, it is not a matter of concern about how the theoretical location performance was predicted, but more a matter of agreement with the measured data.

The third step in the process is to rank order the intersecting grid points by CEP percentages. We could establish the ordering based on either the 100 meter or 300 meter error bounds. We propose that the rank ordering be partitioned so that the intersecting grid points are divided into quartiles. That is, the first quartile will be 1/4 of the total intersecting grid points and may have a maximum CEP percentage of 30%. The second quartile will be 1/4 of the total intersecting grid points whose CEP percentages lie between 30-60%. The third quartile may have CEP percentages between 60-90% and the fourth quartile may have CEP percentages between 90-100%. The objective is to randomly select a collection of intersecting grid points for experimental compliance verification. The experimental procedure will involve placing 9-1-1 calls from the intersecting point and determining the percentage of calls that produce location estimates within the error bound (i.e. 100, 300 meters). The percentages over the collection of all intersecting points will be averaged to determine whether or not 67% (or 95%) or more meet the accuracy requirement. A critical issue in the selection of points is the number required to achieve a prescribed level of confidence. Since we are estimating the mean or averaged percentage of all sampled points, the Central Limit Theorem can be applied to construct a confidence interval about the estimated mean. Using a normal distribution, we can estimate the number of points required so that we are 95% confident that the sample mean CEP percentage is within 1% of the "true" mean percentage. If the number is N, say, then we would select 1/4 N points from the first quartile, 1/4 N from the second, and so on. This random sampling scheme gives us greater assurance that the intersecting grid points are more nearly representative of overall location performance.

The fourth step in the compliance verification process is to place repeated calls from the randomly selected intersecting grid points and to generate a collection of location estimates for each point. A critical issue is the number of repeated calls that we must make to ensure that the estimated percentage is accurate. At each point we have a theoretically predicted percentage. We use a binomial distribution to derive the number of samples required to show that the population proportion is larger than, or equal to, the predicted percentage. If the predicted percentage is 70%, then we can choose the sample size so that we are 95% confident that *at least* 70% of the location estimates are contained within the prescribed error bound (i.e. 100 meters). In addition to the recording of location data, SwRI proposes that the compliance validation process also includes a record of the time that the call was initiated (i.e. "send" key depression) and the time that the location was received at the PSAP. The response time appears to be of intense interest in PSAP operations.

The fifth and final step in the process will involve an analysis of the acquired experimental data. For network based solutions we will compute the percentage of location estimates contained within error bounds of 100 and 300 meters at each grid point. These percentages will be averaged over all sampled intersecting grid points to determine whether or not the averages are at least 67% and 95% respectively. In addition the response times should be summarized so that we can tabulate average, maximum, minimum response times, number of dropped calls, etc. A similar process should be implemented for handset-based systems with error bounds of 50 and 150 meters. CEP percentages for handset-based solutions can be estimated using GPS timing error variances.

Our remaining comments address specific compliance testing issues raised in Public Notice DA99-2130.

Statistical Considerations

The number of measurements that must be made within a carrier's service area will be dependent upon the variance estimate of the sample population of CEP percentages on the grid system. This is only one instance where the CEP characterization is crucially important for overall experimental design. We consider the collection of theoretically predicted CEP percentages over the entire grid system as a sample population with an unknown probability density function. The compliance verification process is designed to estimate the averaged percentage over a randomly sampled subset of the intersecting grid points. Because we are estimating the sample mean, we can apply the Central Limit Theorem to construct a 95% confidence interval and thereby predict the number of points required for a desired level of accuracy.

We believe that the CEP characterization is crucial to the overall experimental design; however, the propagation prediction model and statistical (location) error models used to derive the CEP should be left to the discretion of the party performing the test. The CEP predictions will be experimentally validated as part of the test process, thus a system of checks and balances is in place.

We propose that all calls and location results be included in the data acquisition process. The repeated trials experiment at each grid point will involve multiple 9-1-1 calls that produce a binary outcome, i.e. either the call resulted in a location estimate that met the 100 meter error bound or it did not meet the error bound. Calls that were not completed, were dropped, or resulted in no fix would be included in the total count but not in the successful count.

We are proposing the use of differential GPS for "truth" data and recommend that the resolution be at least 1 meter.

Choice of Measurement Locations

SwRI advocates that the test procedure include the entire coverage area of the wireless service provider. We are advocating the adoption of a "generic" experimental design procedure that can be tailored to meet individual PSAP needs. If a call cannot be completed at a particular test location, we advocate that the intersecting grid point be assigned a percentage of zero and included in the overall tabulation.

We propose the use of a grid system that has a spacing equal to 1/10 the nominal or average separation between base stations. Our vision is that stationary measurements will be made at intersecting points within the grid. Mobile measurements may occur within the 4 cells adjacent to the grid points, but will be associated with the selected grid intersection. SwRI proposes a random selection of grid points based on quartiles of location performance to ensure a more uniform sampling over the coverage area.

SwRI advocates that the collection of candidate intersecting points be initially screened to exclude those points that are inaccessible or could not be used for emergency calls. All other locations would be points included in the random draw process.

We expect that the random draw will produce grid points that are on sidewalks, freeways, city streets and in buildings. The data acquisition process would involve a simulation of conditions appropriate to the randomly selected environment. A moving caller would be placed in any of the four cells surrounding the point of intersection of the grid lines. The percentage of calls resulting in an error bound (i.e. 100 meters) would be associated with the selected intersecting point.

The test in a building should be consistent with the actions of a 9-1-1 caller. For example, one may move near a window to ensure that the call is completed. It is not clear that the added complexity and expense of measurements from various floors in a building would be cost effective, or produce useful information.

SwRI advocates that a continuing validation program be adopted to detect changes in performance due to alterations in foliage, construction or equipment failures. This could involve the use of stationary beacon transmitters, or the location of nearby base stations. Our experience has indicated that a continuing check of system operation is essential. If a problem is detected, then a reduced scope compliance verification test could be performed.

Measurement Techniques

We advocate that the response time be defined as the time between 9-1-1 call initiation (i.e. depression of the "send" key) and receipt of the location estimate at the PSAP. We are proposing

that these time tags be recorded as part of the compliance verification process. The data would be used for statistical purposes, and could be analyzed to determine whether or not an FCC mandated specification is necessary.

For GPS-based systems the data acquisition process should include both "cold start" and "jump start" conditions so that a reasonable estimate of response time and relative accuracy can be obtained for both modes of operation.

Analog and digital service should be sampled in equal proportions and the results combined for a single carrier.

SwRI proposes the use of differential GPS to determine the actual location of the caller. For moving platforms, the measured and actual locations must be time tagged to the nearest 0.1 second for subsequent correlation and error analysis.

SwRI suggests that the proposed compliance verification procedure based on CEP be applied to both network and handset-based technologies.

The predictive model of ALI systems proposed by SwRI is based on the use of measurement error variances to estimate CEP percentages. This model is of crucial importance in the design of the verification experiment. For example, the CEP predictions are used to estimate the number of intersecting grid points required to achieve a prescribed level of confidence in the overall verification process.

SwRI suggests that the data acquired during the comprehensive (fourth phase) of the compliance verification process be used to "tweak" the parameters in the CEP model and a contour plot similar to that shown in Figure 2 be generated. This format presents an excellent overview of system performance and permits rapid identification of areas requiring improvement.

SwRI is pleased to have the opportunity to provide input on the E911 compliance verification process. We would welcome the opportunity to meet with interested parties at the FCC and discuss issues of mutual concern. If we can provide additional information, please contact the undersigned at (210) 522-2753 or e-mail tgreen@swri.org, or Dr. Richard Johnson at (210) 522-2765 or e-mail rjohnson@swri.org.

Sincerely,

Terry C. Green, PE
Vice President

From: "Stephen D. Hayes" <shayes@wbklaw.com> **DOCKET FILE COPY ORIGINAL**
To: K5DOM.K5PO1(RECKERT)
Date: Fri, Oct 29, 1999 4:19 PM
Subject: ET Docket No. 99-300/Comments submitted by counsel for SnapTrack Inc.

October 29, 1999

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By Electronic Mail

Robert Eckert
Office of Engineering and Technology
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: Comments on DA 99-2130 in ET Docket No. 99-300

Dear Mr. Eckert:

SnapTrack, Inc. (*SnapTrack*) submits the following comments in response to the information request issued by the Office of Engineering and Technology and the Wireless Telecommunications Bureau (hereinafter jointly, the *Bureaus*), DA 99-2130, on October 8, 1999 (the *Information Request*). The Request seeks information which the Bureaus intend to use to develop guidelines for test procedures to verify compliance with the Commission*s E911 accuracy standards.

Compliance Verification Approach

SnapTrack is concerned that the verification approach suggested in the Information Request is extremely complex, and would be burdensome for mobile licensees and the Commission to administer. It appears that the Bureaus anticipate implementing a compliance verification regime that requires every mobile licensee to complete a similar, detailed course of E911 accuracy testing within each of its various licensed service areas. This complex series of field tests would be replicated over and over again throughout the United States to ensure the accuracy of each carrier*s E911 technology. Such an approach fails to take adequate advantage of certain practical and technical realities inherent in the routine processes of technology specification and equipment acceptance testing that already goes on between mobile equipment manufacturers and mobile operators, and which could be adapted to provide for the verification of E911 capabilities.

As the Bureaus are well aware, in its Third Report and Order,

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the Commission mandated the development of methods for verifying compliance with E911 standards, but left it to the Bureaus to work with industry to define how such verification would be accomplished. In doing so, however, the Commission was quite clear that the Bureaus should *take into account practical and technical realities.* One such set of *realities* is the already-thorough process by which mobile equipment specifications are developed and the fact that mobile equipment is built to perform in minimum conformance (and often in excess of) FCC specifications. Mobile operators and equipment suppliers complete a rigorous course of acceptance testing and specification conformance verification on new and modified mobile system equipment before a mobile operator will take final *delivery* of the new or modified equipment. These marketplace realities can be broadened and modified to ensure compliance with minimum E911 accuracy standards much more easily and less expensively than would be the case with the field testing approach contemplated in the Information Request.

In essence, SnapTrack recommends that the Bureaus adopt a *technology qualification* approach to E911 compliance verification. The Bureaus, in consultation with industry, should develop a program of technology testing, in varying real-world signal environments and conditions. Any technology, whether network- or handset-based, which is proposed to be installed to satisfy a carrier*s E911 obligations would first have to satisfactorily perform during technology qualification testing. Such qualification testing should include field tests in various morphological combinations of terrain, foliage, indoor/outdoor locations and types of structures, as well as varying mobility and speeds, times of day, network conditions, etc., in classes of scenarios including rural, suburban, urban, highway and on-water environments. If a technology, on a composite basis, meets the minimum E911 performance percentages in what will be the preponderance of likely scenarios to be encountered in real-world applications, then it may be implemented by a carrier without a mandate for further testing by the carrier, in full compliance of the carrier*s E911 obligations.

Even the cumbersome and repetitive field testing procedure contemplated in the Information Request is necessarily based upon sampling. It would not be possible * and it would certainly not be practical * to conduct actual tests in every square inch of a carrier*s service area under all possible combinations of environmental and network conditions that might be experienced at these locations. Such an impossible set of tests would, however, be the only way to verify, in absolute terms, the compliance of a carrier with E911 obligations throughout its service areas. Short of this, any form of verification must rely upon predictive measurement. The technology qualification

methodology recommended by SnapTrack is sufficiently predictive of E911 compliance that it is an appropriate alternative to the field test sampling suggested in the Information Request.

Importantly, technology qualification cuts out the repetitive elements of test sampling. It is likely that minimum compliance for any carrier could be verified through field testing in the core combinations of environments and conditions that are found in abundance throughout all but the most unusual service areas throughout the United States. Rather than replicate this same set of tests in numerous field trials in essentially identical circumstances, the tests could be conducted once for any location technology/air interface combination. Thereafter, the conformance of specific equipment with E911 standards would be verified through acceptance testing between the manufacturer and carrier. Manufacturers will have an incentive to produce equipment which reliably satisfies the E911 standards as this will be required to make the equipment marketable; operators will have an incentive to aggressively verify the compliance of their own equipment with the E911 standards in light of their obligation as an FCC licensee, and because of the potential for liability if a carrier is found to have been negligent in failing to adequately verify its compliance.

Technology Qualification Issues

It is important for the Bureaus and the industry to consider several issues in defining the technology qualification procedures:

* The various testing scenarios discussed above will need to be weighted in developing a composite compliance result. Reference should be given to the data which exists on the frequency of occurrence of these various scenarios in real-world systems, as well as whatever data exists (referenced in the Third Report and Order) on the environments in which actual wireless 911 calls have been received in the past. Reference to both sets of data will better identify the importance of each scenario to the overall assessment of real-world compliance. The standard requires determination of the percent of calls that can be located with specified accuracy. Since percentage is a statistical measure, the measured percentages for each scenario must be weighted by the probability of a call origination in that environment. As better data is developed in the future, the weighting scheme can be modified to further refine its predictive value.

* The composite scoring should, naturally, consider only those instances in which a call is completed. As noted in the Third

Report and Order, there will be *holes* in every service area wherein the environment will prevent calls from being completed, or changing conditions will result in occasional inabilities to complete calls. While these occurrences will arise in the course of testing as well, their occurrence should not be factored into the overall composite scoring, except to the degree they arise within scenarios under which calls should otherwise be completed (i.e., outdoor suburban area in clear sky vs. basement indoor mountainous rural area).

* The testing procedure should provide for multiple attempts to determine a location within a finite period of time as a single data point; each of these multiple attempts should not be separately counted in the composite scoring. Numerous fix attempts can be made within, for example, a 30-second period. Such a short period will, in reality, have an insignificant impact on the ability of dispatched safety personnel to physically locate the caller. However, multiple fix attempts can dramatically increase the reliability and the accuracy of the location estimate. In information previously shared with the Commission, SnapTrack performance analysis has demonstrated that multiple fixes significantly improve the success of locating technology, especially in more challenging environments. The essential results are as follows:

Performance Analysis

Environment	Rural Highway	Suburban Indoor	Suburban Outdoor	Urban Canyon	Urban Indoor
Single Fix Yield (%) (Reliability)	98	85	95	80	20
Five Fix Yield (%) (Reliability)	100	100	100	100	67
Single Fix 1-sigma (m) (Accuracy)	12	36	10	63	63
Five Fix 1-sigma (m) (Accuracy)	10	25	7	47	53

In light of the relative accuracy of single fix location in certain environments, it might be appropriate to set a different period of time to achieve a final location estimate for different environments in developing the composite scoring regime.

In sum, SnapTrack believes that the approach contemplated by the Bureaus in the Information Request places a very high burden on both the carriers and the Bureaus without any countervailing public interest benefits. The Commission*s mandate of developing a verification compliance regime that involves industry and which takes practical and technical realities into account can be fully met by instituting the type of approach recommended above.

Respectfully submitted,

SNAPTRACK, INC.

By Ellen M. Kirk
Vice-President, Marketing and Strategic Planning

ekirk@snaptrack.com.

cc: Marty Liebman (Wireless Telecommunications Bureau)

CC: K3DOM.K3PO2(MLIEBMAN)

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From: "Sorensen, Eric" <esorensen@sccx.com>
To: K5DOM.K5PO1(RECKERT),K3DOM.K3PO2(MLIEBMAN)
Date: Fri, Oct 29, 1999 4:45 PM
Subject: ET Docket No. 99-300 Comments

CC: "Meer, Stephen" <smeer@sccx.com>, "Donaldson, Crai...

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC

In the Matter of	)
	)
Information Sought on Methods for	) CC Docket No. ET 99-300
Verifying Compliance with	)
E9-1-1 Accuracy Standards	)

Comments of SCC Communications Corp.

The Office of Engineering and Technology (OET) and the Wireless Telecommunications Bureau (WTB) have requested technical information on measuring the accuracy of Enhanced 9-1-1 (E911) systems for locating wireless callers with an intent to develop guidelines for test procedures to verify compliance of these systems with the FCC's mandated accuracy standards. Although it is clear that the test procedures are intended to verify compliance, it is not clear to what environment the tests are to be targeted..

Potentially three different environments could be defined for these tests. One environment would establish test procedures to be used by a manufacturer of location technology to "certify" their systems prior to marketing them to the industry. A second environment would test a location system at the time it is implemented in a specific area prior to turning the system over for live call processing. And the third environment would be the ongoing measurement of performance within an operational system to verify continued compliance with the FCC's standards.

It is reasonable to assume that public safety agencies will use the guidelines produced by the FCC to assure that wireless carriers in their jurisdictions are providing systems that meet the FCC's accuracy standards. Therefore, the PSAP jurisdictional area should be established as the focus for sampling points for all wireless location verification. PSAPs should be invited to participate in the information collection process in order to assure their acceptance of the measurement methodology.

SCC suggests that the FCC clarify the specific environment in which verification of compliance will be measured... Additionally, SCC recommends that test procedure guidelines encourage the inclusion of public safety representatives in planning the specifics of a verification test plan.

Statistical Considerations

- *What measurement precision should be required,* i.e., *should the actual caller location be recorded with a precision allowing calculations to be made in fractions of a meter?*

Obviously, to measure performance of the location system, the "true" location of the calling party must be known. Current standards activities suggest that location information be reported as the latitude and longitude of the calling party. To obtain comparable information, the "true" location of the calling party should be determined by using GPS or appropriate technology so that the measurement points are known and authenticated.

Precision of measurements should be calculated at a per meter accuracy. However, higher precision should not be excluded if available and its reporting deferred to agreements between the wireless carrier and the public safety customer(s).

Choice of Measurement Locations

- *Should a test procedure include the entire advertised coverage area of a wireless service provider? Should test locations be organized according to the respective responsibilities of public safety answering points (PSAPs)? And if a call cannot be completed at a particular test location, should that location be ignored?*

Given the assumption that verification of accuracy is being conducted for a specific implementation, it would seem logical that the test procedure should include, at a minimum, the specific boundaries of a PSAP within a wireless carrier's service area.

- *How should test locations be chosen?*

Consideration should be given to environmental factors, such as terrain, elevation, urban/metropolitan, etc. Test locations should span all of the applicable environments within the test boundary area. It may also be useful to consider test areas within areas that have high call volumes for the wireless carrier. Finally, it would be reasonable to allow the PSAP to identify key or critical locations within their jurisdictions to be used as measurement locations.

Measurement Techniques

- *Should there be a maximum time to obtain a location fix? If so, what criteria are appropriate for setting this time limit (*e.g.*, the typical time for call to be routed to a PSAP, some period of time* after *the call has been routed to the PSAP, etc.) and should such criteria vary for different test locations?*

Calling party location is information used to determine the proper routing of a call to 9-1-1. Time to obtain a location fix should generally be within a normal call set up interval for E9-1-1 calls.

Respectfully Submitted,

Eric Sorensen
Director Technology Planning
SCC Communications Corp.
6285 Lookout Road

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October 29, 1999

From: Jonas Neihardt <jonasn@qualcomm.com>

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To: K5DOM.K5PO1(RECKERT)

Date: Fri, Oct 29, 1999 2:39 PM

Subject: QUALCOMM Response Re: ET Docket No. 99-300

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Mr. Eckert:

Attached please find the comments of QUALCOMM, Inc. in response to the Commission's Public Notice DA-2130, dated October 8th, 1999 regarding E-911 accuracy standards (ET Docket No. 99-300). Please contact me if there is any further information QUALCOMM may provide in this matter. If you feel that a meeting would be helpful to follow-up on our comments, please let me know and we will visit you at your convenience.

Sincerely,

Jonas Neihardt
Vice-President for Federal Affairs

CC: K3DOM.K3PO2(MLIEBMAN)

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E911 Compliance Testing Issues

In Public Notice DA 99-2130 the Office of Engineering and Technology (OET) and the Wireless Telecommunications Bureau (WTB) identified specific issues related to developing guidelines for test procedures to verify compliance with E911 accuracy standards.

The issues listed in the Public Notice are not exhaustive, other questions must to be addressed in order to set practical guidelines for obtaining meaningful results. Some of these additional questions are:

- Does the carrier need to test every handset model and every network ranging equipment for compliance?

- Should carriers using the same technology in the same advertised coverage area conduct separate testing?

- Does the FCC expect a frequently generated report showing compliance?

- How often should these reports be produced?

In an attempt to answer these additional questions and the OET original set questions, it became clear that testing for compliance with E911 is not a travail task and requires tremendous amount of the carrier resources. It is not practical to ask the carrier to test every handset model from every vendor or conduct compliance tests for every network ranging piece of equipment.

For these reasons QUALCOMM is proposing the following two step procedure:

1- Develop minimum performance specification: The carriers and vendors work together to develop minimum performance specifications for both handsets and base station ranging equipment. These specification serve two purposes:

(a) Interoperability compliance between equipment from different vendors

(b) Insure a minimum performance for all Automatic Location Identification (ALI) equipment

2- Conduct technology testing: In this step the carrier must test the technology under consideration for all possible scenarios of operation using reference handsets or reference ranging equipment. The test suites must be designed such that every handset and network ranging equipment that meets or exceeds the minimum performance specification must have the same or better performance under the same or better RF environments. These testing may be done once per market, in addition it may be shared between carriers serving the same advertised

coverage area and using the same technology. Also not all advertised coverage areas with the same RF characteristics need to be tested.

The following is an attempt to answer the OET specific set of questions.

1- Statistical Considerations

Q1.1 How many measurements must be made within a carrier's service area to ensure statistical confidence?

A1.1 Analysis indicates that at least 100 samples are required at each point to achieve statistically significant results. See Appendix 1 for more details.

Q1.2 Should a test procedure include a precisely defined statistical model?

A1.2 There is no one statistical error model that can be used for all scenarios (testing points). The shape and parameters of the statistical model at a given point depend on the location of the caller with respect to sources used in calculating the position. That is, a set of position calculations cannot be modeled from samples drawn from a single distribution. Field measurements are required, but given that field measurements vary tremendously; a repeatable test scenario is required. QUALCOMM proposes that carriers and location equipment vendors are given freedom to use their own statistical model to predict performance of a given technology, but technology evaluation should be done through field testing.

Q1.3 What special statistical considerations, if any, should be introduced to handle "outliers" (*e.g.*, measurements made where no fix was obtained at all, or large errors in location suspected to be due to faulty test equipment)?

A1.3 It is true that accuracy can only be determined in the case of a successful position determination. Nevertheless, no special consideration should be introduced to handle "outliers." All measurements should be taken into consideration while evaluating the performance of any ALI technology. It may be useful to report three numbers: the error corresponding to 67 of all calls, the error corresponding to 95% of all calls, and the % of calls that resulted in no fix.

Q1.4 What measurement precision should be required, *i.e.*, should the actual caller location be recorded with a precision allowing calculations to be made in fractions of a meter?

A1.4 In areas where there are more than four visible GPS satellites, a differential GPS receiver can be used to determine the actual position of the caller. In areas where differential GPS techniques do not work, conventional GPS with appropriate time averaging can be used instead. In areas where not enough satellites are available, a rolling measuring wheel can be used to measure exact distances between points with known locations and test points. Differential GPS can achieve 5-feet rms accuracy.

2. Choice of Measurement Locations

Q2.1 Should a test procedure include the entire advertised coverage area of a wireless service provider? Should test locations be organized according to the respective responsibilities of public safety answering points (PSAPs)? And if a call cannot be completed at a particular test location, should that location be ignored?

A2.1 No, testing the entire advertised area will require huge amounts of effort and is considered unrealistic. The test procedure should prioritize scenarios that need to be modeled and tested against, taking into consideration the probability of occurrence and seriousness of need for a position fix. It is not necessary to organize test locations according to the respective responsibilities of PSAPs. In order to simplify testing and reduce the carrier's burden, it may not be necessary for carriers using the same ALI technology and serving the same advertised coverage area to conduct separate testing. Also carriers serving two advertised coverage areas with the similar RF characteristics may test only one of them. It may be even better to limit testing to areas where it is well known that a technology has some limitations. For example, testing a handset solution in urban canyon areas and the network solution at the edge of coverage, close to cell sites and areas with special geometry.

If a call cannot be completed at a particular test location, that location should not be considered as part of the statistics.

Q2.2 How should test locations be chosen?

(See sub-questions and answers below.)

Q2.2.1 Should test locations be picked in a purely random fashion? If so, they should be chosen by reference to a rectangular grid of cells? If so, should measurements be made at the intersecting points within the grid, or should a certain number of points be made within each cell (*e.g.*, in proportion to the carrier's current distribution of calls, 911 calls only)? In any case, how large should cells be?

A2.2.1 QUALCOMM proposes dividing the advertised area into regions according to morphology (RF environment). Further, each region should be divided into square grids. Weighting the regions according to the current distribution of 911 calls is not necessary because the call distribution pattern may change. In addition, the current distribution does not represent the real number of incidents (many calls may represent the same accident on a highway). The size of each square grid is selected such that the number of points in each region is manageable, say 100 points. A field test is done at each grid point to experimentally validate the statistical model selected by the ALI vendor or the carrier. In addition, some tests should be conducted while the caller is in motion, i.e. walking, driving at city speed, and driving at highway speeds.

Q2.2.2 Should test locations be picked by reference to irregularly bounded areas, such as the estimated coverage areas of individual base stations? If so, how far should test locations be from

base stations and, especially for network-based systems, should tower configuration be a consideration in determining test locations (*e.g.*, test locations directly between two towers, equidistant between three towers, etc.)?

A2.2.2 Test points should represent every possible scenario of callers inside the coverage area. Provisions should be made such that points inside the advertised areas with special geometry or influenced by seasonal changes should be thoroughly tested. Examples are points close to cell sites, along highways covered by linear configuration of cells, inside tunnels, inside parking garages, on the fringes of the coverage area of the wireless communication system, etc. QUALCOMM would like to emphasize that not only geometry, but also the time of day impacts the performance of all location technologies. For example, technologies that depend only on GPS for geolocation are sensitive to the time of day.

Q2.2.3 Should test locations be classified by the type of reception environment (on a sidewalk, in a vehicle, in a building, rural, urban, suburban, etc., or with reference to parameters of predictive ALI models)? How would such areas be precisely defined? What techniques are practical and appropriate to assure randomness, if needed?

A2.2.3 Test locations should be classified by the type of reception environment. The following is a simple description of different scenarios:

Dense urban areas: metropolitan centers and the large cities characterized by 20-50-floor skyscrapers, 10-20-story office buildings, high-rise apartments, and hotels. Examples are typical in downtown areas and in business districts.

Urban areas: medium sized city characterized by buildings with less than 10 stories such as medium size office and apartments buildings.

Suburban areas: primarily residential neighborhoods with few businesses. Typical structures are one and two story homes and small shopping centers.

Rural (open) areas: countryside and large, open-plan houses.

Again, enough number of test points in each area must be selected to make sure that the results have statistical significance.

Q2.2.4 Should tests be made on various floors of a building, *i.e*, should there be a vertical dimension to the test procedure?

A2.2.4 Yes, tests should be made at various floors of a building. Nevertheless, the vertical accuracy should not be factored into calculating the accuracy of the results.

Q2.3 How should the test procedure recognize changes that occur over time in the test area, such as foliage changes and construction of new buildings?

A2.3 In areas where seasonal changes may impact the performance of the location technology, tests must be conducted as many times as required to achieve the expected results. Similarly, tests must be repeated in areas around newly constructed buildings. In addition, for some ALI technologies, the process must be repeated every time the service provider changes the configuration of one or more sites, such as changing site/sector transmit power, changing antenna height, antenna tilting, etc.

3 - Measurement Techniques

Q3.1 Should there be a maximum time to obtain a location fix? If so, what criteria are appropriate for setting this time limit (*e.g.*, the typical time for call to be routed to a PSAP, some period of time *after* the call has been routed to the PSAP, etc.) and should such criteria vary for different test locations?

A3.1 Yes, there should be a limit on the maximum time to obtain a fix. A typical time for a call to be routed to a PSAP is a good target. These criteria should not vary for different test locations.

Q3.2 For GPS-based systems, should some or all location attempts be made from phones that have not acquired a recent location fix (*i.e.*, a "cold start")?

A3.2 All locations attempts should be made from phones that have not acquired recent location fix.

Q3.3 Should both portable and mobile phones be tested? If so, in what proportion should they be tested? Should the test procedure specify how portable phones should be oriented, or how a mobile antenna should be mounted?

A3.3 No, only portable phones should be tested. Portable phones can be tested under moving conditions at city-driving and highway speeds. QUALCOMM strongly believes that if a portable phone passes the test, a mobile phone will also.

Q3.4 Should some proportion of measurements of portable phones be made with phones in motion (*i.e.*, at walking speeds)? If mobile phone measurements are made, at what speeds should the mobile unit be moving?

A3.4 Yes, some tests should be conducted while the caller is in motion. For example, walking, driving at city speeds and driving at highway speeds.

Q3.5 If a carrier provides both analog and digital service, should separate tests be prescribed for each mode? Should the accuracy and reliability standards apply separately to each mode, or should the test results be combined in some specific proportion?

A3.5 No, the FCC recent Report and Order does not require legacy handset to support ALI. Accuracy and reliability standards should apply only to callers in digital mode.

Q3.6 What techniques are available for determining the distance between the actual location and the measured location?

A3.6 Differential GPS should be used when there are four or more visible GPS satellites and differential correction service is available. Conventional GPS with appropriate time averaging can be used in areas where differential correction service is not available. In scenarios where the number of satellites is not adequate, a rolling measuring wheel can be used to measure exact distances between points with know locations and test points.

Q3.7 Is there a need to develop a different test procedure for network vs. handset technologies?

A3.7 No, the same test procedure should be applied to both technologies.

Q3.8 Should provisions be made for the use of predictive models of ALI systems, now or in the future? If so, what accuracy and reliability standards should be required of such models and how should they be tested?

A3.8 QUALCOMM does not see a need to standardize predictive models of ALI systems. All ALI vendors should be free to use their own predictive models. It is important though to standardize the field testing and validation procedures.

Appendix

This appendix addresses the issue of the minimum number of samples required to provide statistically significant test results. For each confidence interval, there are two sets of numbers. One set of numbers applies to the sample mean and other set applies to the sample variance. The results can be used as a guideline to determine the minimum number of tests at each point to validate the performance of Automatic Location Identification (ALI) technologies.

A.1 Mathematical Model:

A.1.1 Sample mean statistics

A population cannot be sampled without error unless the entire population is sampled. It would be impractical to conduct the test infinite number of times to reduce uncertainties. Instead, a large random sample of the same test should be collected and the proportion of success trials is then calculated. Typically, the result calculated is the sample mean (called also point estimator of the sample mean).

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (1)$$

Sample mean itself is a random variable whose distribution is approximately normal with mean and variance:

$$\mu_{\bar{x}} = \mu \qquad (2)$$

$$\sigma^2_{\bar{x}} = \frac{\sigma^2}{n} \qquad (3)$$

Sample mean does not reveal information on how big is the error between the point estimator and the true mean. An interval estimate of a population parameter **x** is an interval of the form $x_1 < \bar{x} < x_2$. The wider we make the interval, the more confident we can say that a particular sample size we selected will produce an interval estimate that contains the unknown parameter.

A.1.2 Sample Variance Statistics

Similarly, an unbiased point estimate of the population variance s^2 is defined by the statistic

$$s^2 = \frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{n-1} \tag{4}$$

If the samples are chosen from a normal population, then $(n-1)s^2/\sigma^2$ is a chi-square distribution with $(n-1)$ degrees of freedom.

A.2 Confidence Intervals

A.2.1 Confidence interval for sample mean

The (1-α)100% confidence interval for μ is

$$\bar{x} - z_{\alpha/2}\frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + z_{\alpha/2}\frac{\sigma}{\sqrt{n}} \tag{5}$$

where $\bar{x}$ is the mean of a sample of size n from a population with known variance σ^2 and $z_{\alpha/2}$ is the value of the standard normal distribution having an area of α/2 to the right.

The above equation can be interpreted as follows: if $\bar{x}$ is used as an estimate of μ, we can be (1-α)100% confident that the error will be less than $z_{\alpha/2}\frac{\sigma}{\sqrt{n}}$.

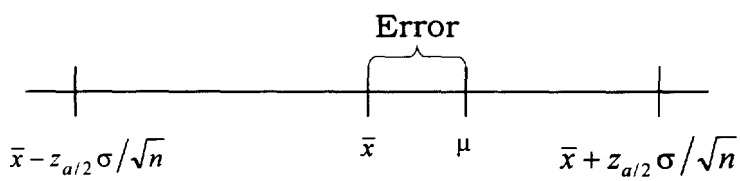

Figure 1: Error in estimating μ by $\bar{x}$

Table 1 is a list of $z_{\alpha/2}$ vs. confidence levels.

Table 1		
Confidence level	$\alpha/2$	$z_{\alpha/2}$
90%	0.05	1.645
95%	0.025	1.960
97%	0.015	2.170
99%	0005	2.575

A.2.2 Confidence interval for sample variance

It can be shown that

$$P\left[\frac{\chi^2_{1-\alpha/2}}{n-1} < \frac{s^2}{\sigma^2} < \frac{\chi^2_{\alpha/2}}{n-1}\right] = 1-\alpha \tag{6}$$

where $\chi^2_{1-\alpha/2}$ and $\chi^2_{\alpha/2}$ are values of the chi-square distribution with $(n-1)$ degrees of freedom leaving areas of $\left(1-\frac{\alpha}{2}\right)$ and $\left(\frac{\alpha}{2}\right)$, respectively, to the right.

A.3 Sample Size Formula

If $\bar{x}$ is used as an estimate of μ, we can be $(1-\alpha)100\%$ confident that the error will be less than a specific amount e when the sample size is

$$n \geq \left(\frac{z_{\alpha/2}\,\sigma}{e}\right)^2 \tag{7}$$

Now, normally we do not know the standard deviation of the population but if the experiment we are conducting can be modeled as a binomial random variable with probability of success p. Then the standard deviation (for n> 5/(1-p)) is

$$\sigma^2 = p(1-p) \tag{8}$$

Substituting in (7), yields

$$n \geq \frac{z^2_{\alpha/2}\,p(1-p)}{e^2} \tag{9}$$

At the extreme tails of the distribution, equation (9) becomes invalid and the following lower bound should be imposed

$$n \geq \frac{5}{(1-p)} \tag{10}$$

The minimum number of samples is the maximum of equations (9) and (10). Equation (9) reveals that the smaller the error e, the higher the number of samples required. Also the smaller the probability p, the smaller the number of samples for the same error. This is intuitive, consider for example the coin flipping experiment, more flips are required to prove the probability of obtaining a "head" with 50% unbiased coin than with 99% biased coin. The confidence interval is the confidence that the number of samples used to determine the performance parameter are within the specified error.
For the sample variance, equation (6) can be used to estimate the minimum number of samples to achieve certain upper and lower bounds as will be shown in the results section.

A.4 Numerical Results

A.4.1 Sample mean results

Tables 2 and 3 lists the minimum number of samples for different success rates and confidence levels.

Table 2 90.00% Success rate

e	90.00%	95.00%	97.00%	99.00%
1.00%	2435	3457	4238	5971
2.00%	609	864	1060	1493
3.00%	271	384	471	663
4.00%	152	216	265	373
5.00%	97	138	170	239

Table 3 95.00% Success rate

e	90.00%	95.00%	97.00%
1.00%	1285	1825	2237
2.00%	321	456	559
3.00%	143	203	249
4.00%	100	114	140
5.00%	100	100	100

A.4.2 Sample Variance Results

Based on sample variance Figures 1-3 show lower and upper bounds on s^2/σ^2 for different confidence levels.

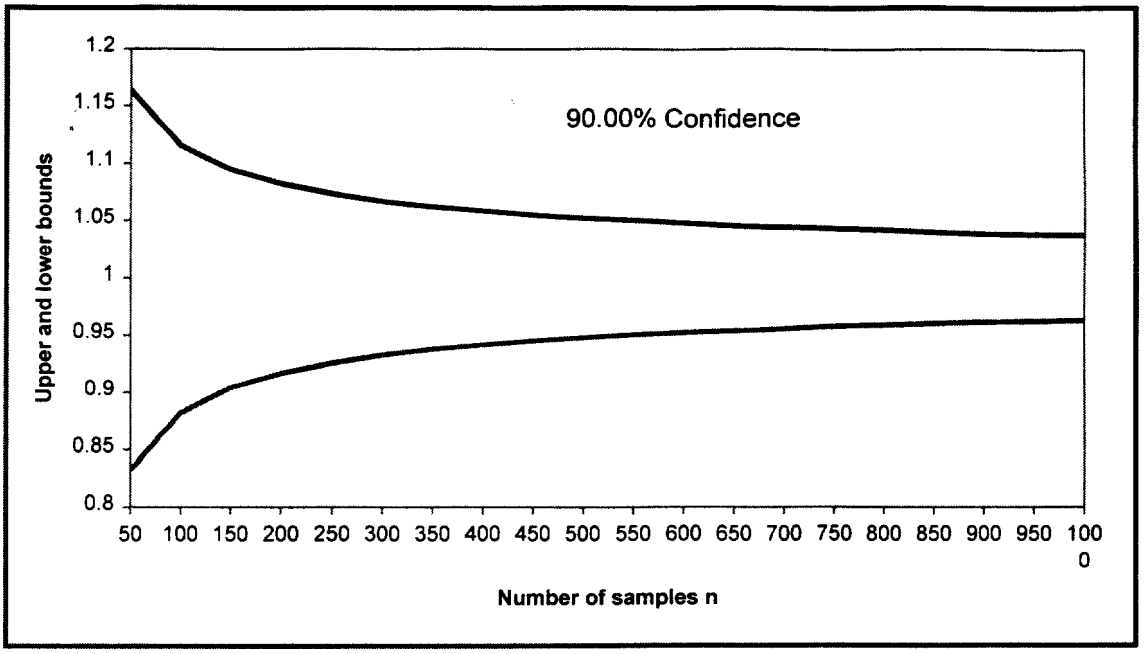

Figure 2: Lower and upper bounds on S/σ for 90 % confidence level

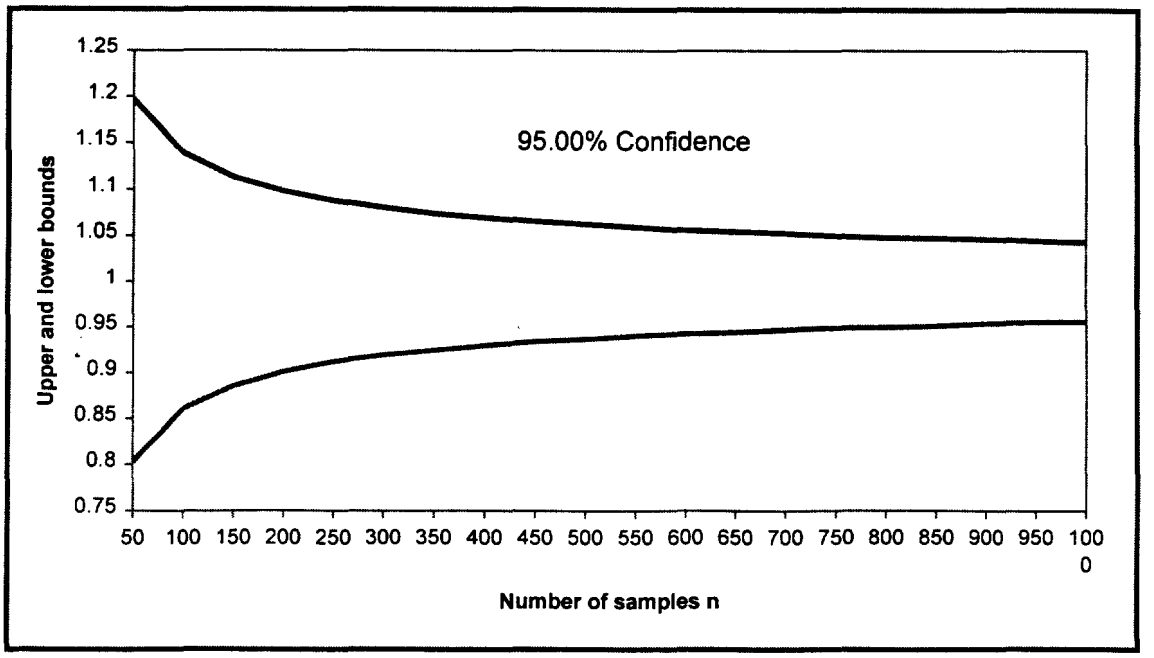

Figure 3: Lower and upper bounds on S/σ for 95 % confidence level

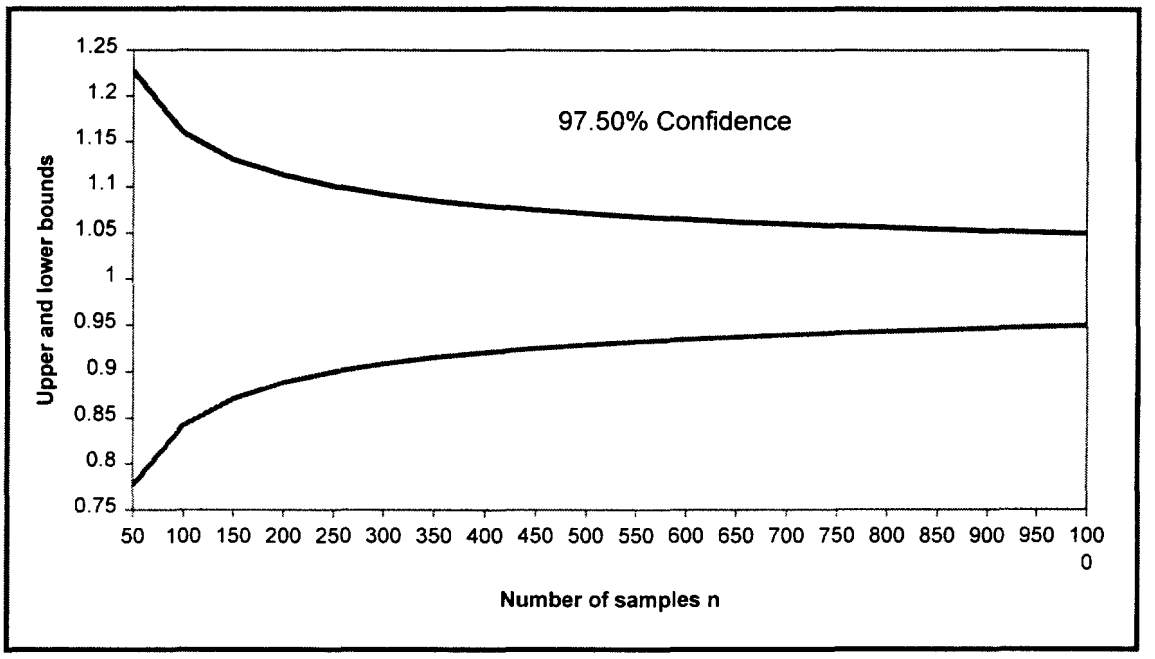

Figure 4: Lower and upper bounds on S/σ for 97.5 % confidence level

Note that since the location error is a two-dimensional vector, and assuming that the two components are independent and identically distributed, then the number of degrees of

freedom is *2n-1* and the required number of samples is half the number shown in the above figures. The results are summarized in Table 4.

Table 4 Number of samples based on sample variance			
Error	90% Conf. Level	95% Conf. Level	97.5% Conf. Level
5%	225	400	500
6%	200	280	300
7%	140	200	250
8%	115	150	200
9%	135	115	160
10%	65	100	125

A.5 Conclusions

From the above results, it is clear that at least 100 samples are required to achieve statistically significant results.