

**Before the  
Federal Communications Commission  
Washington, D.C. 20554**

In the Matter of	)	
	)	
Wireless E911 Location Accuracy Requirements	)	PS Docket No. 07-114
	)	
E911 Requirements for IP-Enabled Service Providers	)	WC Docket No. 05-196
	)	

**COMMENTS OF POLARIS WIRELESS, INC.**

Polaris Wireless, Inc. (“Polaris”),<sup>1</sup> through its attorneys, hereby submits these Comments in response to the Federal Communications Commission’s (“FCC” or “Commission”) Further Notice of Proposed Rulemaking and Notice of Inquiry (“*FNPRM*” and “*NOI*”) in the above-captioned proceeding.<sup>2</sup> In the *FNPRM*, the Commission seeks comment on ways to improve wireless location accuracy for E911.<sup>3</sup>

Polaris strongly supports the efforts of the Commission, public safety groups, wireless carriers, and vendors to improve the accuracy and reliability of E911 Phase II systems. To this end, Polaris urges the Commission to take advantage of continued technology and industry advancements affecting what is achievable with E911 Phase II systems, and maintain the technical innovation and leadership of the United States in this area. As the questions raised in the *FNPRM* and *NOI* suggest, there are many new challenges associated with E911 as wireless

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<sup>1</sup> Founded in 1999, Polaris is a privately held company that has developed and commercialized a wireless location software technology for the delivery of location services, including E911 Phase II.

<sup>2</sup> *Wireless E911 Location Accuracy Requirements*, Further Notice of Proposed Rulemaking and Notice of Inquiry, 75 FCC Rcd 67321 (2010) (“*FNPRM*” and “*NOI*”).

<sup>3</sup> *Id.* ¶ 3.

consumers explore new ways to communicate. In order to meet these challenges, the Commission should encourage the deployment of hybrid E911 solutions, specify a common definition for hybrid systems, and establish a hybrid implementation timeline. It should also gather input from industry members and advisory groups regarding indoor testing and requiring E911 compliance testing to include an appropriate mix of indoor measurements. Finally, it should facilitate the development of vertical coordinate location information by forming a stakeholders group to investigate the relevant emerging technologies and public safety requirements to make use of this additional information.

## **I. TODAY’S WIRELESS LOCATION SOLUTIONS HAVE LEAPFROGGED FIRST-GENERATION TECHNOLOGIES.**

In the *FNPRM*, the Commission seeks comment on the current state of wireless location technologies.<sup>4</sup> Polaris has substantial experience in developing robust E911 location solutions that are far superior to costly, hardware-centric first-generation technologies. For example, Polaris’s Wireless Location Signatures (“WLS”) technology has been widely deployed since 2002. The WLS system uses serving and neighboring cell measurement information to estimate location and provides excellent accuracy and yield in the challenging dense urban and indoor environments. WLS technology is based on the observation that the radio environment varies from location to location due to features such as terrain, buildings, foliage, and cellular signal coverage. If enough elements of the radio environment can be measured with sufficient accuracy, each set of measured values provides a radio signature that uniquely identifies a particular location.

In addition, Polaris and its partners have developed hybrid solutions that represent the cutting edge of blending satellite- and network-based location technologies. The companies

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<sup>4</sup> *Id.* ¶ 15.

developed and extensively tested technology that maximizes location reliability and the overall positioning performance. The hybrid solution merges two main technologies:

- Already-proven Assisted-Global Navigation Satellite System (“A-GNSS”) technology, including GPS, Glonass, and future satellite constellations such as Galileo and modernized GPS, which paves the way to significantly improved satellite location availability and accuracy, particularly in outdoor environments; and
- Innovative WLS network-based technology, a cost-effective positioning technology that performs well in indoor, dense urban, and urban environments.

This hybrid solution provides an extremely high yield location solution with accuracy performance, and it can help advance the Commission’s E911 goals.

## **II. HYBRIDIZATION CAN SUBSTANTIALLY IMPROVE E911 LOCATION ACCURACY AND YIELD, PARTICULARLY IN URBAN AND INDOOR AREAS.**

The Commission seeks comment in the *FNPRM* on whether carriers can employ hybrid solutions to improve location accuracy.<sup>5</sup> It also seeks comment on ways to improve location information and accuracy “in more challenging environments.”<sup>6</sup> Because hybrid solutions can significantly enhance E911 location accuracy, especially in challenging environments, the Commission should encourage their deployment and establish a hybridization timeline.

Hybrid approaches have the potential to deliver more consistent accuracy performance because of the diversity benefit achieved from combining network-based technologies, which typically work best in high cell density environments (*e.g.*, dense urban), with handset-based technologies that tend to work best in open sky environments. A hybrid approach, defined in this

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<sup>5</sup> *Id.* ¶ 18.

<sup>6</sup> *Id.* ¶ 22.

manner, incorporates the best of both worlds, and only systems that employ a combination of terrestrial- and satellite-based technologies can adequately meet accuracy and yield requirements in all of the potential environments in which E911 calls might be originated. Weaker definitions of hybrid systems, such as those that propose handset-based solutions in some geographic areas and network-based solutions in other disjointed areas, do not meet these requirements across the range of environments and usage scenarios. Polaris advocates that the Commission define hybrid systems as meaning a true blending of handset-based and network-based systems in the same geographic areas.

Both the 3rd Generation Partnership Project (“3GPP”)<sup>7</sup> and the Open Mobile Alliance (“OMA”)<sup>8</sup> have been working to facilitate collaboration among E911 location solution stakeholders over the last few years. Polaris and its partners are active within 3GPP and OMA and continue to work with the vendor and carrier community to enable better cooperation and integration of E911 technologies. Polaris and its partners have also been working together to align their technologies and make them work seamlessly in a hybrid system.

With current technologies, hybrid systems can be applied in the near term to realize county-level accuracy in both rural and urban areas and to achieve better indoor performance. Without hybrid systems, all carriers will be challenged to meet the Commission’s new E911 requirements at a county or PSAP-based level. For example, carriers with legacy satellite technologies (*e.g.*, CDMA2000 carriers) will face accuracy and yield problems in dense urban and indoor environments, while carriers with a legacy of network-based technologies (*e.g.*, GSM carriers) will be challenged to meet accuracy requirements in rural areas. Therefore, the

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<sup>7</sup> 3GPP Technical Specification 25.305, Section 6.6.5.1.3: PCAP for SAS based Positioning Method Selection, *available at* <http://www.3gpp.org/ftp/Specs/html-info/25305.htm> (last accessed Jan. 3, 2011).

<sup>8</sup> *See, e.g.*, Open Mobile Alliance, Work Item Document for Global Location (OMA-WID\_0152-GL-V1\_0-20071009-A.doc).

Commission should adopt clear guidelines, a specific hybrid system definition, and a timeline for the implementation of hybrid systems in order to ensure realization of its goals for E911 accuracy and yield. It should not, however, adopt a single location accuracy requirement until it adopts a hybridization timeline<sup>9</sup> because carriers continue to face different implementation challenges that depend on their legacy E911 Phase II technology (the fundamental physics differences between handset-based technologies using satellites and network-based systems using terrestrial networks have not changed).

*Real-world trials confirm the benefits of hybridization.* Polaris and wireless service providers have conducted a number of field tests on all prominent wireless air interface protocols to assess the potential performance improvements of hybrid systems, compared to existing handset-based systems. Many of these tests have been conducted predominantly in dense urban, urban, and indoor areas, where satellite-based systems often experience challenges due to obstructions of the weak satellite signals. The overall results from several of these trials have been summarized in Polaris's prior comments in this proceeding and are attached hereto as Appendix A.<sup>10</sup> As a further example of the advancements that are possible with hybrid systems, Polaris also submitted a technical paper jointly published by Polaris and Stanford University's GPS Laboratory on the design and performance of hybrid algorithms for positioning in dense urban environments.<sup>11</sup> Based on actual field trial data sets from two sample markets, the paper demonstrates that hybrid algorithms combining WLS and A-GPS can achieve significant

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<sup>9</sup> See *FNPRM* ¶ 17.

<sup>10</sup> See, e.g., Comments of Polaris Wireless, Inc., PS Docket No. 07-114, 5-9 (filed Nov. 20, 2009); Comments of Polaris Wireless, Inc., PS Docket No. 07-114, 13-14 (filed Aug. 20, 2007).

<sup>11</sup> *Ex parte* filing of Polaris Wireless, Inc., PS Docket No. 07-114 (filed Oct. 16, 2009), attaching De Lorenzo, D. S.; Lo, S. C.; Enge, P. K.; Feuerstein, M.; Bhattacharya, T.; Spain, S.; and Kang, Z, *Design and Performance of a Minimum-Variance Hybrid Location Algorithm Utilizing GPS and Cellular Received Signal Strength Inputs for Positioning in Dense Urban Environments*, presented at the Institute of Navigation ("ION") International Technical Meeting, Anaheim, CA (Jan. 26-28, 2009).

performance gains, particularly for prevalent indoor and urban calling scenarios, that should be harnessed to drive accuracy and consistency improvements for E911 Phase II.

*Polaris' WLS technology is ideal for hybridization.* Carriers are increasingly deploying small (*e.g.*, micro-, pico-, and femtocell) base stations, and radio hardware-based technologies will be restricted from access to a growing percentage of the base stations in a carrier's network. This trend will result in added cost and/or reduced accuracy. (On a positive note, the addition of numerous small base stations will have a generally beneficial effect on location capability.) To deploy a WLS system and obtain enhanced location accuracy, however: (1) no modifications are required in the handset; and (2) the location algorithms are implemented on a standard computer server, which requires no hardware additions to the base stations. Due to the system's ability to leverage existing infrastructure, the initial investment to deploy an E911 solution with WLS is more cost-effective than alternate technologies, and deployment times are significantly faster than what is necessary to install a new radio network overlay or to replace the installed base of wireless handsets in the marketplace. Moreover, to comply with the new E911 location accuracy requirements, current network-based providers will likely need to migrate to handset-based solutions. Because the handset component represents the bulk of the cost of a combined A-GPS/WLS system, the benefits of a hybrid solution could be obtained at modest marginal costs.

### **III. THE COMMISSION SHOULD EVALUATE SOLUTIONS FOR IMPROVING INDOOR LOCATION ACCURACY AND REQUIRE E911 COMPLIANCE TESTING TO INCLUDE INDOOR MEASUREMENTS.**

The *FNPRM* seeks comment on the methodology that carriers should use to measure compliance with the Commission's E911 Phase II requirements, along with whether its rules should specify a certain level of indoor testing.<sup>12</sup> Given the predominance of indoor wireless

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<sup>12</sup> *FNPRM* ¶¶ 19-20.

usage and the rapidly growing trend of wireline replacement, a substantial amount of E911 calls are now made indoors. Absent timely progress on indoor performance, the U.S. is likely to fall behind other countries with respect to public safety and emergency location technology.

Currently, a large percentage of wireless calls are made indoors. ATIS notes in their standard for indoor testing that “[t]he recent remarkable growth of wireless communications has been accompanied by a steady increase of wireless use indoors and an increased reliance on wireless in indoor settings.”<sup>13</sup> Polaris agrees with ATIS’s assessment. However, this important and growing call segment is not being properly addressed, or even measured, under the current E911 rules paradigm. For example, obtaining accurate location information for indoor calls is a significant challenge for many E911 location technologies that rely on GPS technology. Even with increased power and sensitivity, satellite-based systems have failed to provide adequate location accuracy or yield in the in-building environment without the support of a strong terrestrial (*i.e.*, network-based) technology.<sup>14</sup>

Polaris strongly advocates that the Commission establish testing and reporting requirements for in-building location accuracy and yield. With better information regarding the scope and impact of the challenges associated with indoor E911 location information, the Commission will be able to properly assess the best way to improve indoor performance (and the appropriate metrics that need to be put in place). Specifically, the Commission should hold workshops and other events to get input from industry members and advisory groups regarding indoor testing. Based on this input, the Commission should also consider requiring indoor testing and establishing a testing schedule.

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<sup>13</sup> ATIS 0500013 – Approaches to E9-1-1 Indoor Location Performance Testing, *available at* <http://www.atis.org/esif/docs.asp> (last accessed Jan. 3, 2011).

<sup>14</sup> As discussed above and in Appendix A, however, hybrid systems (such as systems incorporating WLS technology) can overcome the deficiencies associated with indoor calls.

#### **IV. THE COMMISSION SHOULD FACILITATE THE DEVELOPMENT OF VERTICAL LOCATION INFORMATION.**

The Commission seeks comment in the *FNPRM* on how location information can include an accurate vertical (*i.e.*, Z-axis) component.<sup>15</sup> Polaris and its partners understand the desire to add vertical location information to the current latitude-longitude E911 horizontal reporting. No *currently mature* technology exists to meet this goal, and it is too early to adopt vertical location requirements. However, Polaris's WLS technology, with additional research and development, can provide accurate vertical location information. There are also other technologies being pursued for this purpose, either alone or in combination, by the industry.

In addition to the location technology challenges with estimating the vertical coordinates of E911 callers, there are substantial implementation and usage challenges that must be overcome for PSAPs to receive and effectively employ vertical location information. For example, PSAP call takers must be able to visualize vertical location information in computer-aided design ("CAD") or other display formats in order to dispatch personnel to the correct place. In addition, vertical location information is often best conveyed in contextual form, such as the floor number in a building, instead of a raw height estimate. Thus, significant challenges lie ahead in defining and upgrading public safety equipment, databases, and procedures in preparation for future availability of vertical information.

Accuracy requirements for the vertical dimension are also a subject of significant debate. For the horizontal dimension, accuracy of 50 meters at the 67th percentile has been deemed useful for outdoor scenarios to dispatch emergency personnel; however, it is unclear how well that metric translates to indoor call scenarios in general, and to the vertical dimension in particular. For example, to identify the floor from which an emergency call is made may require

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<sup>15</sup> *FNPRM* ¶ 23.

5 meter or better accuracy, which is an order of magnitude tighter than the current accuracy standards. The availability of new technologies to meet such demanding vertical accuracy requirements in real-world operating conditions has not been demonstrated. To meet such strict requirements may require a combination of technologies, such as combining network-based location technologies with sensors (*e.g.*, barometric pressure altimeters) in handsets. Moreover, these methods may require standards changes to make the appropriate information available to locate emergency calls.

Polaris and its partners will continue to work with the industry and the Commission towards achieving enhanced vertical location capabilities, and they encourage the Commission to facilitate stakeholder meetings to analyze these multifaceted issues.

## **V. CONCLUSION**

Polaris applauds the efforts of the Commission to facilitate the evolution and improvement of the performance of wireless caller location for emergency services. While currently available technologies can provide the accuracy needed to meet the Commission's new E911 requirements in all caller environments, no single vendor has the *total* solution, and it will only be through collaboration and hybrid technology that the Commission's E911 goals will be met. Thus, the Commission should establish a timeline for hybridization. In addition, it should work with industry groups regarding requiring indoor testing and facilitating vertical location information. Polaris and its partners have worked together and within the appropriate industry groups to further these efforts and look forward to being active participants in addressing the ongoing E911 challenges.

Respectfully submitted,

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January 19, 2011

# Appendix A

**Before the  
Federal Communications Commission  
Washington, D.C. 20554**

In the Matter of	)	
	)	
Wireless E911 Location Accuracy Requirements	)	PS Docket No. 07-114
	)	
Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems	)	CC Docket No. 94-102
	)	
Association of Public-Safety Communications Officials-International, Inc. Request for Declaratory Ruling	)	
	)	
911 Requirements for IP-Enabled Service Providers	)	WC Docket No. 05-196
	)	

To: The Commission

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August 20, 2007

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**COMMENTS OF POLARIS WIRELESS, INC.**

Polaris Wireless, Inc. (“Polaris”), through its attorneys, hereby submits its Comments in response to Section III.B of the Federal Communications Commission’s Notice of Proposed Rulemaking in the above-captioned proceeding.<sup>1</sup>

**SUMMARY**

Polaris reiterates its support for the Commission’s efforts to improve the performance of public safety E911 systems in general and to achieve greater location accuracy in particular. The goals outlined in the *NPRM* represent objectives that the entire wireless industry should strive to achieve in the interest of delivering the best possible information to the nation’s first responders in emergency call scenarios. The lines of inquiry raised by the Commission in the *NPRM* Section III.B, such as accuracy standards, location technologies, testing methods and

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<sup>1</sup> See *Wireless E911 Location Accuracy Requirements*, PS Docket 07-114, *Revision of the Commission’s Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, *Association of Public-Safety Communications Officials-International, Inc. Request for Declaratory Ruling*, CC Docket No. 94-102, *911 Requirements for IP-Enabled Service Providers*, WC Docket No. 05-196, Notice of Proposed Rulemaking, 22 FCC Rcd 10609 (rel. Jun. 1, 2007) (“*NPRM*”).

enforcement time frames, represent many of the difficult, practical challenges that must be addressed to achieve these goals. Based on its E911 Phase II research, development, deployment and testing experience, Polaris is in a unique position to comment on the important questions raised by the Commission in Section III.B of the *NPRM*, particularly those related to hybrid location technologies. By hybrid, Polaris means those systems that combine handset-based technology (typically GPS) with network-based technology (such as received signal strength measurements).

Based on Polaris's experience, hybrid systems can play a significant role in improving accuracy as a step toward meeting the Commission's stated goals in the *NPRM*. Hybrid approaches have the potential of providing more consistent accuracy performance across the wide range of environments encountered with E911 calls. This is because of the diversity benefit achieved from combining network-based technologies, which typically work best in high cell density environments (*e.g.*, dense urban), with handset-based technologies that tend to work best in open sky environments. As noted by other commenters, hybrid systems are not a panacea,<sup>2</sup> but based on Polaris's test results, hybrid systems can most certainly improve accuracy beyond current levels. The necessity to adopt hybrid approaches underpins Polaris's positions on many of the *NPRM* Section III.B issues and questions raised by the Commission.

In the overall context of the *NPRM*, the Commission should consider carefully the appropriate geographic scope of its location accuracy rules, as addressed in Section III.A, in direct relation to the accuracy standards, location technologies and testing issues raised in Section III.B. As Polaris and other commenters pointed out,<sup>3</sup> the geographic scope, location technology and testing considerations are inextricably linked to the question of meeting Phase II

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<sup>2</sup> See Comments of QUALCOMM Inc., PS Docket No. 07-114, at 6-7 (filed Jul. 5, 2007) ("QUALCOMM Comments").

<sup>3</sup> See Reply Comments of Polaris Wireless, Inc., PS Docket No. 07-114, at 3 (filed Jul. 11, 2007); Comments of Verizon Wireless, PS Docket No. 07-114, at 17-20 (filed Jul. 5, 2007) ("Verizon Wireless Comments"); QUALCOMM Comments at 5-6.

accuracy requirements at the PSAP service area level. The record being created on Section III.B should inform the Commission's future decisions with regard to Section III.A.

***About Polaris.*** Founded in 1999, Polaris is a privately held company that has developed and commercialized a wireless location software technology for the delivery of location services, including E911 Phase II public safety applications. Polaris's software products have been deployed extensively since 2003 by eleven U.S. wireless carriers in sixteen TDMA IS-136 and GSM networks to meet E911 Phase II emergency call location requirements and enhance their customers' safety. Currently, Polaris's location systems provide E911 Phase II services to about 900 PSAPs nationwide and process approximately 10,000 emergency call locates daily.

Polaris's Wireless Location Signatures (WLS) technology has several key advantages over alternative technologies: no modifications are required in the handset, as opposed to GPS/A-GPS technologies; and the location algorithms are implemented on a standard computer server, which requires no hardware additions to the base stations, as opposed to other network-based technologies such as U-TDOA (uplink time-difference-of-arrival) or AOA (angle-of-arrival) that require new radio hardware. In addition, the WLS system achieves high accuracy and reliability results due to its reliance on measurements that are made as a part of normal wireless network operations.

Because the WLS system uses serving and neighbor cell measurement information to estimate location, it is most accurate in high cell density environments where many measurements are often reported, such as dense urban and many indoor settings. Unlike other technologies, such as TDOA and AOA, WLS does not rely on line-of-sight paths between the base stations and handset, so performance can actually be improved in heavily cluttered, multipath environments. Moreover, due to its ability to leverage existing infrastructure, the initial investment to deploy an E911 solution with WLS is a fraction of the cost of alternate

technologies, and deployment times are significantly faster than what is necessary to install new radio network equipment or to replace the installed base of wireless handsets in the marketplace.

The Polaris WLS technology is based on the observation that the radio environment varies from location to location due to features such as terrain, buildings, foliage and cellular signal coverage. If enough elements of the radio environment can be measured with sufficient accuracy, each set of measured values provides a radio signature that uniquely identifies a particular location. Because the control channels of a wireless network are broadcast at a constant power (*i.e.*, the power does not vary over time), they provide a signature that is predictable and repeatable. In typical cellular networks, handsets measure the signal strengths (or signal-to-interference ratios) of serving and neighbor sector broadcast control channels for normal handover operations. These measurements form the basis of the radio signatures used to locate the handsets.

WLS is a pattern-matching technique in which the measured radio signatures from the handset are compared against a Predicted Signature Database (PSD) to estimate the user's location. The location algorithms use the predicted signal strength values in the PSD and the time series of measurements from the handset to calculate the probability distribution of the handset's location. Polaris has implemented a location algorithm primarily based on relative signal strength that mitigates the effects of any biases that are common to all channels. When the algorithm has processed the time series of measurements currently available, it will have calculated the probability that the handset is at each point in the array of possible locations. When a new measurement becomes available, the algorithm uses its knowledge of the possible motions of the handset during the time period between the last measurement and the new measurement to predict a new location probability distribution.

WLS is well-suited to provide high accuracy in urban and indoor situations because of its unique ability to take advantage of shadowing conditions that can degrade other approaches that

rely on line-of-sight circumstances, such as TDOA, AOA and GPS. First, urban areas typically contain extremely high cell densities because of the large concentrations of wireless users; therefore, many neighbor measurements are reported in the signatures, enabling especially accurate location estimation. Second, through use of radio propagation modeling, geographical information system data and measurements, the PSD contains information about local shadow fading conditions, which is particularly critical in urban areas where non-line-of-sight conditions are predominant due to extensive building obstructions and clutter. As Professor Henry Bertoni, a noted radiowave propagation researcher at Polytechnic University, observed for pattern-matching location-signature approaches (using the terminology Power Signature), “[a]nother urban location technology gaining attention is known as the Power Signature (PS) method. . . Power signatures contain information about the shadowing of the signals by the buildings surrounding the mobile. To the extent that this shadowing is unique to each mobile location the shadowing information can serve to locate the mobile.”<sup>4</sup>

In addition, the PSD contains information about predicted radio signal penetration into local buildings that can be used for indoor location estimation. As Professor Gregory Durgin from the Georgia Institute of Technology observed from his research and field testing, “[t]he [received signal strength method] technique is particularly powerful for locating and discriminating indoor users, which is not possible for other triangulation techniques.”<sup>5</sup> He further noted that, “[a]n extensive measurement campaign conducted on the Georgia Tech campus indicates that RSS [received signal strength] location techniques can locate handset calls

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<sup>4</sup> See H. L. Bertoni and J. W. Suh, “Simulation of Location Accuracies Obtainable from Different Methods,” Institute for Electrical and Electronics Engineers 62nd Vehicular Technology Conference, Sept. 25-28, 2005, Proceedings Volume 4 at 2196-2200.

<sup>5</sup> See J. Zhu and G. D. Durgin, “Indoor / Outdoor Location of Cellular Handsets Based on Received Signal Strength,” *Electronics Letters*, Jan. 6, 2005, Volume 41, Number 1.

within 100 meter error distance to its ground truth 78% of the time for a network with a majority of indoor users.”<sup>6</sup>

## **I. THE OVERALL ACCURACY AND CONSISTENCY OF E911 PHASE II SYSTEMS CAN BEST BE ACHIEVED THROUGH THE APPLICATION OF HYBRID TECHNOLOGIES**

Fundamentally, Polaris’s experience indicates that the overall accuracy and consistency<sup>7</sup> of E911 Phase II systems can be improved through the application of hybrid technologies, combining network-based and handset-based elements. As the record on this *NPRM* demonstrates, hybrid systems cannot solve all of the complex and varied challenges associated with achieving PSAP-level accuracy compliance. However, Polaris believes that the Commission’s overarching goal of improving E911 Phase II accuracy can best be achieved by adopting hybrid approaches. Therefore, the evolution to hybrid systems underpins Polaris’s viewpoints on the fundamental questions raised in the *NPRM*’s Section III.B, such as deferred enforcement, accuracy standards, and compliance time frames.

Polaris does not believe that it is possible to meet the Commission’s goals of improving E911 Phase II accuracy within short time frames by using new and unproven handset-based technologies. For example, approaches using other GPS-alternative satellite systems (*e.g.*, GLONASS), future satellite proposals (*e.g.*, Galileo), unlicensed band wireless local networks (*e.g.*, WiFi IEEE 802.11a/b/g), or other terrestrial signal sources (*e.g.*, broadcast TV stations) all require significant handset changes. None of these handset-based approaches solves all the issues raised in the *NPRM*. For example, the availability of more satellites does not address problems with urban multipath reflections and deep indoor scenarios, unlicensed band networks are uncoordinated and ever-changing, and broadcast signals do not always provide the geometric

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<sup>6</sup> *Id.*

<sup>7</sup> Both location estimation accuracy and consistency are critical to providing reliable and trustworthy E911 Phase II location information to PSAPs. Approaches that reduce gross errors (*i.e.*, outliers) can be extremely valuable.

diversity needed for accurate location measurements. In order to enter commercial service, these approaches would need to be tested, proven practical, standardized in industry bodies, built into commercial handsets, and then rolled out to the mass market. These steps would take a number of years, resulting in a much longer time needed to positively impact public safety accuracy. In contrast, hybrid systems represent a faster, more orderly and efficient evolution to increased accuracy for E911 Phase II systems.

New developments in state-of-the-art satellite navigation deserve particular comment. Galileo, an ambitious and admirable undertaking being developed by the European Union,<sup>8</sup> represents a particularly high-risk path to a reliable E911 service. Indeed, this year the European Union made fundamental changes to Galileo's plans to recover costs.<sup>9</sup> Up until this summer, Galileo sought to realize a Public-Private Partnership (PPP), in which the general tax fund would pay for the deployment of the system, and users would pay for the operation and maintenance of the system (at a cost of several hundred million dollars per year). No suitable business arrangement could be made, however, and the European Transport Ministers recently scrapped this approach and called for a re-planning to realize a navigation system wholly funded by the public. In view of this recent sea change, the Galileo operational date of 2010 seems optimistic. Indeed, closer followers of Galileo are hinting that 2014 would be the earliest possible operational date.

GLONASS, the satellite navigation system operated by Russia, also suffers from appreciable financial uncertainty.<sup>10</sup> Indeed, GLONASS dwindled from a 25-satellite constellation in December 1995 to fewer than six satellites in November 2002. Today,

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<sup>8</sup> See, e.g., "Galileo: European Satellite Navigation System," at [http://ec.europa.eu/dgs/energy\\_transport/galileo/index\\_en.htm](http://ec.europa.eu/dgs/energy_transport/galileo/index_en.htm).

<sup>9</sup> See, e.g., "Europe to Fund Galileo Satellite Navigation System; Junks Private Consortium," *SatNews Daily*, May 18, 2007, available at <http://www.satnews.com/stories2007/4472/>.

<sup>10</sup> See, e.g., "Radical Change in the Air for GLONASS," *GPS World*, January 22, 2007, at <http://www.gpsworld.com/gpsworld/article/articleDetail.jsp?id=399504>.

GLONASS has 12 satellites in orbit, and the probability of achieving a successful position fix using GLONASS is approximately 33% (even under open sky). GLONASS may be enjoying a resurgence, however, as its planners claim that 18 satellites will be in orbit by the end of 2007 and that the constellation will utilize a full 24 satellites by the end of 2009. Unfortunately, GLONASS employs a multiple-access scheme that differs markedly from that used by GPS or proposed for Galileo. Thus, the handset receiver implementations will be appreciably different than that required for GPS, and the costs would reflect this serious complication.

GPS itself is being modernized. New GPS satellites carry a second civil signal at the so-called L2 frequency. In fact, three such satellites are included in the current constellation of 30 GPS satellites. Commencing in 2008, new GPS satellites will broadcast three civil signals. However, the constellation will not be fully populated with this new capability until 2016 at the earliest.

Even if all of these new satellite resources are deployed and combined (*e.g.*, creating a future handset-based system that used GPS, GLONASS and Galileo satellite signals together), the aggregation of signal power across three frequencies and three constellations will only result in a 10 dB improvement in signal power. Perhaps advanced signal processing of the so-called data-free components in the new satellite signals will provide another 6 dB of gain. While helpful, this potential gain of 16 dB is less than the loss experienced due to a single floor, exterior wall or tinted glass window in a modern office building, and will provide little improvement in the probability that the satellite signals will reach the distressed user of E911 calling from inside a building. Thus, Polaris strongly believes that some of the improved E911 capability must come from both space-borne and terrestrial sources working in concert together as a hybrid system.

Other handset-based approaches using terrestrial signal sources, such as WiFi IEEE 802.11 Wireless Local Area Networks (WLANs) or broadcast TV stations, are constrained by

time-to-market and technical limitations. For example, WiFi WLANs for consumers, enterprises and public entities operate in a shared manner using unlicensed bands. These networks are unplanned (*i.e.*, deployment and placement of access points are not coordinated, managed or catalogued by a single source). On the other hand, cellular networks are planned by wireless service providers operating in licensed bands; therefore, base station information (*e.g.*, location, height, antenna type, transmit power, channels) is known and controlled. Estimating position, particularly indoors, based on WiFi WLAN signals is problematic because of the unknown, changing and transitory nature of WiFi access points in unplanned networks. In addition, there are battery life, cost and time-to-market constraints associated with adding WiFi capabilities to commercial handsets on the mass scale required for E911.

Approaches using broadcast TV signals face similar challenges with integrating new TV tuner functionality into handsets, since broadcast TV services operate at different frequency bands than CMRS networks, necessitating radio hardware (*e.g.* filters, antennas, low noise amplifiers) and signal processing changes in handsets. In many markets, broadcast TV station towers are not geometrically diverse because the transmitter sites tend to be congregated near each other at geographically high locations. Without geometric diversity of TV signal sources, position estimation accuracy is degraded due to the well-known effects of geometric dilution of precision. Therefore, Polaris believes the best hybrid approach to improve E911 Phase II accuracy in practical timeframes combines information from network-based (terrestrial cellular networks) with handset-based (satellite A-GPS) systems.

As noted in Polaris's prior comments, currently deployed E911 Phase II location technologies cannot practically and economically meet the Commission's goal of compliance at the PSAP level in some cases, and it will take time for wireless carriers and location system vendors to develop new technologies, such as hybrid approaches. There are numerous and considerable challenges that wireless carriers must still overcome to achieve PSAP-level

accuracy in their networks, including those faced by network-based technologies in sparse rural areas and handset-based technologies in dense urban and indoor areas.

## **II. THE COMMISSION SHOULD ONLY REQUIRE A SINGLE LOCATION ACCURACY REQUIREMENT IF IT IS A HYBRID SOLUTION**

Although the Commission tentatively concluded in paragraph 9 of the *NPRM* that a single location accuracy requirement would best serve the public interest, Polaris finds that this is only appropriate as part of a hybrid solution. The prior record before the Commission on E911 Phase II clearly established the fundamental physics differences between handset-based technologies using satellites and network-based systems using terrestrial networks.<sup>11</sup> These underlying differences and their impact on accuracy have not changed in the intervening years and remain true today. Although some underlying technologies, such as signal processing algorithms, have improved, they have tended to do so for both handset-based and network-based technologies. Accordingly, should the current network-based and handset-based paradigm remain in place, a single accuracy requirement is not appropriate. Once hybrid systems are widely available in the marketplace, however, the distinction between handset-based and network-based solutions will effectively dissolve. Only at that point would it be appropriate for the Commission to adopt a single location accuracy requirement.

Because of the numerous challenges and uncertainty of success identified in the record with regard to achieving PSAP-level accuracy compliance,<sup>12</sup> Polaris believes it is best to first address the accuracy improvement mechanisms under the current bifurcated approach before the Commission considers introducing additional complexity by unifying the accuracy requirements.

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<sup>11</sup> See, e.g., Verizon Wireless Comments at 3, 16.

<sup>12</sup> See Comments of Polaris Wireless, Inc., PS Docket No. 07-114, at 6-8 (filed Jul. 5, 2007); QUALCOMM Comments at 5-6.

### **III. THE IDEAL HYBRID SOLUTION IS TO PAIR A NETWORK-BASED AND A HANDSET-BASED TECHNOLOGY**

Polaris has much to add to the record in response to the *NPRM*'s questions regarding location technologies (paragraph 11), including current performance and future improvements possible with hybrid systems. Polaris views a hybrid solution as the best long-term approach to improve location accuracy and consistency. Although there are many conceivable hybrid combinations of different technologies to improve accuracy, Polaris considers the ideal hybrid solution to be the pairing of a network-based and a handset-based technology. The foundation for improving location accuracy in a hybrid system is the introduction of measurement diversity, which reduces the detrimental impacts of errors (particularly large outliers). The best diversity is achieved when the measurements are derived from systems in which the errors are not correlated. For example, combining one network-based technology with another would not optimally improve location accuracy because the errors would tend to be correlated. Network-based technologies have errors that vary based on terrestrial cell site densities and geometries (among other factors), so different network-based technologies may tend to experience large errors in similar locations. However, handset-based technologies have errors that vary based on satellite densities and geometries (among other factors). Thus, combining a network-based technology with a handset-based technology results in better accuracy benefits because the terrestrial cell site and satellite configurations are independent of one another (*i.e.*, not correlated).

The hybrid solution leverages the strengths of two highly complementary technologies, particularly when combining handset-based A-GPS with a network-based pattern-matching technology such as Polaris's WLS approach. Polaris's WLS location information is less correlated with handset-based A-GPS than other network-based technologies, such as U-TDOA or AOA, in urban environments. Urban shadowing that leads to multipath conditions can cause

location errors in A-GPS systems, as well as in U-TDOA or AOA systems; however, urban shadowing improves the location accuracy of Polaris's WLS.

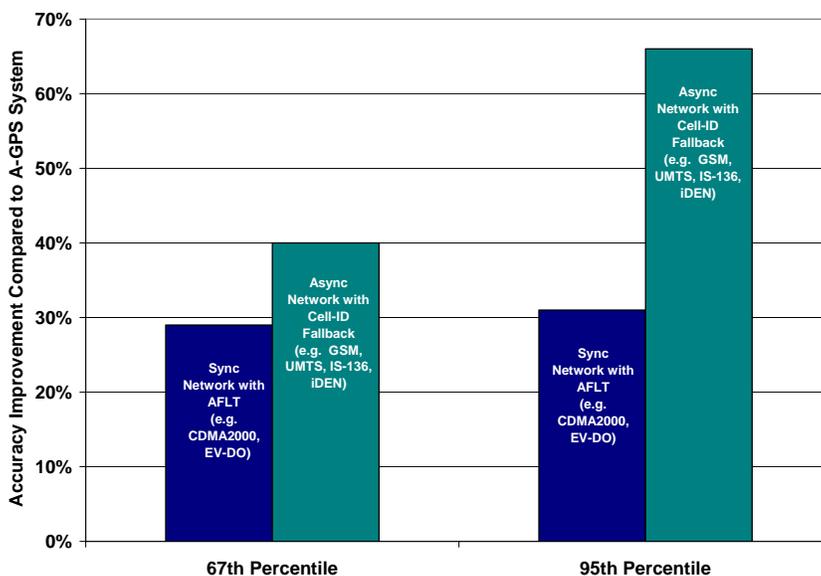
In hybrid systems, pattern-matching technologies, such as Polaris's WLS method, can produce accuracy improvements with potential advantages in performance, without the cost and complexity of U-TDOA or AOA. Both U-TDOA and WLS are network-based technologies with accuracies that depend on cell tower (base station) densities and geometries, so they typically perform best in high cell density scenarios. TDOA methods, such as U-TDOA, depend on direct line-of-sight propagation from the base stations to the handsets to estimate the differences in times-of-flight. This means that they can be impacted negatively by obstructions that block or shadow the line-of-sight paths, such as buildings in urban scenarios. On the other hand, pattern-matching technologies such as WLS can take advantage of shadowing effects to improve accuracy (rather than be degraded by them). Therefore, WLS represents a better network-based approach for combining with handset-based methods in a hybrid combination to produce accuracy improvements.

The Polaris WLS pattern matching system achieves its best accuracy in high cell density and cluttered environments, such as urban outdoor and indoor locations. In contrast, A-GPS achieves its best performance in open sky conditions, such as outdoor suburban and rural settings, where several satellites are visible in line-of-sight to the handset. Polaris's hybrid system uses information from both WLS and A-GPS to provide more consistent accuracy across the range of environments.

Polaris has conducted a number of field tests to assess the potential performance improvements of hybrid systems, compared to existing handset-based systems (commercial A-GPS systems which fallback to Cell-ID or Advanced Forward Link Trilateration [AFLT])

technologies). These tests have been conducted predominantly in dense urban, urban, and indoor areas, where satellite-based systems may experience challenges with obstructions. The results from several of these trials are consolidated in the bar chart of Figure 1 and illustrate the percent improvement expected from a hybrid system using WLS at the 67<sup>th</sup> and 95<sup>th</sup> percentiles. The percentage improvements in accuracy vary from about 30% to over 65%, depending upon the type of existing network and A-GPS system; these numbers represent significant performance gains that could be harnessed to drive accuracy and consistency improvements.

Separate bar chart entries in Figure 1 are shown for hybrid systems on asynchronous networks (cellular networks where the base stations are not synchronized in time) and synchronous networks (cellular networks where the base stations are synchronized in time using a precise reference clock). Performance of A-GPS is expected to be better (in terms of accuracy, time to fix, and location yield) in synchronous networks, where the cellular network's time reference information can be used to aid the handset in acquiring the satellite signals. Currently deployed CDMA2000 networks are synchronous networks, where the A-GPS system uses AFLT for the position fix fallback. Many asynchronous networks, such as GSM, UMTS/WCDMA and iDEN, use Cell-ID or similar network technologies as fallbacks when A-GPS position fixes are not available. In general, AFLT provides better accuracy performance than Cell-ID. As Figure 1 shows, the improvements of hybrid systems using WLS are expected to be higher on asynchronous networks using A-GPS with Cell-ID than for synchronous networks using A-GPS with AFLT; these measured differences are believed to be caused by the reasons outlined above.



**Figure 1.** Expected Accuracy Improvement of Hybrid System using WLS Compared to Existing A-GPS Systems from Field Tests in Dense Urban, Urban and Indoor Areas

While the expected performance improvement of hybrid systems with WLS, based on these test results, is promising and significant, further testing is required in different environments and conditions. The evolution to hybrid systems does not guarantee that PSAP-level accuracy will be achieved in each and every case, but it is critical that the industry seize the major improvements that are available. Industry stakeholder groups, such as the E911 Technical Advisory Group (ETAG) proposed by AT&T,<sup>13</sup> would be excellent forums to exchange test data and compare test methodologies, since different systems need to be compared on a level playing field and across a broad range of scenarios.

On the performance of handset-based systems, the record in this proceeding contains assessments from several commenters with expertise and experience using the technology. For example, Qualcomm, the pioneer of A-GPS technology, stated unequivocally that “AGPS cannot

<sup>13</sup> See Comments of AT&T, PS Docket No. 07-114, at i (filed Jul. 5, 2007).

today, nor in the foreseeable future, meet the E911 Phase II accuracy requirements in each and every PSAP on a PSAP-by-PSAP basis.”<sup>14</sup>

Verizon noted that due to the limitations of GPS technology, PSAP level accuracy is technically infeasible. It stated that “because of the physical limitations on satellite signal propagation where there are ground-based obstructions, there are PSAPs where compliance with 150 meter/95% threshold is infeasible.”<sup>15</sup> Adding further clarification, Verizon stated, “GPS solutions are generally challenged, however, in situations where satellite visibility is poor, such as dense forest, medium and high density urban areas and indoor permanent structures.”<sup>16</sup> “GPS satellite transmission signals at 1.5 GHz are low power and do not penetrate structures or dense forest areas as well as signals lower in the frequency spectrum, resulting in loss of GPS signals from in-building callers and remote users areas.”<sup>17</sup> Finally, Verizon noted that, “a clear view of the sky is critical for achieving the Commission’s accuracy requirement for handset solutions.”<sup>18</sup>

For indoor scenarios, Verizon has stated that “[i]ndoor GPS solutions generally only have the ability to travel through a single sheetrock wall, with the most advanced GPS techniques only providing an extra 6-10 feet of penetration within a building.”<sup>19</sup> In relation to outdoor accuracy in urban areas, Verizon stated that “dense urban areas with many buildings will preclude test calls from assessing a sufficient number of GPS satellites. Test calls made on sidewalks and street corners will ‘see’ only portions of the sky. Depending on the slice of the sky that is visible, accuracy within 150 meters may not be possible . . . Even parts of the cities away from buildings

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<sup>14</sup> See Qualcomm Comments at 4.

<sup>15</sup> See Verizon Wireless Comments at 14.

<sup>16</sup> *Id.* at 17.

<sup>17</sup> *Id.* at 18.

<sup>18</sup> *Id.*

<sup>19</sup> *Id.*

will not be able to achieve accuracy due to tree cover, overpasses, and other obstacles.”<sup>20</sup>

Verizon added that “For AGPS solutions, concentrations [of calls] in dense urban areas (with poor satellite visibility and multipathing) will make meeting the 95% accuracy level very difficult.”<sup>21</sup>

Verizon’s real-world findings are wholly consistent with what would be concluded from a first principles engineering analysis. A-GPS provides two varieties of assistance (*i.e.*, the ‘assist’ part of Assisted-GPS). First, A-GPS provides an alternate delivery of the contents of the navigation message normally provided by the GPS satellite signals. This assistance is valuable, because the satellite uses a very low transmission rate of only 50 bps. Thus, the entire message can consume 30 seconds while transmitting all the needed data. Needless to say, an uninterrupted 30-second window is unlikely in an urban canyon. Second, A-GPS provides data to extend the averaging time of the roving receiver. This data includes the Doppler shifts for the satellites in view, and/or the actual navigation bits that are currently being broadcast.

This second variety of assistance allows GPS receivers to operate in more challenging radio environments, but the improvement is not large compared to the losses introduced by the floors, walls or tinted glass windows of buildings (or combinations of other typical obstructions encountered inside buildings, such as partitions, pillars, soft walls, furniture, and cabinets). Under open skies, GPS signal-to-noise ratios are typically 40 dB-Hz. With A-GPS assistance, GPS receivers can tolerate signal-to-noise ratios of 14 to 16 dB-Hz.<sup>22</sup> However, a single floor, exterior wall or tinted glass window in a modern office building may introduce 20 dB or more of loss, so that the building structure quickly overcomes the gain provided by A-GPS.

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<sup>20</sup> *Id.* at 21.

<sup>21</sup> *Id.* at 20.

<sup>22</sup> See Misra and Enge, “Global Positioning Systems: Signals, Measurements and Performance,” Ganga-Jamuna Press, 2006

Sprint Nextel stated that for their handset-based A-GPS location systems, “[t]he ability to obtain a location fix can be affected by numerous factors outside the carrier’s control, including, but not limited to: time of day, time of year, weather, geographic features, the proximity of buildings, the speed at which the handset is moving, whether the handset is inside a building, under a tree canopy, inside an automobile, the quality of voice coverage (which impacts the delivery of data), the number of towers available, etc. Once one or more of these factors comes into play, the accuracy of the solution can begin to vary widely.”<sup>23</sup>

To be balanced, it should be pointed out that while handset-based systems face challenges predominantly in urban and indoor areas, network-based systems face equally difficult challenges in low cell density environments, such as sparse rural areas. The record also contains many comments in this regard. As previously noted, handset-based systems could benefit from hybrid elements in urban and indoor situations, while network-based systems could benefit from hybrid features in rural and low cell density scenarios. Neither system alone is likely to meet the Commission’s objectives of improving accuracy performance, particularly to the PSAP-level.

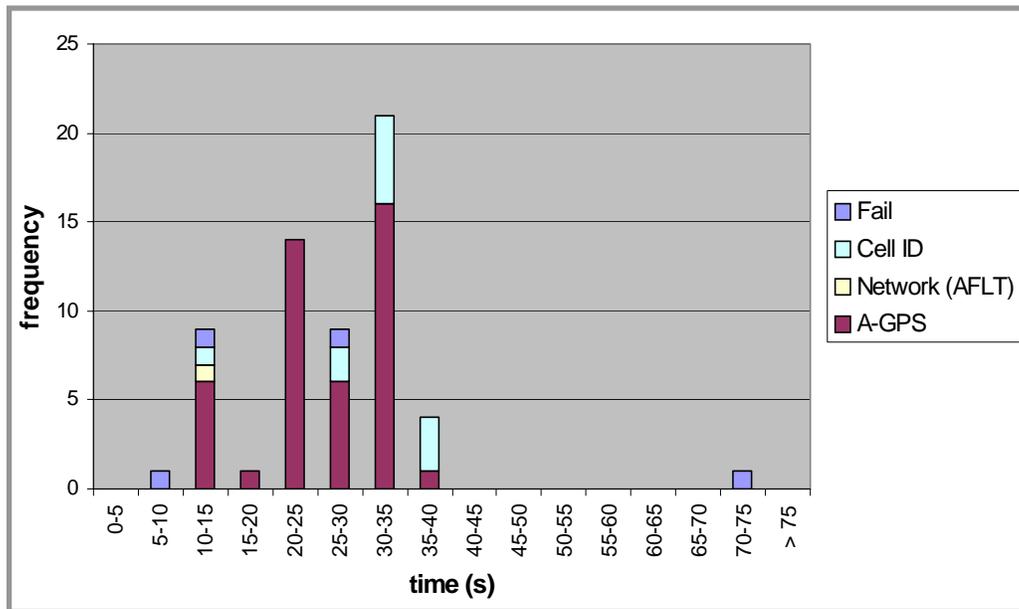
The public domain industry literature also contains some assessments of A-GPS performance. Location yield and accuracy are factors to consider in evaluating performance of a system, but another critical consideration is the time latency of the location fixes. The E911 Phase II application requires location fixes within a 30-second time window. In challenging urban and indoor environments, A-GPS can take an unacceptably long time to obtain a position estimate. This is illustrated in the bar chart in Figure 2 from Helios Technologies, based on its testing of A-GPS systems in Tokyo, Japan.<sup>24</sup> The horizontal axis is the time required for the handset to produce a position fix. The colored bars show the frequency of calls where an A-GPS

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<sup>23</sup> See Comments of Sprint Nextel, PS Docket No. 07-114, at 11 (filed Jul. 5, 2007).

<sup>24</sup> See A. Sage, “The Practical Reality of Today’s Positioning Systems and Their Implications for E112,” Helios Technologies Ltd., EENA Conference, Brussels (Dec. 2, 2004).

fix was achieved (magenta), network-based AFLT fall back was used (tan), Cell ID fall back was used (light blue), and failure to produce any estimate (blue). In these outdoor urban tests, the time for A-GPS to produce a position estimate from a cold start was often more than 30 seconds, with some calls taking as long as 40 seconds to locate.



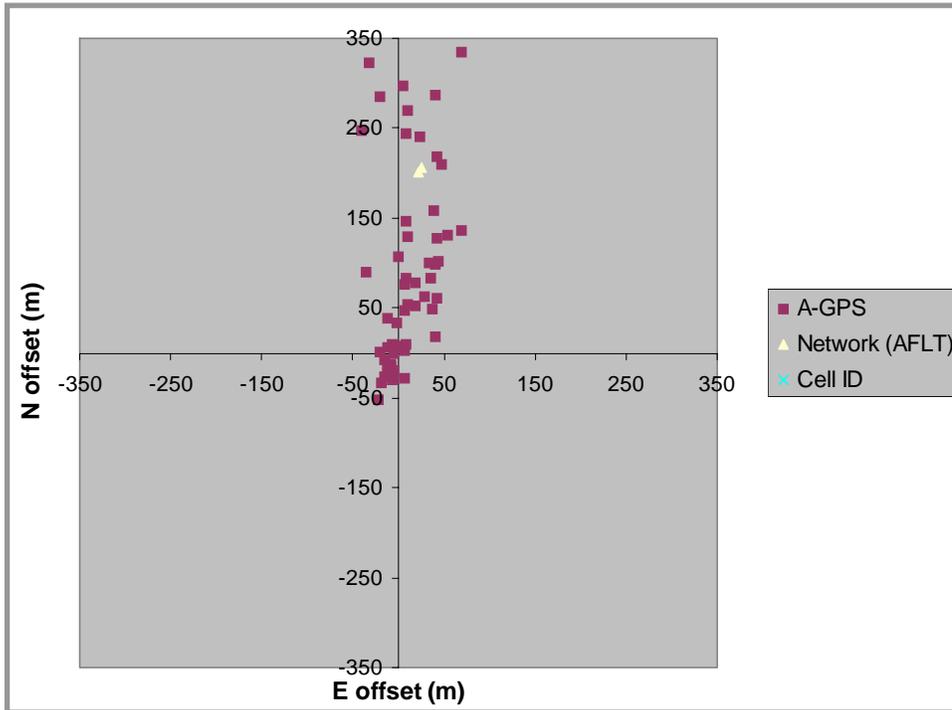
**Figure 2.** Time Latency of A-GPS Location Fixes in Tokyo, Japan Field Testing<sup>25</sup>

In addition to the location fix time delays noted in the outdoor latency results above, the Helios indoor tests in Tokyo, Japan, obtained results reflecting “virtually 0% A-GPS yield across a range of indoor scenarios.” In separate indoor testing done by Polaris in New York City (Manhattan), the WLS system was able to locate 100% of indoor calls, with the resulting accuracy within 30% of that obtained outdoors.

In urban and indoor settings, even when A-GPS can produce a position estimate, it may not be of sufficient accuracy. In obstructed situations, the signals measured by the A-GPS handset may be corrupted by multipath reflections from distant buildings or walls. The result is

<sup>25</sup> See *id* at 19.

potentially large A-GPS errors. This is illustrated in the scatter plot of Figure 3 from the same Helios Technologies EENA conference presentation. The plot shows the position accuracy variation over time for a specific outdoor urban Tokyo, Japan test location where numerous test calls were located. The magenta squares show the A-GPS position estimate, where the center crosshair (0,0 meters) represents the ground truth location. The horizontal and vertical axes depict North-South and East-West errors, respectively, in meters. One can see that the A-GPS errors vary widely, with maximum errors of over 350 meters. The large error variations over time presumably were due to the ever-changing satellite geometries, handset movements and other factors affecting the local multipath reflections and signal levels. These are precisely the types of location estimation inconsistencies that potentially could be addressed by adopting hybrid systems.



**Figure 3.** Accuracy of A-GPS Location Fixes in Tokyo, Japan Field Testing<sup>26</sup>

<sup>26</sup> See *id* at 18.

#### **IV. NOTHING IN THE RECORD INDICATES THAT TECHNOLOGIES EXIST TO SUPPORT A STRICTER STANDARD THAN THE CURRENT HANDSET-BASED STANDARD**

Regarding the *NPRM*'s questions on accuracy standards (paragraph 12), nothing in the record indicates that practical technologies exist to support a standard tighter than the current handset-based level of 50 meters for 67% of calls and 150 meters for 95% of calls. As the Commission pointed out, wireless location technology has advanced since the current location accuracy standards were adopted in 1999. However, it is important to recognize that views on testing methods and compliance measures have also changed considerably. This is readily evident from the current debate regarding PSAP-level accuracy performance. Indoor testing is another area that was not clearly identified or defined in 1999, but has grown in relative importance due to wireless substitution of wireline communications. Finally, in the 1999 time frame the industry did not have real-world experience with the location technologies across the broad range of environments and call scenarios. Therefore, Polaris does not find justification for adopting accuracy standards more stringent than current levels; there is no indication that more stringent standards are technically or economically feasible.

On the question of including additional information, such as elevation, Polaris does not know of a practical and economical solution to estimate elevation accurately at this time. Polaris is actively researching the issue and conducting field tests. There are fundamental physics limitations (including geometrical dilution of precision) associated with accurately estimating elevation using typical terrestrial cellular network and satellite approaches. We are aware of methods using barometric pressure sensors such as altimeters to estimate elevation, but these methods run into practicality, reliability and accuracy issues when contemplated for widespread use in consumer wireless E911 applications. For example, significant air pressure variations exist within typical buildings, which could result in erroneous altitude readings, particularly in

elevators. In addition, accuracy requirements for elevation may be different than for horizontal (latitude, longitude) location, as might be needed to identify from which floor within a multistory building an emergency call was placed. The Commission, along with industry stakeholders' groups, should first consider whether new accuracy requirements are necessary for the vertical elements. Tackling the vertical dimension will require significant research prior to identifying and testing feasible solutions. Therefore, Polaris believes that including additional information, such as elevation, into the Commission's E911 standard would be extremely premature.

#### **V. THE COMMISSION SHOULD INCORPORATE PREVIOUS WORK PRODUCT ON E911 TESTING METHODS AND PROCEDURES INTO THE E911 ACCURACY IMPROVEMENT PROCESS**

To answer the *NPRM*'s compliance testing questions in paragraph 14, it should be noted that significant industry effort has already gone into E911 compliance testing methods and procedures, such as the work done by the Emergency Services Interconnect Forum<sup>27</sup> and the National Reliability & Interoperability Council.<sup>28</sup> To make rapid and efficient progress, the Commission should also incorporate these previous work products into the overall E911 accuracy improvement process. For example, the ESIF E911 Test Methodologies document contains a strong section on achieving statistical significance in testing, which could help to answer the Commission's question on the required numbers of test points.<sup>29</sup> The NRIC Focus Group 1A recommendations provide guidance on the percentage of indoor calls, which could inform the Commission's question on the level of indoor versus outdoor testing.<sup>30</sup> Polaris

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<sup>27</sup> See Emergency Services Interconnect Forum Technical Report, ATIS 0500001, *High Level Requirements for Accuracy Testing Methodologies*, (Jul. 23, 2004) available at <http://www.atis.org/esif/docs.asp> ("ESIF E911 Test Methodologies Report").

<sup>28</sup> See National Reliability Interoperability Council VII, Focus Group 1A Near Term Issues for Emergency/E911 Services, Final Report (Dec. 2005), available at <http://www.nric.org/fg/index.html> ("NRIC Focus Group 1A Report").

<sup>29</sup> See ESIF E911 Test Methodologies Report at 7-11.

<sup>30</sup> See NRIC Focus Group 1A Report at 24.

believes that the foundation for compliance testing has already been laid through a combination of OET 71, ESIF E911 Test Methodologies, and the NRIC Focus Group 1A Report. The Commission should rely on these excellent resources as the starting point to avoid “reinventing the wheel.” Industry stakeholders groups, including possibly ETAG, ESIF and NRIC, would be the forums to evaluate and propose any changes.

## **VI. THE COMMISSION SHOULD DEFER ENFORCEMENT OR THE EFFECTIVE DATE OF ANY NEW COMPLIANCE RULES FOR FIVE YEARS**

On the questions raised in the *NPRM* on deferred enforcement (paragraph 8) and on the appropriate compliance time frame (paragraph 13), Polaris believes that any new compliance rules adopted by the Commission must be accompanied by a deferral period (or a stay of the effective date). Because accuracy needs to be improved beyond current levels, and hybrid systems are the best solution to provide reliable accuracy performance, network-based operators will be required to deploy complementary handset-based solutions and *vice versa*. For wireless carriers that are currently using network-based approaches, the availability of A-GPS capable handset devices then becomes a major factor to consider. Some radio air interface technologies, such as GSM, do not currently have a wide variety of A-GPS handsets on the market at reasonable prices for most consumers. While Polaris is not a handset vendor and cannot comment on handset development times and market availabilities, historical examples would indicate that it takes one or more years for added technologies, such as A-GPS, Bluetooth and WiFi, to be deployed in commercial devices and available in large quantities. To reach the desired customer penetration rates, numerous different terminal device models must be available to suit the widely varied tastes and price points in the marketplace. After the handsets reach the marketplace, it will take significant time for the carriers’ distribution channels and market forces to diffuse large numbers of devices into the customer populations, as was seen with the rollout of handset-based E911 Phase II systems.

Historical precedent from the experiences of wireless carriers that have deployed E911 Phase II handsets indicates that five years from the effective date of new rules would be required for this process to achieve a high level of penetration.<sup>31</sup> Currently, wireless carriers that are using handset-based solutions for E911 Phase II would have to deploy network-based complementary technologies for hybrid technologies. Although it is expected that the amount of time necessary for this rollout or upgrade would be less than for rolling out new handset-based technologies, it still would require significant time, the amount of which would depend on the network-based technology selected. Accordingly, Polaris believes that five years from the effective date is a reasonable amount of time for the Commission to permit network-based carriers to implement hybrid technologies; less time, perhaps two or three years, could be required for current handset-based carriers.

## CONCLUSION

Polaris appreciates the Commission's efforts in the *NPRM* to seek public comment on these crucial E911 Phase II matters and strongly believes that the hybrid solution combining network-based and handset-based technologies is by far the best approach to achieve the desired outcome of consistent accuracy across urban, suburban, rural, outdoor, and indoor scenarios. Any rules resulting from the *NPRM* should drive the wireless industry toward the most efficient methods of directly implementing hybrid systems without wasting resources on interim methods that do not achieve the Commission's ultimate objectives. Based on these intimate technology linkages, the compliance issues raised in *NPRM* Section III.A cannot be evaluated separately

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<sup>31</sup> See, e.g., *Revision of the Commission's Rules To Ensure Compatibility with Enhanced 911 Emergency Calling Systems, Phase II Compliance Deadlines for Non-Nationwide CMRS Carriers*, Order to Stay, CC Docket No. 94-102, 17 FCC Rcd 14841, 14842 ¶ 5 (2002) (the Commission "recognized that the E911 deployment schedule was aggressive in light of the need for further technological advancement..."); *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Fourth Memorandum Opinion and Order, CC Docket No. 94-102, 15 FCC Rcd 17442 (2000); *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Third Memorandum Opinion and Order, CC Docket No. 94-102, 14 FCC 17388 (1999).

from the technology and testing lines of inquiry in Section III.B, and the Commission should determine the appropriate geographic area for E911 Phase II accuracy and testing requirements in the context of the broader proceeding.

Due to the fact that currently deployed E911 Phase II location technologies cannot practically and economically meet the Commission's goal of geographical service area compliance at the PSAP level in some cases, it will take time for wireless carriers to bring new technologies, such as hybrid approaches, to bear on the problem at hand. Therefore, if the Commission determines that Section 20.18(h) requires E911 measuring and testing at the PSAP service area level, it should defer enforcement or stay the effective date of the PSAP-level accuracy requirements until carriers have an opportunity to deploy hybrid networks. A deferral or stay of approximately five years from the Commission's adoption of new rules would be appropriate for current network-based carriers, because currently deployed E911 location technologies will require time to be upgraded to hybrid systems. The Commission should also facilitate stakeholder meetings to discuss location accuracy issues and assess the best methods of improving accuracy and promoting public safety and homeland security.

Respectfully submitted,

**POLARIS WIRELESS, INC.**

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Its Attorneys

August 20, 2007

**Before the  
Federal Communications Commission  
Washington, D.C. 20554**

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

**COMMENTS OF POLARIS WIRELESS, INC.**

Polaris Wireless, Inc. (“Polaris”),<sup>1</sup> through its attorneys, hereby submits its Comments in response to the Federal Communications Commission’s (“FCC” or “Commission”) Public Notice seeking to refresh the record in the above-captioned proceeding regarding location accuracy standards for wireless Enhanced 911 (“E911”) calls.<sup>2</sup> Polaris supports the Commission’s decision to refresh the record in light of continued technology and industry advancements affecting what is achievable with E911 Phase II systems. Although wireless E911 Phase II has been a demonstrable area of technical innovation and leadership for the United States, the absence of any recent significant E911 Phase II rulemaking developments may allow other countries and regions of the world to leapfrog the United States in this area of critical public safety importance.

Polaris strongly supports the efforts of the Commission, public safety groups, wireless carriers, and vendors to improve the accuracy and reliability of E911 Phase II systems. The proposals in the record to achieve compliance at the county level clearly indicate that continued

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<sup>1</sup> Founded in 1999, Polaris is a privately held company that has developed and commercialized a wireless location software technology for the delivery of location services, including E911 Phase II. Polaris’s software products have been deployed extensively since 2003 in 20 GSM and IS-136 networks covering 39 states to meet E911 Phase II emergency call location requirements and enhance customer safety. As deployed, Polaris’s software-only location systems provide E911 Phase II services to about 1,000 PSAPs nationwide and process more than 10,000 emergency call locates daily. In addition, Polaris’s location systems have been deployed on three carriers’ UMTS networks in the Asia-Pacific region for lawful interception applications.

<sup>2</sup> *Public Safety and Homeland Security Bureau Seeks to Refresh the Record Regarding Service Rules for Wireless Enhanced 911 Phase II Location Accuracy and Reliability*, PS Docket No. 07-114, Public Notice, DA 09-2397 (rel. Nov. 6, 2009) (“*Public Notice*”). All filings referenced herein were submitted in PS Docket No. 07-114.

progress is possible,<sup>3</sup> but they fail to take full advantage of the technical solutions that have been trialed and are readily available to more rapidly address the current challenges in urban and indoor areas. Polaris notes that technical solutions can be applied in the near term to: (1) realize county-level accuracy in urban areas; and (2) achieve better indoor performance in urban areas.

***The Benefits of Wireless Location Signatures Technology.*** Polaris's Wireless Location Signatures ("WLS") technology has several key advantages over alternative location technologies: (1) no modifications are required in the handset; and (2) the location algorithms are implemented on a standard computer server, which requires no hardware additions to the base stations, as opposed to other network-based technologies such as U-TDOA (uplink time-difference-of-arrival) or AOA (angle-of-arrival) that require a new radio hardware overlay. In addition, the WLS system achieves high accuracy and reliability results, particularly in urban environments, due to its reliance on measurements that are made as a part of normal wireless network operations.

Because the WLS system uses serving and neighbor cell measurement information to estimate location, it is most accurate in high cell density environments where many measurements are often reported, such as dense urban and many indoor settings. Unlike other technologies, such as TDOA and AOA, WLS does not rely on line-of-sight paths between the base stations and handsets, so performance can actually be improved in heavily cluttered, multipath environments. Moreover, due to the system's ability to leverage existing infrastructure, the initial investment to deploy an E911 solution with WLS is more cost-effective than alternate technologies, and

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<sup>3</sup> Letter from APCO and NENA to Derek Poarch, Chief, Public Safety and Homeland Security Bureau (July 14, 2008); Letter from NENA, APCO, and Verizon Wireless to Kevin J. Martin, Chairman (Aug. 20, 2008); Letter from Sprint Nextel to Kevin J. Martin, Chairman (Aug. 21, 2008); Letter from NENA, APCO, and AT&T to Kevin J. Martin, Chairman (Aug. 25, 2008); Letter from AT&T to Marlene H. Dortch, Secretary (Sept. 5, 2008); Letter from Verizon Wireless to Marlene H. Dortch, Secretary (Sept. 5, 2008); Letter from APCO and NENA to Marlene H. Dortch, Secretary (Sept. 9, 2008).

deployment times are significantly faster than what is necessary to install a new radio network overlay or to replace the installed base of wireless handsets in the marketplace.

The Polaris WLS technology is based on the observation that the radio environment varies from location to location due to features such as terrain, buildings, foliage, and cellular signal coverage. If enough elements of the radio environment can be measured with sufficient accuracy, each set of measured values provides a radio signature that uniquely identifies a particular location. In typical cellular networks, handsets measure the signal strengths (or signal-to-interference ratios) of serving and neighbor sector broadcast control channels for normal handover operations. These measurements form the basis of the radio signatures used to locate the handsets.

WLS is well-suited to provide high-accuracy measurements in urban and indoor situations because of its unique ability to take advantage of shadowing conditions that can degrade other approaches that rely on line-of-sight circumstances, such as TDOA, AOA, and GPS. First, urban areas typically contain extremely high cell densities because of the large concentrations of wireless users. Therefore, many neighboring cell site measurements are reported in the signatures, enabling especially accurate location estimation. Second, through use of radio propagation modeling and geographical information system data and measurements, the Predicted Signature Database (“PSD”) contains information about local shadow fading conditions. This is particularly critical in urban areas, where non-line-of-sight conditions are predominant due to extensive building obstructions and clutter. Third, the PSD contains information about predicted radio signal penetration into local buildings that can be used for indoor location estimation. Finally, Polaris is actively working to further improve location accuracy by incorporating additional measurement information into the signatures.

*Although the E911 proposals on the record demonstrate continued progress, they fail to address critical location accuracy challenges in urban and indoor environments.* Throughout this proceeding, Polaris has consistently advocated that hybrid systems should play a significant role in improving the accuracy and reliability of the nation's vital E911 Phase II system. Hybrid approaches have the potential to deliver more consistent accuracy performance across the wide range of environments in which E911 calls are made because of the diversity benefit achieved from combining network-based technologies, which typically work best in high cell density environments (e.g., dense urban), with handset-based technologies that tend to work best in open sky environments. A hybrid approach incorporates the best of both worlds.

While the new E911 rule proposals provide benchmarks toward compliance over smaller county-level geographical areas, they also propose relaxed accuracy thresholds and exclude many counties. Regrettably, Polaris believes that this proposed framework will not drive the adoption of the best E911 Phase II technologies available today, such as hybrid systems, nor will it achieve the greatest or fastest possible outcome for the American public. On the contrary, the new proposals will bring about two much less effective outcomes: (1) for handset-based carriers, it will maintain the status quo; and (2) for network-based operators, it will spark a migration to predominantly handset-based technologies.

After the proposed eight-year benchmarks have expired, the nation will be left with handset-based technologies, which often revert back to crude network-based fallback approaches when satellite fixes are not available in indoor and dense urban areas. Given the predominance of indoor wireless usage and the rapidly growing trend of wireline replacement, this is a far less than satisfactory outcome if you imagine a world eight years into our future, and in some ways represents a stagnation of E911 technology. In addition, the proposals fail to address important

deficiencies with A-GPS technologies regarding location performance in urban areas (e.g., urban canyons). Absent timely progress on urban and indoor performance, the United States is likely to fall behind other countries with respect to public safety and emergency location technology.

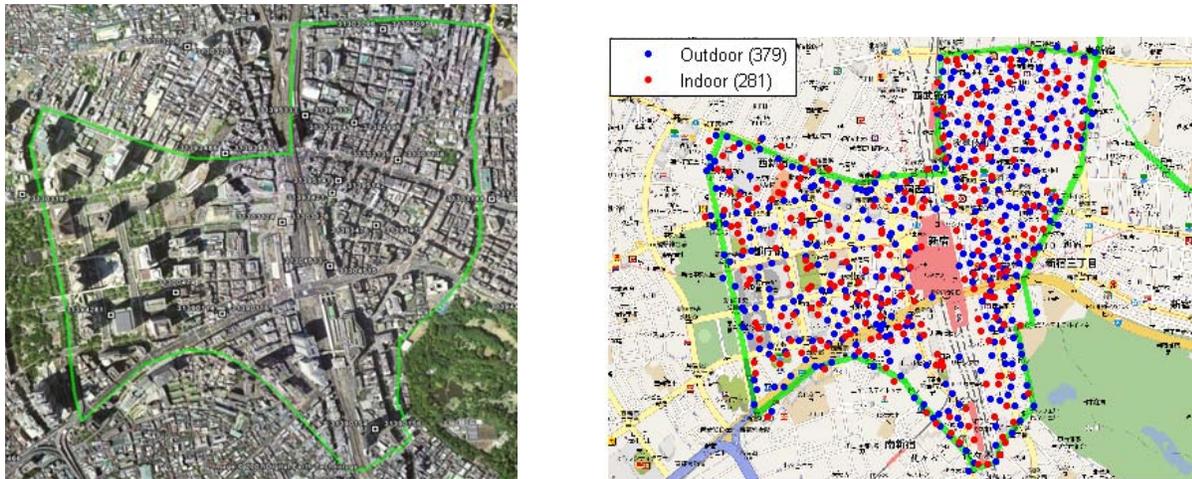
***Solutions exist today to achieve county-level performance in urban areas and to improve indoor location performance.*** Polaris and wireless service providers have conducted a number of field tests on all prominent wireless air interface protocols to assess the potential performance improvements of hybrid systems, compared to existing handset-based systems. Many of these tests have been conducted predominantly in dense urban, urban, and indoor areas, where satellite-based systems may experience challenges with obstructions. The overall results from several of these trials were summarized in Polaris's prior comments.<sup>4</sup> For indoor testing in urban areas – where A-GPS alone often cannot obtain a location fix – Polaris's test results indicate that WLS accuracy performance is at or close to the handset-based accuracy thresholds. As part of these tests of hybrid methods, some field trials were conducted using blind test protocols in which only the wireless service provider that conducted the tests knew the ground truth locations of the test calls. Even under this type of rigorous test protocol, the field test results indicate that accuracy compliance measured at the county level is achievable in urban scenarios using hybrid methods.

As an example of field trial results relevant to indoor location performance, Figure 1 shows the trial area for testing conducted in Tokyo, Japan. The left side of the figure shows an aerial photograph of the urban trial area with green line border, depicting a mix of tall and medium height high-rise buildings near the Shinjuku train station in Tokyo. The right side of the figure shows the outdoor test call locations in blue and indoor test points in red. A total of 379 outdoor and 281

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<sup>4</sup> Comments of Polaris Wireless, Inc. at 13-14 (filed Aug. 20, 2007).

indoor call locations were tested, and about 43% of the total calls were indoor. The call locations were designed to uniformly and densely (approximately every 40 meters) sample the trial area.

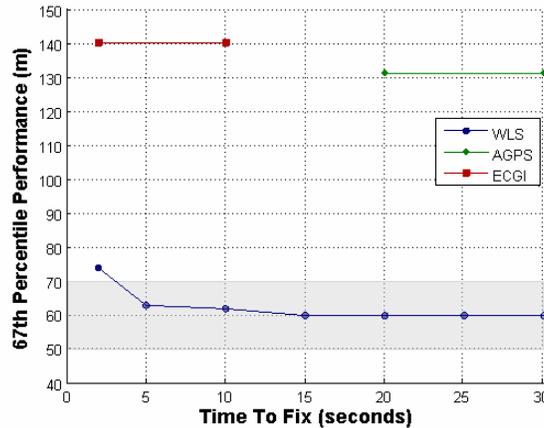


**Figure 1. Tokyo urban trial satellite aerial photo (left) and test call locations (right), with outdoor calls as blue dots and indoor calls as red dots.**

The field trial was conducted over a widely deployed commercial 3G Universal Mobile Telecommunications System (UMTS) Wideband Code Division Multiple Access (WCDMA) network. The wireless carrier conducting the trial also has a commercial A-GPS system and a commercial Enhanced Cell Global Identity (ECGI, also called Enhanced Cell-ID) system. The objective of the trial was to assess the performance of hybrid systems combining Polaris's WLS with A-GPS technology. The measurements compared the location accuracy versus time-to-fix for Polaris's WLS, A-GPS and ECID location systems.

The Tokyo location accuracy results for the indoor test points are shown in Figure 2, which plots the 67<sup>th</sup> percentile accuracy versus the time-to-fix. The wireless carrier's existing A-GPS system (green curve) produces a location fix in 20 to 30 seconds with 67% of the calls located closer than 130 meters (presumably the A-GPS system falls back to ECGI for most of the indoor calls). The carrier's existing ECGI system (red curve) produces a fix in two seconds but with 67% of the calls located closer than 140 meters. The Polaris WLS system produces an initial fix in two

seconds with 67% of the calls located closer than 75 meters. Results improve to 67% of the calls located closer than 60 meters in 10 to 15 seconds, as would be appropriate to operate within the 30-second window for location delivery under E911 Phase II requirements.

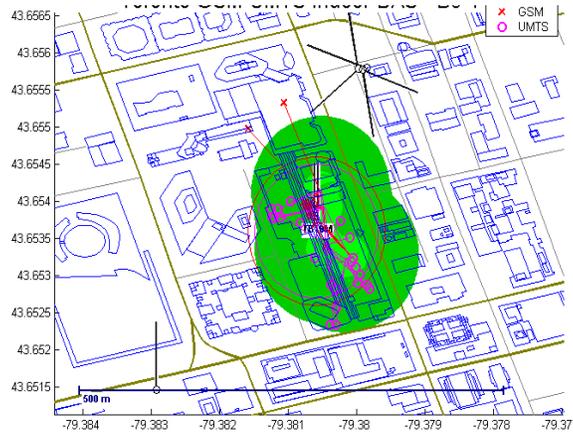


**Figure 2. Tokyo urban trial indoor test call performance. Plot shows accuracy at 67<sup>th</sup> percentile (meters) versus time-to-fix (seconds) for existing commercial A-GPS system (green), existing commercial Enhanced Cell Global Identity (ECGI) (red) and Polaris WLS (blue).**

These results are for 100% indoor test calls, with WLS alone achieving 60-meter performance at the 67<sup>th</sup> percentile. In a hybrid combination with A-GPS, assuming a mix of outdoor and indoor calls as is contemplated for future E911 Phase II testing, achieving the handset-based benchmarks of 67% at 50 meters and 95% at 150 meters in urban areas is quite realistic, even at heavy mixes of indoor test calls.

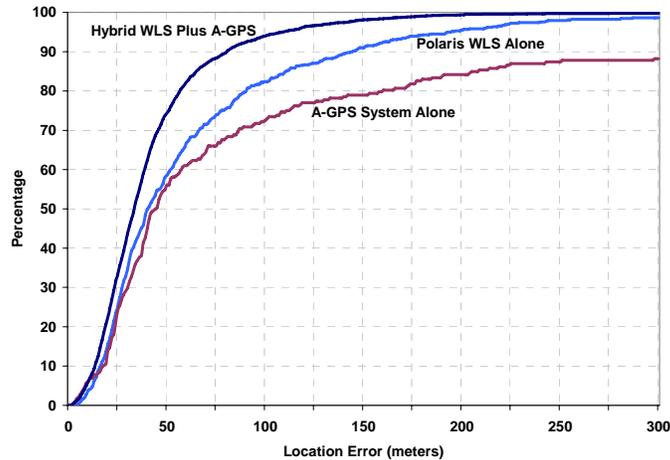
Another example of indoor performance is shown in Figure 3 from testing conducted in Toronto, Canada. These results are from blind testing conducted by the wireless service provider on a widely deployed commercial UMTS WCDMA network. Figure 3 shows a Geographical Information System (GIS) diagram of the building outlines in the urban trial area. The particular building with test calls is shown in the center of the figure, with dark green circles marking a 100-meter radius around ground truth and light green marking a 25-meter radius. The location estimates for the Polaris WLS system on GSM are shown as red ‘x’ symbols and on UMTS as

magenta ‘o’ circles. Figure 3 shows that many of the location estimates are within 25 meters and most are within 100 meters. Of the 40 test calls, all but two were estimated to be within the correct building. This is particularly encouraging because for indoor scenarios, many, if not most, calls would not be able to get A-GPS fixes due to obstructions of the satellite signals.



**Figure 3. Toronto urban indoor location accuracy example. Dark green circles show 100-meter ring around ground truth, light green represents a 25-meter ring. Polaris WLS position estimates for GSM use a red ‘x’ and for UMTS are shown as magenta circles.**

To demonstrate the overall performance improvement that can be achieved with hybrid systems in typical urban scenarios, results from an urban trial for a mix of indoor and outdoor test calls are shown in Figure 4. Error curves are presented for the A-GPS system alone (magenta), Polaris’s WLS system alone (light blue), and the hybrid combination of WLS plus A-GPS (dark blue). The test results reflect that the 150-meter performance of the A-GPS system alone is about 79%, while the WLS-alone performance is better than 91%. The hybrid combination position estimates from both WLS and A-GPS, however, achieved 150-meter performance of 98%, better than either the handset-based A-GPS system alone or the network-based WLS system alone. This hybrid improvement is most evident in the “tails” of the distribution (toward the right half of the figure) by the reduction in large outlier errors – an important factor in achieving the E911 Phase II consistency that the public safety community has noted is necessary.



**Figure 4. Plot of location accuracy in urban areas comparing A-GPS system alone (magenta), Polaris WLS alone (light blue) and hybrid combination of WLS plus A-GPS (dark blue) demonstrating hybrid improvement.**

As a further example of the advancements that are possible with hybrid systems, Polaris recently placed into the Commission’s record a technical paper jointly published by Polaris and Stanford University on the design and performance of hybrid algorithms for positioning in dense urban environments.<sup>5</sup> Based on actual field trial data sets from two sample markets, the paper demonstrates that hybrid algorithms combining WLS and A-GPS can achieve compliant accuracy performance levels in urban areas. These improvements represent significant performance gains, particularly for prevalent indoor and urban calling scenarios, that should be harnessed to drive accuracy and consistency improvements for E911 Phase II.

**Conclusion.** The proposals on the record reflect continued progress in this proceeding. However, after carefully weighing these proposals, Polaris observes that they fall short of achieving the maximum benefit in county-level urban accuracy and also in achieving better indoor performance. A hybrid solution that combines network-based and handset-based technologies is

<sup>5</sup> *Ex parte* filing of Polaris Wireless, Inc. (filed Oct. 16, 2009), attaching De Lorenzo, D. S.; Lo, S. C.; Enge, P. K.; Feuerstein, M.; Bhattacharya, T.; Spain, S.; and Kang, Z, *Design and Performance of a Minimum-Variance Hybrid Location Algorithm Utilizing GPS and Cellular Received Signal Strength Inputs for Positioning in Dense Urban Environments*, presented at the Institute of Navigation (“ION”) International Technical Meeting, Anaheim, CA (Jan. 26-28, 2009).

by far the best approach to achieving consistent accuracy – for emergency callers both outdoors and indoors. Yet the proposals under review only address half the problem, creating a 50% solution. The field trial results and publications referenced herein, including blind tests conducted by major wireless carriers in multiple cities and on various air interface protocols, demonstrate that urban and indoor performance can be dramatically improved beyond current levels by employing hybrid systems. With such options readily available, documented in the literature, and demonstrated in field trials, the FCC should consider adopting new requirements for indoor location performance and earlier effective dates for its county-level urban accuracy rules.

Respectfully submitted,

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November 20, 2009