



**ATIS-0500045**

**Interworking of 2D and 3D Shapes Across Industry  
Standards**

**TECHNICAL REPORT**



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*Published by*

**Alliance for Telecommunications Industry Solutions  
1200 G Street, NW, Suite 500  
Washington, DC 20005**

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# **Interworking of 2D and 3D Shapes Across Industry Standards**

**Alliance for Telecommunications Industry Solutions**

Approved November 8, 2021

## **Abstract**

This Technical Report will be used as a vehicle for communicating elevation or height acquisition concepts in liaisons with other relevant Standards Development Organizations (SDOs). The Z-axis information associated with location estimates can be reported using either ellipsoidal or orthometric height, among other representations.

This report describes the terms used to represent height and then elaborates the ellipsoidal versus orthometric representations of height. It also provides an overview of the uncertainty shapes used in representing Z-axis information and adds clarifying visualizations. It offers recommendations for the end-to-end delivery of Z-axis information and includes suggested mappings for both 2D and 3D uncertainty shapes, exploring some limitations and risks associated with the mapping process. This report investigates each shape but does not presume that any single shape will be used universally. The various tables within the document specify uncertainty shape mapping recommendations and highlight impacts to downstream entities.

## Foreword

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The Alliance for Telecommunications Industry Solutions (ATIS) serves the public through improved understanding between carriers, customers, and manufacturers. The Emergency Services Interconnection Forum (ESIF) provides a forum to facilitate the identification and resolution of technical and/or operational issues related to the interconnection of wireline, wireless, cable, satellites, Internet, and emergency services networks.

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes an optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, Emergency Services Interconnection Forum (ESIF), 1200 G Street NW, Suite 500, Washington, DC 20005.

At the time of consensus on this document, ESIF, which was responsible for its development, had the following leadership:

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- D. Morkunas, ESIF 1<sup>st</sup> Vice-Chair (Intrado)
- J. Torres, ESIF 2<sup>nd</sup> Vice-Chair (Verizon Wireless)
- K. Springer, ESIF ESM Co-Chair (AT&T)
- J. Green, ESIF ESM Co-Chair (T-Mobile USA)

The Emergency Services & Methodologies (ESM) Subcommittee was responsible for the development of this document.

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ATIS Technical Report on –

# Interworking of 2D and 3D Shapes Across Industry Standards

## 1 Scope, Purpose, & Application

### 1.1 Scope

Current standards define several two-dimensional and three-dimensional shapes and numerous reporting formats with varying underlying assumptions and approaches for capturing the wireless location estimate with its uncertainty bounds and confidence. These varying approaches to reporting two-dimensional and three-dimensional shapes have the potential to cause confusion and introduce additional errors, particularly as the shapes propagate between components in a broader positioning system from wireless network to PSAP. Furthermore, these varying representation approaches can cause confusion when testing location solutions, potentially impairing test results. This Technical Report presents the results of a survey of the existing standards related to location reporting shapes along with recommendations.

### 1.2 Purpose

In addition to surveying the related standards where reporting formats are defined, identifying common features and potential gaps, this Technical Report makes recommendations for reporting two-dimensional and three-dimensional shapes and best practices for propagating the shapes to minimize the accumulation of errors. It also makes recommendations for performing the minimum number of position estimate shapes conversion between elements in the end-to-end location system, where different standards may be used.

Detailed discussion of the entities responsible for performing shapes conversion under various network interconnection architectures is outside the scope of this document.

### 1.3 Application

This Technical Report should be used by wireless carriers, infrastructure vendors, handset manufacturers, and public safety to: (1) implement best practices, and (2) understand where information conversion can occur and could introduce some additional error in the position estimates.

## 2 References

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

### 2.1 Normative References

The following references are normative.

[Ref 1] ATIS J-STD-036-C-2, *Addendum to J-STD-036-C, Enhanced Wireless 9-1-1 Phase II*.<sup>1</sup>

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<sup>1</sup> This document is available from: [https://www.techstreet.com/atis/standards/atis-j-std-036-c-2?product\\_id=1984450](https://www.techstreet.com/atis/standards/atis-j-std-036-c-2?product_id=1984450).

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[Ref 2] NENA-STA-010.3, *NENA i3 Standard for Next Generation 9-1-1*.<sup>2</sup>

[Ref 3] ETSI TS 102 650, *Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); Analysis of Location Information Standards produced by various SDOs*.<sup>3</sup>

[Ref 4] 3GPP TS 23.032, *Technical Specification Group Services and System Aspects; Universal Geographical Area Description (GAD)*.<sup>4</sup>

[Ref 5] NENA-STA-018.2, *NENA Standard for the Implementation of the Wireless Emergency Service Protocol E2*.<sup>5</sup>

[Ref 6] OGC 06-142r1, *GML 3.1.1 PIDF-LO Shape Application Schema for use by the Internet Engineering Task Force (IETF)*.<sup>6</sup>

[Ref 7] OMA TS OMA-TS-LPPE-V1\_0, *LPP Extensions Specification*.<sup>7</sup>

[Ref 8] Wireless E9-1-1 Location Accuracy Requirements, PS Docket No. 07-114, Fourth Report and Order, 30 FCC Rcd 1259 (2015) (Fourth Report and Order), corrected by, Erratum (PSHSB Mar. 3, 2015).<sup>8</sup>

[Ref 9] Wireless E9-1-1 Location Accuracy Requirements, PS Docket No. 07-114, Fifth Report and Order and Fifth Further Notice of Proposed Rulemaking, 34 FCC Rcd 11592 (2019) (Fifth Report and Order or Fifth Further Notice), corrected by, Erratum (PSHSB Jan. 15, 2020).<sup>9</sup>

[Ref 10] Wireless E9-1-1 Location Accuracy Requirements, Sixth Report and Order and Order on Reconsideration, FCC 20-98 (Jul. 17, 2020) (Sixth Report and Order and Order on Reconsideration), corrected by Erratum (PSHSB Aug. 28, 2020).<sup>10</sup>

[Ref 11] National Geospatial Intelligence Agency, *WGS 84*.<sup>11</sup>

[Ref 12] ATIS-0500036, *ATIS Standard for IMS-based Next Generation Emergency Services Network Interconnection*.<sup>12</sup>

## 2.2 Informative References

The following references are informative.

[Ref 101] NENA-ADM-000.21.1-2018, *NENA Master Glossary of 9-1-1 Terminology*.<sup>13</sup>

[Ref 102] IETF RFC 3261, *SIP: Session Initiation Protocol*.<sup>14</sup>

[Ref 103] IETF RFC 4119, *A Presence-based GEOPRIV Location Object Format*.<sup>15</sup>

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<sup>2</sup> This document is available from: <https://www.nena.org>.

<sup>3</sup> This document is available at: [https://www.etsi.org/deliver/etsi\\_ts/102600\\_102699/102650/01.01.01\\_60/ts\\_102650v010101p.pdf](https://www.etsi.org/deliver/etsi_ts/102600_102699/102650/01.01.01_60/ts_102650v010101p.pdf).

<sup>4</sup> This document is available at: [https://www.3gpp.org/ftp/Specs/archive/23\\_series/23.032/23032-f10.zip](https://www.3gpp.org/ftp/Specs/archive/23_series/23.032/23032-f10.zip).

<sup>5</sup> This document is available at: <https://www.nena.org>

<sup>6</sup> This document is available at: [http://portal.opengeospatial.org/files/?artifact\\_id=21630](http://portal.opengeospatial.org/files/?artifact_id=21630).

<sup>7</sup> This document is available at: [www.openmobilealliance.org/release/Lppe/V1\\_0-20140108-C/OMA-TS-LPPE-V1\\_0-20140108-C.pdf](http://www.openmobilealliance.org/release/Lppe/V1_0-20140108-C/OMA-TS-LPPE-V1_0-20140108-C.pdf).

<sup>8</sup> This document is available at: <https://ecfsapi.fcc.gov/file/60001025925.pdf>.

<sup>9</sup> This document is available at: <https://docs.fcc.gov/public/attachments/FCC-19-111A1.pdf>.

<sup>10</sup> This document is available at: <https://docs.fcc.gov/public/attachments/FCC-20-98A1.pdf>.

<sup>11</sup> WGS 84 information is available at: <https://earth-info.nga.mil/GandG/update/index.php?action=home>.

<sup>12</sup> This document is available at: <https://www.atis.org>

<sup>13</sup> This document is available at: <https://www.nena.org/page/Glossary>.

<sup>14</sup> This document is available at: <https://tools.ietf.org/html/rfc3261>.

<sup>15</sup> This document is available at: <https://tools.ietf.org/html/rfc4119>.

[Ref 104] IETF RFC 5139, *Revised Civic Location Format for Presence Information Data Format Location Object (PIDF-LO)*.<sup>16</sup>

[Ref 105] IETF RFC 5491, *GEOPRIV Presence Information Data Format Location Object (PIDF-LO) Usage Clarification, Considerations, and Recommendations*.<sup>17</sup>

[Ref 106] IETF RFC 7459, *Representation of Uncertainty and Confidence in the Presence Information Data Format Location Object (PIDF-LO)*.<sup>18</sup>

### 3 Definitions, Acronyms, & Abbreviations

For a list of common communications terms and definitions, please visit the *ATIS Telecom Glossary*, which is located at < <http://www.atis.org/glossary> >.

#### 3.1 Definitions

Emergency Call Routing Function (ECRF)	A functional element in an ESNet that is a LoST protocol server where location information (either civic address or geo-coordinates) and a Service URN serve as input to a mapping function that returns a URI used to route an emergency call toward the appropriate PSAP for the caller's location or towards a responder agency [Ref 101].
Emergency Services IP network (ESInet)	A managed IP network that is used for emergency services communications, and that can be shared by all public safety agencies [Ref 2]. It provides the IP transport infrastructure upon which independent application platforms and core functional processes can be deployed, including, but not restricted to, those necessary for providing NG9-1-1 services. ESNets may be constructed from a mix of dedicated and shared facilities. ESNets may be interconnected at local, regional, state, federal, national, and international levels to form an IP-based inter-network (network of networks).
IMS-based NG9-1-1 Service Architecture	An IMS-based NG9-1-1 Service Architecture provides transit, routing, and other services required to support citizen-to-authority multimedia emergency services between the originating network and the emergency authority, e.g., PSAP. The IMS-based NG9-1-1 Service Architecture includes the i3 Legacy Network Gateway and i3 Legacy PSAP Gateway.
Legacy Network Gateway (LNG)	A signaling and media interconnection point between callers in legacy wireline/wireless originating networks and either the IMS-based NG9-1-1 Emergency Services Network or the i3 NG9-1-1 Emergency Services Network. This Functional Element provides MF/SS7-to-SIP signaling interworking, as well as emergency services-specific processing of legacy emergency originations and location acquisition/dereferencing functionality.
Legacy PSAP Gateway (LPG)	A signaling and media interconnection point between either the IMS-based NG9-1-1 Emergency Services Network or the i3 NG9-1-1 Emergency Services Network and legacy PSAPs. This Functional Element provides SIP-to-Traditional/Enhanced MF signaling interworking as well as emergency services-specific processing to support: the delivery of emergency originations to legacy PSAPs; emergency call transfers involving legacy PSAPs; ALI queries from legacy PSAPs; and location and additional data dereferencing functionality.

<sup>16</sup> This document is available at: <https://tools.ietf.org/html/rfc5139>.

<sup>17</sup> This document is available at: <https://tools.ietf.org/html/rfc5491>.

<sup>18</sup> This document is available at: <https://tools.ietf.org/html/rfc7459>.

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Legacy Selective Router Gateway (LSRG)	A signaling and media interconnection point between a legacy Selective Router (SR) and an NG9-1-1 Emergency Services Network (i.e., i3 ESInet/NGCS or IMS-based NG9-1-1 Emergency Services Network). To an SR, the LSRG looks like a tandem SR. To the ALI system, an LSRG on the ingress side of an NG9-1-1 Emergency Services Network looks like a PSAP using a conventional ALI query interface. An LSRG operating on the egress side of an NG9-1-1 Emergency Services Network looks to the ALI system like an MPC/GMLC or VPC, connected via an E2 interface. An LSRG supports SS7-SIP interworking for call delivery, as well as legacy ALI interfaces (ingress LSRGs) and E2 interfaces (egress LSRGs) to support location acquisition/dereferencing functionality.
NG9-1-1	An IP-based system comprised of managed IP-based networks (ESInets), functional elements (applications) which comprise the NGCS, and databases that replicate traditional E9-1-1 features and functions and provide additional capabilities. NG9-1-1 is designed to provide access to emergency services from all connected communications sources and provide multimedia data capabilities for PSAPs and other emergency service organizations.
Public Safety Answering Point (PSAP)	The PSAP is an entity operating under common management which receives 9-1-1 calls from a defined geographic area and processes those calls according to a specific operational policy.

### 3.2 Acronyms & Abbreviations

2D	2-Dimensional
3D	3-Dimensional
3GPP	3rd Generation Partnership Project
ALI	Automatic Location Identification
ATIS	Alliance for Telecommunications Industry Solutions
BCF	Border Control Function
BP	Best Practices
CMA	Cellular Market Area
CMRS	Commercial Mobile Radio Service
CRS	Coordinate Reference System
CSCF	Call Server Call Function
E9-1-1	Enhanced 911
ECRF	Emergency Call Routing Function
ECS	Emergency Call Service
E-CSCF	Emergency CSCF
EPSG	European Petroleum Survey Group
ESIF	Emergency Services Interconnection Forum
ESInet	Emergency Services IP Network
ESM	Emergency Services and Methodologies
ESP	Emergency Service Protocol
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
GAD	Geographic Area Description
GML	Geography Markup Language
GMLC	Gateway Mobile Location Center

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GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAE	Height Above Ellipsoid
HUNC	Horizontal Uncertainty
IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
LIS	Location Information Server
LNG	Legacy Network Gateway
LoST	Location-to-Service Translation Protocol
LPG	Legacy PSAP Gateway
LPP	LTE Positioning Protocol
LPPe	LTE Positioning Protocol Extensions
LRF	Location Routing Function
LSRG	Legacy Selective Router Gateway
MF	Multi-frequency
MPC	Mobile Positioning Center
MSAG	Master Street Address Guide
MS	Mobile Station
MSL	Mean Sea Level
NENA	National Emergency Number Association
NG9-1-1	Next Generation 9-1-1.
NGA	U.S. National Geospatial Intelligence Agency
NGCS	Next Generation Core Service
OGC	Open Geospatial Consortium
OMA	Open Mobile Alliance
PAM	PSAP-to-ALI-Messaging
PIDF-LO	Presence Information Data Format Location Object
PSAP	Public Safety Answering Point
RFC	Request For Comment
SDO	Standards Development Organization
SIP	Session Initiation Protocol
SS7	Signaling System 7
TIA	Telecommunications Industry Association
UE	User Equipment
URI	Uniform Resource Identifier
URN	Uniform Resource Name
VUNC	Vertical Uncertainty
WGS84	World Geodetic System 84
XML	eXtensible Markup Language

## 4 Regulatory and Standards Summary

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### 4.1 FCC Mandate

The United States Federal Communications Commission (FCC) has issued the Fourth, Fifth, and Sixth Report and Orders in PS Docket No. 07-114 addressing requirements for vertical position reporting for 911 calls. In the November 2019 Fifth Report and Order [Ref 9], the Commission adopted a vertical (Z-axis) location accuracy metric of plus or minus three meters for 80% of wireless Enhanced 911 (E9-1-1) calls, and required Commercial Mobile Radio Service (CMRS) providers to report Z-axis information as Height Above Ellipsoid (HAE). Under the timetable previously established in the Commission's E9-1-1 wireless location accuracy rules under the Fourth Report and Order [Ref 8], nationwide Commercial Mobile Radio Service (CMRS) providers must meet April 3, 2021 and April 3, 2023 deadlines for market-based deployment of Z-axis technology that complies with this metric, for the top 25 and top 50 Cellular Market Areas (CMAs), respectively, and non-nationwide CMRS providers have an additional year to meet these deadlines in the top 25 and 50 CMAs. In the July 2020 Sixth Report and Order and Order on Reconsideration [Ref 10], the FCC affirmed the April 2021 and April 2023 deadlines; allowed CMRS providers the flexibility to deploy technologies that focus on multi-story buildings, where vertical location information is most vital to first responders; required nationwide CMRS providers to deploy Z-axis technology nationwide by April 2025; and required nationwide CMRS providers to deliver dispatchable location with wireless 911 calls when it is technically feasible and cost effective to do so beginning January 6, 2022.

### 4.2 Standard Network Architectures

Emergency calls in North America convey the caller's location to the PSAP in different ways. While landline E9-1-1 has traditionally provided an MSAG valid civic address location, wireless emergency calls have been required to deliver both the coarse geodetic geolocation of their serving cell tower location, known as a Phase 1 location, as well as a more precise geodetic geolocation estimate of the caller's device, known as a Phase 2 location. The systems and networks used to convey this information have evolved over the past two decades. Furthermore, the regulatory actions described in Clause 4.1 mean that the precise geodetic geolocations must also now include vertical 'Z-axis' altitude information.

Geodetic location estimates, including X, Y, and Z coordinate information, can be determined using various technologies and methods, and can originate from a variety of sources, including from carrier-based location platforms, from third-party location services, or from device-based hybrid technologies. These originating networks deliver to different types of downstream terminating networks, which further convey and deliver location to the PSAP using several methods. These terminating networks vary by design, and include:

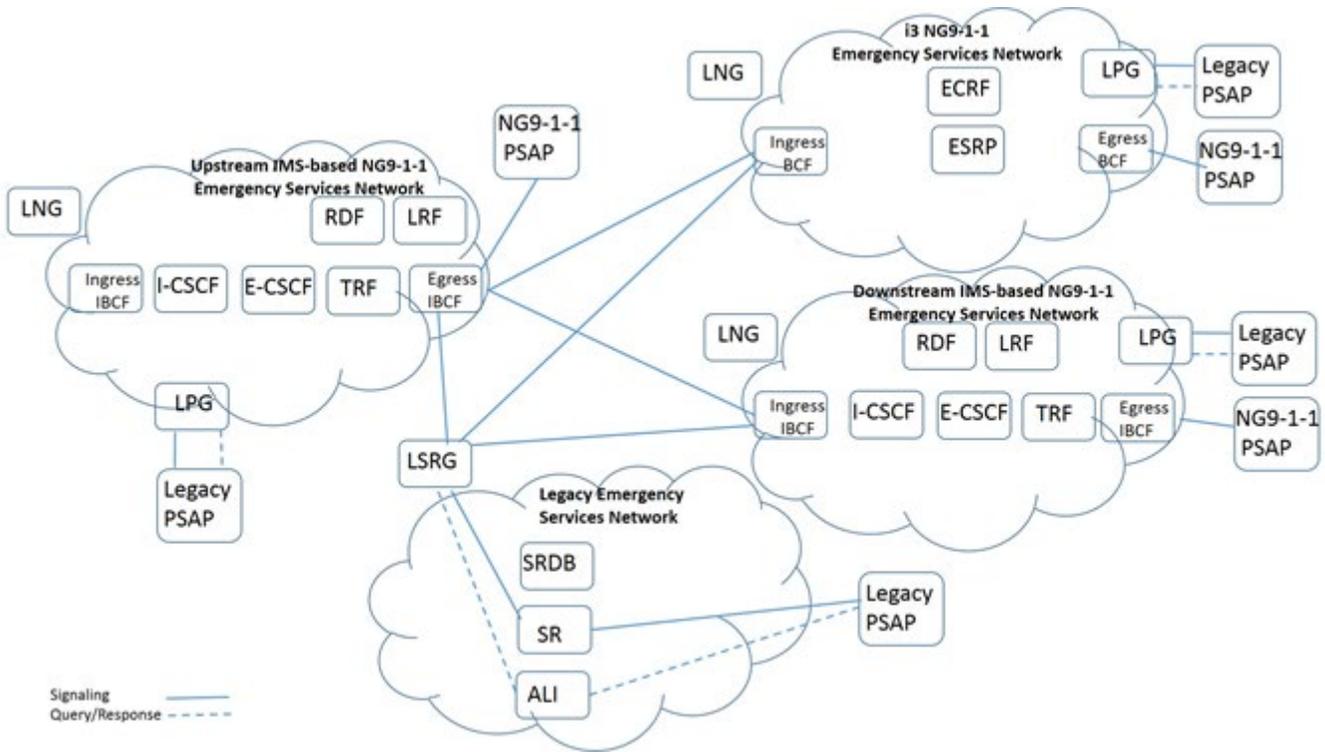
- Legacy Emergency Services Networks
- NENA i3 NG9-1-1 Emergency Services Networks
- IMS based Emergency Services Networks

An assortment of standard interfaces and protocols exist to define Z-axis information and specify how it is conveyed. This document was developed to outline these various transport formats, and to point out any potential gaps in delivering the Z-axis component as part of a 3D location as Z-axis information becomes widely deployed.

Figure 4-1<sup>19</sup> shows a variety of scenarios with interconnections to support both Next Generation 9-1-1 architectures and E9-1-1 Legacy Emergency Services architectures. The manner in which location information is conveyed can be varied, either conveyed within the SIP signaling protocol "by-value", in combination with HTTPS based dereferencing protocols "by-reference", or via the standard E2 interface to support location delivery to legacy PSAPs.

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<sup>19</sup> From ATIS-0500036, ATIS Standard for IMS-based Next Generation Emergency Services Network Interconnection [Ref 12]



**Figure 4.1 Internetwork Architectural Configuration**

NOTE: This document uses the terms NG9-1-1 PSAP (shown in the previous figure) and i3 PSAP (shown in the following figure) interchangeably.

Figure 4.2 shows different implementation examples for the E2 interface, including interconnection from a wireless origination network to an ESInet/NGCS through a Legacy Network Gateway, direct interconnection from a wireless origination network to a legacy ALI in the context of a traditional E9-1-1 Emergency Services Network architecture, or interconnection of an ESInet/NGCS to a legacy ALI system via a Legacy Selective Router Gateway,

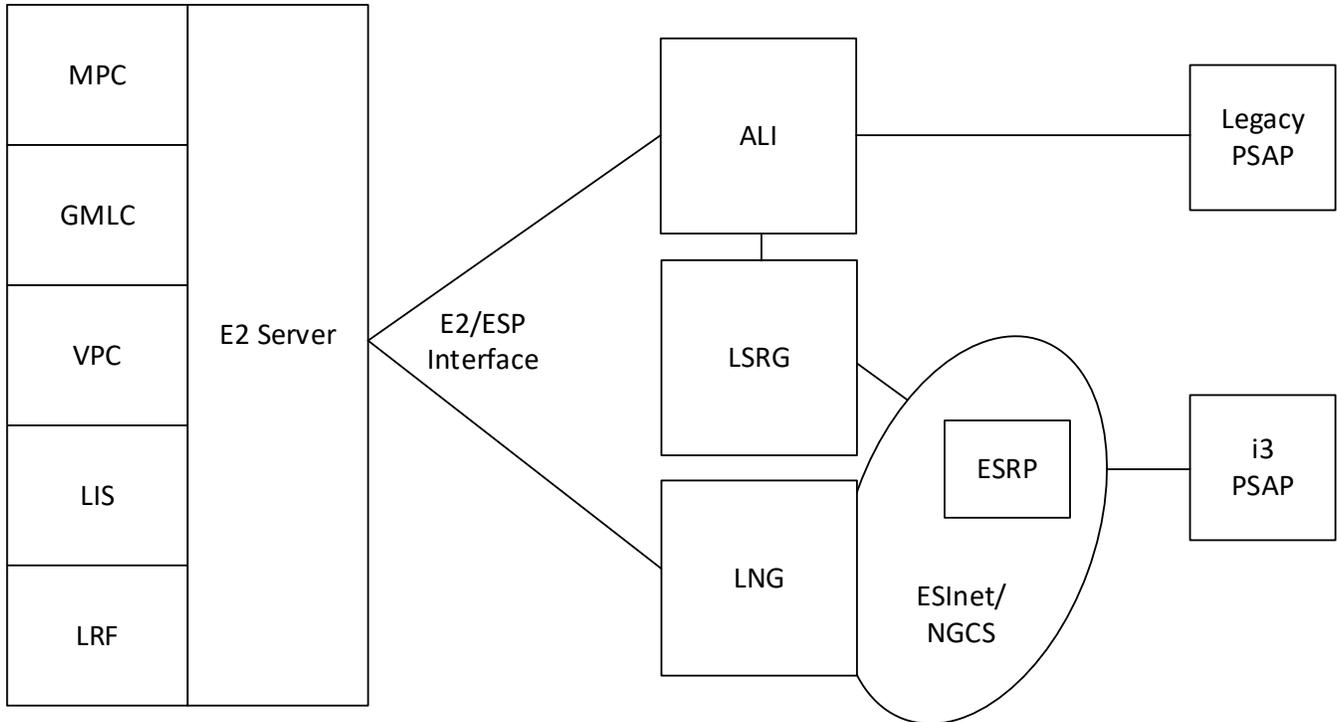


Figure 4.2 General Reference Architecture for E2 Location

## 5 Representation of Height

Height is generally defined as “the vertical distance between two points, or above a specified datum<sup>20</sup>”, but this simple definition conceals some tricky details. Conveying height is complicated because two distinct representational approaches exist – ellipsoidal and orthometric – and because several terms for the measured distance in a vertical context are used interchangeably without precise definition. To provide clarity to the 9-1-1 community, this clause summarizes the ways of representing height, explains why an ellipsoidal representation has been mandated by the FCC for use in 9-1-1 systems, and clarifies the terms used in this document.

### 5.1 Terms Used to Represent Height

Note that several terms are used interchangeably in common language when referring to measured distance in a vertical context, including height, altitude, and elevation. Except where noted otherwise, in this document, the terms ‘height’, ‘altitude’, and ‘elevation’ are synonymous and refer to the height above the WGS-84 ellipsoid, the FCC-mandated preferred means of conveying height information, as explained in Clause 5.2.1. Note also that ‘Floor Level’ does not represent a measure of distance in the vertical context, since a given floor level is a sub-premise of a civic location or address, rather than a product of measurement.

### 5.2 Ellipsoidal vs. Orthometric Representations of Height

Two ways of representing height exist:

- Ellipsoidal, as described in Clause 5.2.1
- Orthometric, as described in Clause 5.2.2

<sup>20</sup> Per the ESRI GIS Dictionary, [http://webhelp.esri.com/arcgisserver/9.3/java/geodatabases/definition\\_frame.htm](http://webhelp.esri.com/arcgisserver/9.3/java/geodatabases/definition_frame.htm).

complicating matters, and sometimes causing confusion that has the potential to introduce error. The following two clauses explain the differences between these two representations and explain why the “Height Above the WGS84 Ellipsoid” representation is now required by the FCC.

### 5.2.1 Ellipsoid Height

Earth’s own shape is ellipsoidal rather than spherical, though it may look like a sphere as viewed from outer space, due to rotational dynamics, external gravitational forces, and other physical phenomena. Height Above Ellipsoid as used in GNSS systems refers to the distance above (or below) some globally defined “smooth” reference ellipsoid. This type of modeled ellipsoid does not take into account crust density or gravity, thus it does not necessarily align with the more physically defined geoid reference, as shown in Figure 5-1 and Figure 5-2.

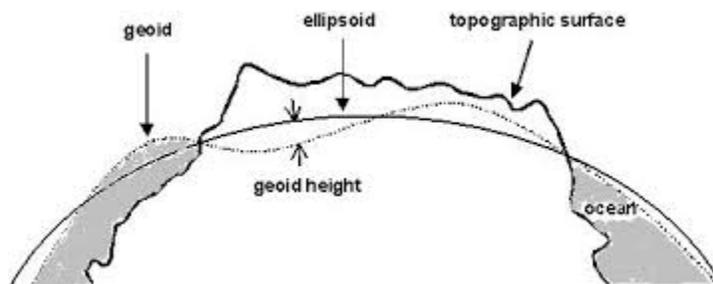


Figure 5.1 Ellipsoid and Geoid

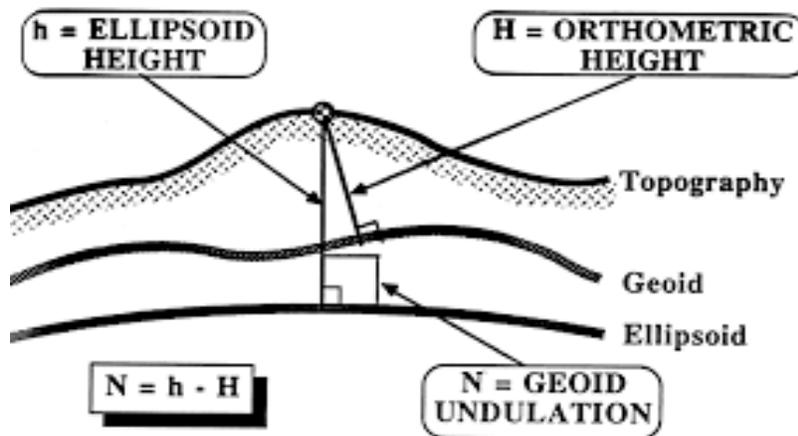


Figure 5.2 Ellipsoidal Height

Nearly all sources of Z-axis positions utilized in the 9-1-1 context report height using one specific ellipsoidal representation – the Height Above the WGS84 Ellipsoid. Height Above the WGS 84 Ellipsoid is sometimes simply referred to as ‘Height Above Ellipsoid’ or ‘HAE’. WGS 84 is the reference frame maintained by the U.S. National Geospatial Intelligence Agency (NGA) used by the Global Positioning System (GPS) [Ref 11] that includes a definition of the “smooth” reference ellipsoid against which heights are measured. Because Height Above the WGS84 Ellipsoid is used widely in position generation systems, and because it is precisely defined, the FCC has mandated that all heights used in the 9-1-1 context be reported using this approach.

## 5.2.2 Orthometric Height

Orthometric height (H), and specifically one form of orthometric height known as height above “Mean Sea Level (MSL)” is the distance H along a plumb line from any point to the geoid, as shown in Figure 5-2 and Figure 5-3. The geoid is described as the equipotential surface that would coincide with the mean ocean surface of the Earth if the oceans and atmosphere were in equilibrium, and thus is influenced by variable crust density and gravity.

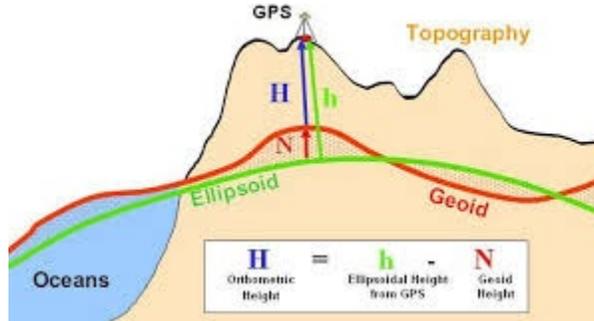


Figure 5.3: Orthometric height

Orthometric height is the distance from a point to the geoid, given by the expression

$$H = h - N, \text{ where } (H) \text{ is the orthometric height, a result of ellipsoid height } (h) \text{ minus geoid undulation } (N).$$

PSAPs, the weather industry, surveyors, and many terrain & building databases often use an Orthometric Height above MSL to represent altitude. It is assumed that PSAPs will prefer orthometric height over HAE for the basis and presentation of data in how it relates to floor estimation. Since altitude information is conveyed as HAE, conversion from HAE must be done on the PSAP side if an orthometric height is desired.

Conversion from HAE to orthometric height requires accurate knowledge of the horizontal position, which is used to look up a correction factor referenced as Geoid Height (N) in a Geoid grid database – two such databases are in common use today:

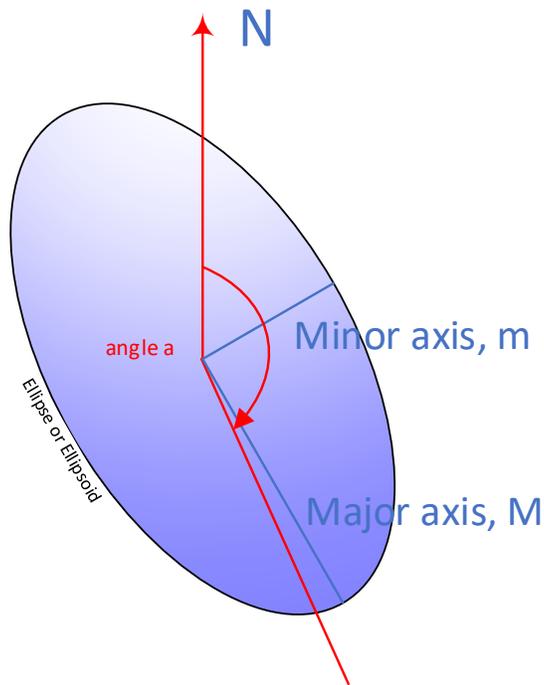
- EGM96 – 15-minute spacing – 16 squares per degree – coarser, less precise, thus up to 3 meters of error
- GEOID12 – one-minute spacing – 3600 squares per degree – can achieve one-centimeter accuracy with cubic spline interpretation.

Given that terrain (topographical) height can vary across a reported position’s area of uncertainty, it follows that for some reported locations it is important to acquire position information with a small Horizontal Uncertainty value.

## 6 Overview of Shapes to Represent Z-Axis Information

### 6.1 Representation of 3-Dimensional Position Information

While 2-Dimensional (2D) position information is defined within several standards as a point (an x/y coordinate pair) with a Horizontal Uncertainty value (error) and confidence (probability), 2D positions can also be produced and conveyed having two radius values around the point each representing Horizontal Uncertainty in the direction shown. When of differing values, these major and minor radii describe an ellipse around the point, oriented by an angle “a” from the x and y axes in a coordinate plane, as shown in Figure 6-1.



**Figure 6.1 2D Ellipse Position**

Note that when the major and minor axes are equal, the 2D ellipse reduces to the shape of a circle, having a single Horizontal Uncertainty value, which is how most locations are currently conveyed and reported in E9-1-1.

When the third dimension of altitude is added, a 2D ellipse becomes an ellipsoid shape representing an uncertainty in three dimensions. When both horizontal uncertainties of an ellipse as well as the altitude are all equal in value, the ellipsoid shape reduces to a sphere. (Figure 6-2 shows an example ellipsoid shape with its ellipsoidal parameters.) Other 3D shapes besides an ellipsoidal shape also exist, those in scope of this document are described below.

## 6.2 Standards Defined Shapes

Several standards development organizations (SDOs) have defined or referenced ways in which geodetic location information should be conveyed or presented. In support of emergency calls, the SDOs outside of ATIS that have either defined or specified geolocation from an originating network perspective include TIA, 3GPP, OGC, IETF, and OMA. Termination networks that convey, consume and present location information, such as Emergency Service Networks and PSAPs rely on additional specifications, which are beyond the scope of this document.

### 6.2.1 Shapes supported in J-STD-036, E2/ESP

The standard for wireless emergency services, J-STD-036-C-2 [Ref 1], defines the ESP (Emergency Services Protocol) as the delivery method for location information, including Z-axis vertical location information towards public safety. In terms of 3D position information, a shortcoming within the standard is that it lists Z-axis data as optional only, due to lack of regulatory requirements at the time. Based on updated rules from the FCC 6<sup>th</sup> Report & Order, Z-axis information is now required, and dispatchable location will be required when technically feasible.

Because J-STD-036 is not explicit in its specification of 3D position information, it is important to show how it can effectively still be used to support the delivery of Z-axis information. The standard defines position information in terms of GeographicPosition:

From J-STD-036-C-2 [Ref 1], section 2.3.2.11 GeographicPosition,

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The *GeographicPosition (GEOPOS)* parameter specifies position in latitude and longitude coordinates (e.g., reference WGS-84), and optionally, altitude.

The FCC mandate (Docket 94-102) requires the MS latitude and longitude. In addition, confidence level (including uncertainty) of the geodetic position is required per agreement with Public Safety. At a minimum, in order to provide the required fields the “Type of shape” field values recommended to be supported are:

-- Ellipsoid point: meets minimum requirement of FCC Docket 94-102.

-- Ellipsoid point with uncertainty: meets minimum requirement of FCC Docket 94-102, plus the minimum requirement of the Public Safety confidence agreement.<sup>21</sup>

By definition, these two named shapes only support two-dimensional position information. By including the optional altitude in the definitions, support can then be shown for delivering location in three dimensions.

3D Point w/o Uncertainty            [a point in space that has no Uncertainty and Confidence]

3D Ellipsoid Point with both Horizontal & Vertical Uncertainty and Confidence    [a point that includes HUNC, VUNC and a single Confidence value that applies to both]

Though J-STD-036-C-2 [Ref 1] doesn’t directly mention 3D, VUNC, Z-axis, normative references to the ATIS specification 1000628 (formerly T1.628) titled, Emergency Calling Service (ECS) provides support for 3D within the standard.

The shape types defined in ATIS-1000628 are:

0000000	ellipsoid point
0000001	ellipsoid point with uncertainty
0000010	point with altitude and uncertainty

... [note: other shapes are listed, but stated as “not for ECS”]

The above values, (decimal values of “0”, “1”, “2”) define what can be conveyed over the E2 interface. The values “0” and “1” describe the 2D shape encodings, while the two values, “0” and “2” describe 3D positions. Note that “0” can describe either a 2D or 3D point.

As a result, J-STD-036-C-2 [Ref 1] defines the delivery method for location information using the following possible shapes:

1. 2D Point w/o Uncertainty (e.g., non-calculated, manually provisioned x/y)
2. 3D Point w/o Uncertainty (e.g., stated x/y/z coordinates)
3. 2D Point with Horizontal Uncertainty and Confidence
4. 3D Ellipsoid Point with both Horizontal & Vertical Uncertainty and Confidence

The current version of J-STD-036 refers to Z-axis information as optional due to a lack of regulatory requirements at the time it was adopted. Based on the updated FCC rules [Ref 8, Ref 9, Ref 10], Z-axis information is now required beyond that which is included in the first and third shapes, therefore they are no longer adequate to convey location estimate information for all calls. The second shape, while technically possible to convey position information, is not suitable because it lacks reporting of uncertainty. Only the fourth shape – “3D Ellipsoid Point with both Horizontal & Vertical Uncertainty and Confidence” – meets the updated FCC rules.

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<sup>21</sup> In the Fourth Report and Order in PS Docket No. 07-114, the FCC required confidence and uncertainty data for all wireless 911 calls, whether placed from indoors or outdoors, be delivered at the request of a PSAP, on a per-call basis, with a uniform confidence level of 90 percent.

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J-STD-036 makes reference to ATIS-1000628 for both Confidence and Horizontal Uncertainty values. Confidence is specified as a percentage, reserving the value of “0” for “no information”. Horizontal Uncertainty has a range of values between 1 and 1800 km (“0” not supported).

### 6.2.2 2D & 3D Shapes supported by 3GPP

The 3GPP TS 23.032 [Ref 4] standard defines the following shapes:

- Ellipsoid Point
- Ellipsoid point with uncertainty circle
- Ellipsoid point with uncertainty ellipse
- Polygon
- Ellipsoid point with altitude
- Ellipsoid point with altitude and uncertainty ellipsoid
- Ellipsoid Arc
- High Accuracy Ellipsoid point with uncertainty ellipse
- High Accuracy Ellipsoid point with altitude and uncertainty ellipsoid.

NOTE: 3GPP uses the term “ellipsoid point” to represent a point on Earth, or “Earth Point” for its 2D Ellipse shape description. This connotes a different sense than that of an estimated point in space whose estimated error is represented by a 2D ellipse or 3D ellipsoid shape.

3GPP identifies each of these shapes in terms of a numbered Geographic Area Description (GAD) type, for example, GAD Shape 9, representing ellipsoid point with altitude and uncertainty ellipsoid as noted in Table 7-2: Mapping from 3GPP Originated Location to E2 Location.

While any shape listed by 3GPP is technically possible for a location associated with an emergency call, the expected shape to support 3D position information with associated uncertainties and confidence value would be the “Ellipsoid point with altitude and uncertainty ellipsoid” or “High Accuracy Ellipsoid point with altitude and uncertainty ellipsoid”.

### 6.2.3 2D & 3D Shapes supported by OGC (per IETF)

The Open Geospatial Consortium (OGC) published an application schema of the Geography Markup Language (GML), version 3.1.1, for XML encoding of various geometric shapes required in the ‘Presence Information Description Format - Location Object’ (PIDF-LO) [Ref 6]. These shapes were in turn referenced by a number of IETF documents, including RFC 4119 [Ref 103], and more recent IETF RFC updates to 4119 [Ref 103] including RFC 5139 [Ref 104], RFC 5491 [Ref 105], and RFC 7459 [Ref 106]. The supported shapes from IETF RFC 5491 [Ref 105] and OGC 06-142r1 [Ref 6] are listed here:

- Point
- Polygon
- Polygon, Upward Normal\*\*
- Circle
- Ellipse
- Arc Band
- Sphere
- Ellipsoid
- Prism

NOTE: \*\* The ‘Polygon, Upward Normal’ shape is exclusive to OGC 06-142r1 [Ref 6].

Any shape listed by OGC could be included within a PIDF-LO for location with an emergency call, with the expected shape being an Ellipsoid, in order to convey the 3D position information with associated uncertainty values and confidence value.

### 6.2.4 3D Shapes supported by OMA LPPe

The OMA LPPe (OMA LPP Extensions Specification) [Ref 7] specifies a “HighAccuracy3Dposition” location format that complemented the shapes defined by 3GPP up to Release 14. The OMA LPPe protocol is used between User Equipment and a location platform. The “HighAccuracy3Dposition” format consists of:

- Latitude and Longitude based on WGS84
- Horizontal Uncertainty defined as an uncertainty circle or an uncertainty ellipse
- Horizontal confidence
- Altitude
- Altitude uncertainty
- Altitude confidence.

NOTE: Latitude, Longitude and Altitude information as well as related uncertainties are mandatory elements. Confidence elements are optional.

The “HighAccuracy3Dposition” format in LPPe can be mapped to the following 3GPP 3D shapes:

- High Accuracy Ellipsoid point with altitude and uncertainty ellipsoid
- Ellipsoid point with altitude and uncertainty ellipsoid.

## 6.3 Shape Visualizations

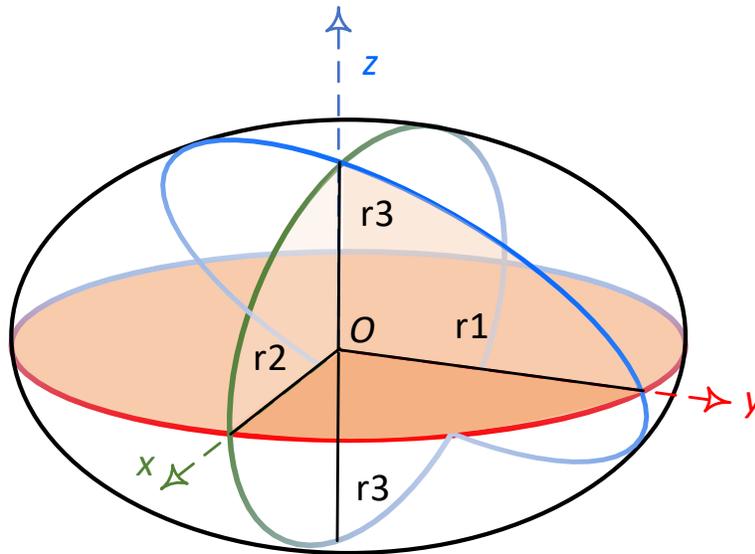
Any 2-dimensional or 3-dimensional shape can either be described in words, using a mathematical formula, or be shown graphically using a 2D or 3D visual rendering. In this clause, an ellipsoid shape and a cylinder with an elliptical base shape are visually presented and explained.

### 6.3.1 Ellipsoid

This clause provides a visual representation of an Ellipsoid shape – i.e., a 3D version of a 2D ellipse with a separately reported, but functionally dependent, Z-axis. The shape shown in Figure 6-2 uses an elliptical base, with both major and minor axes for separate Horizontal Uncertainty values possible.

The visual model shows that the magnitude of Vertical Uncertainty is not a constant value, but is functionally dependent on 2D coordinate values, which does not match the reality of 3D location reporting in practical implementations. In other words, the Vertical Uncertainty as reported to public safety is not expected to change depending on the position of the actual latitude and longitude. For example, actual Z-axis uncertainty is not expected to go to zero (no reported vertical error) at the outer edge of the 2D area of uncertainty.

The assumption in this visual model is that the magnitude of Vertical Uncertainty,  $r_3$ , is expected to vary over the distributed ellipse area given by a function, despite the fact that it is represented as a single value in this 3D location representation. This approach is recommended for conveyance only of Z-axis conclusive information.



**Figure 6.2: Visualization of Ellipsoid Representing a 3D Position**  
(shown where  $r_2$  may not be equal to  $r_1$ , and  $r_3$  is independent)

### 6.3.2 Cylinder with Elliptical Base

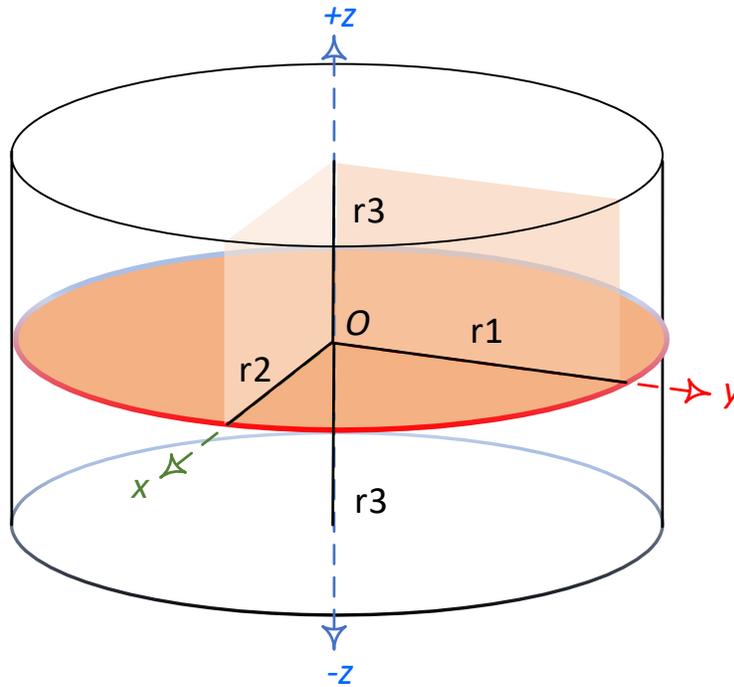
Figure 6-3 shows a shape based on a 3D point that includes both horizontal and vertical uncertainties, but where the Z-axis dimension, both above and below what is shown as the horizontal plane, is constant. The base of the cylinder is an ellipse, with Horizontal Uncertainty shown as having two separate values,  $r_1$  and  $r_2$ . This visual model shows an elliptical cross section on this same horizontal plane. Note that as shown in the figure, it is possible to have an elliptical base, with differing major and minor axis values, denoting separate perpendicular Horizontal Uncertainty values. However, when  $r_1$  and  $r_2$  are equal, the shape reduces to a cylinder having a circular cross section.

This shape has the following properties:

- It references standard “Earth Point” with 2D Ellipse shape plus Altitude.
- It can include Horizontal Uncertainty either as two values or a single value.
- Vertical Uncertainty is assumed to be constant across the Horizontal Uncertainty area.
- A single value for Confidence for both horizontal and Vertical Uncertainty is assumed if not stated explicitly.
- Vertical Uncertainty is shown as not being dependent on 2D horizontal coordinate values.

NOTE: A simpler rendering of a cylinder shape with a circular cross section that incorporates a single Horizontal Uncertainty value is required for use in legacy emergency service network conveyance, since this type of elliptical cylinder is not supported over the E2/ESP interface in the J-STD-036-C-2 [Ref 1] or NENA-STA-018.2 [Ref 5], though it is supported within the PIDF-LO specification [Ref 6] allowing for its potential use in NG9-1-1 systems and networks.

This visualization is recommended for use with presentation of the Z-axis information.



**Figure 6.3: Visualization of Elliptical Cylinder (where r1 and r2 represent Horizontal Uncertainties and r3 is Vertical Uncertainty in both upward and downward directions)**

### 6.3.3 Mapping Between Visual Representation & Standards-defined Shapes

Table 6-1 represents a comparison between different standards-based representations for 3D shapes. For each visual representation (shape analogy), the shape defined by 3GPP TS 23.032 [Ref 4], IETF PIDF-LO/OGC [Ref 6], and J-STD-036-C-2 E2/ESP [Ref 1] are named, if such a shape exists in that standard.

**Table 6-1: Comparison between different standards based representations for 3D shapes**

Resulting Visual Representation	3GPP TS 23.032	IETF PIDF-LO/OGC	J-STD-036-C-2 E2/ESP
Point in 3D space	Ellipsoid point with altitude	Point	Ellipsoid Point
Cylinder (circular or elliptical horizontal cross section)	Ellipsoid point with altitude and uncertainty ellipsoid	Ellipsoid	Ellipsoid Point w/Uncertainty
Cylinder (circular or elliptical horizontal cross section)	High Accuracy Ellipsoid point with altitude and uncertainty ellipsoid	Ellipsoid	Ellipsoid Point w/Uncertainty
Australian rules football (3D oval), compressed/expanded on vertical axis	Ellipsoid point with altitude and uncertainty ellipsoid	Ellipsoid	Ellipsoid Point w/Horiz. Uncertainty and Vert. Uncertainty
Australian rules football (3D oval), compressed/expanded on vertical axis	High Accuracy Ellipsoid point with altitude and uncertainty ellipsoid	Ellipsoid	Ellipsoid Point w/Horiz. Uncertainty and Vert. Uncertainty
Ball	Ellipsoid point with altitude and uncertainty ellipsoid (all described axes are equal)	Sphere	Ellipsoid Point w/Horiz. Uncertainty and Vert. Uncertainty

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Resulting Visual Representation	3GPP TS 23.032	IETF PDF-LO/OGC	J-STD-036-C-2 E2/ESP
Ball	High Accuracy Ellipsoid point with altitude and uncertainty ellipsoid (all described axes are equal)	Sphere	Ellipsoid Point w/Horiz. Uncertainty and Vert. Uncertainty
Vertically projected volume with polygon base		Prism	

## 7 End-to-End Delivery of Z-Axis Information

Z-axis information is delivered toward public safety entities according to one of two standardized methods. Legacy PSAPs receive Z-axis information utilizing the J-STD-036 defined E2 interface [Ref 1]. NG9-1-1 PSAPs conform to SIP location conveyance protocols (e.g., defined in NENA i3 [Ref 2]) and deliver Z-axis information as a GML position component within the PIDF-LO xml structure [per IETF RFC 4119 [Ref 103], RFC 5139 [Ref 104], RFC 5491 [Ref 105], and RFC 7459 [Ref 106]].

There are two types of originating networks for location conveyance, either SIP, a call-associated method, or Network Initiated Location Request (NILR), a non-call-associated method, and two types of terminating networks that interconnect to Legacy PSAPs and NG9-1-1 PSAPs. For the majority of Legacy PSAPs, Z-axis information will be conveyed over the standard E2 interface and then delivered to the PSAP over a serial ALI interface.

NOTE: Other proprietary or non-standard interfaces exist, e.g., PSAP-to-ALI-Messaging (PAM) but are not addressed in this standard.

NG9-1-1 PSAPs (e.g., those conforming to NENA i3 standards) will receive Z-axis information over the standards-defined SIP interface [Ref 102]. This will be either by-value or by-reference. In both cases, location is conveyed within a PIDF-LO and may contain either civic location or geodetic position, or both. Z-axis coordinate information will be included as part of a 3D geodetic position and requires no mapping from one form to another when location is initially conveyed within a PIDF-LO and also delivered to an NG9-1-1 PSAP using a PIDF-LO.

### 7.1 Mapping of Location Representations

Acquisition of location may be done by the User Equipment (UE) or the location platform within the originating network. Upon conveyance of a location that is associated with an emergency call, the location may need to be mapped into another form, depending on both the originating and terminating networks involved, as indicated in Table 7-1.

**Table 7-1: Mapping of Location Form Based on Originating and Terminating Networks**

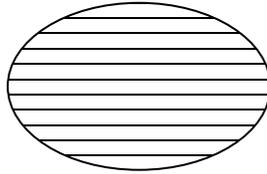
Originating Network Standard	Terminating Network Standard	Mapping Required?
3GPP location format	E2	Yes
3GPP location format	PIDF-LO	Yes
PIDF-LO	E2	Yes
PIDF-LO	PIDF-LO	No

### 7.2 Considerations when Mapping Shapes

As mentioned previously, shapes representing the area of uncertainty (or search area) for location estimates can be rendered as two-dimensional or three-dimensional objects. When describing uncertainty solely in the horizontal plane a two-dimensional shape will be utilized. With the addition of Z-axis information, a three-dimensional shape is necessary. When there is not an identical representation of the shape in the destination network due to a variance of standards in the networks involved in any particular location conveyance operation, certain principles should be applied upon performing shape mapping.

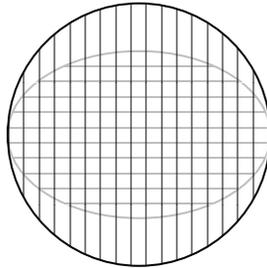
#### 7.2.1 Minimum Bounding Shape

It is recommended that the resultant uncertainty shape be the smallest rendering fully containing the original shape. For example, if an uncertainty is represented as an ellipse in the originating network and must be expressed as a circle in the terminating network, the smallest, or minimum bounding circle would ideally be utilized. Retention of the original geometric center, or centroid, should strictly be maintained where possible. See Figure 7.1 through Figure 7.10, noting that in each example, where appearing, visual horizontal marking identifies the shape corresponding to the originating network representation and vertical marking that of the terminating network representation. Cross hatching indicates areas of intersection between the shapes when overlaid.



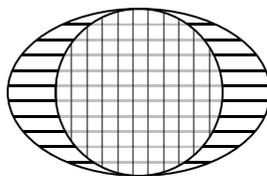
**Figure 7.1: Representation of an Elliptical Uncertainty Shape**

Figure 7.1 depicts an elliptical uncertainty as may be described in 3GPP-compliant networks. Rendering this via E2 would require that the elliptical uncertainty be mapped into one which is circular. It is recommended that the smallest circle which fully contains the original ellipse be utilized, as shown in Figure 7.2.



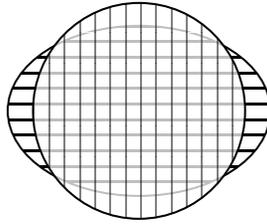
**Figure 7.2: Resultant Shape Fully Contains the Original – Recommended**

It is easy to see the common area between the two shapes on account of the cross hatching. The areas with only vertical markings, namely at the top and bottom of the circle, represent additional area described by the E2, or circular representation not in the original 3GPP representation. In effect, this means that the search area is expanded when this shape is presented in emergency response scenarios. Such an approach is preferred to alternative renderings, such as a circle which is encompassed by the original ellipse or a circle of equivalent confidence. Although the utilization of such approaches may be appealing in some ways, they should be avoided due to their tendency to neglect representation of the entire area originally described. Such a condition is evidenced in the following scenarios.



**Figure 7.3: Resultant Shape Fully Contained by the Original – NOT Recommended**

Figure 7.3 depicts the resultant shape as being contained by the original shape, thus underrepresenting the area of uncertainty and suggesting the possibility of a reduced search effort by First Responders. Mapping among shapes in this way is NOT recommended.



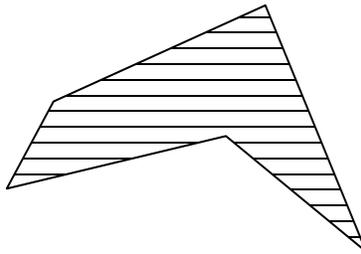
**Figure 7.4: Resultant Shape Describes an Equivalent Confidence to the Original – NOT Recommended**

The example in Figure 7.4 shows a resultant shape of equivalent confidence. This approach is also NOT recommended unless sufficient metadata exists to produce a shape of equivalent confidence.

### 7.2.2 Represented Location Coordinates

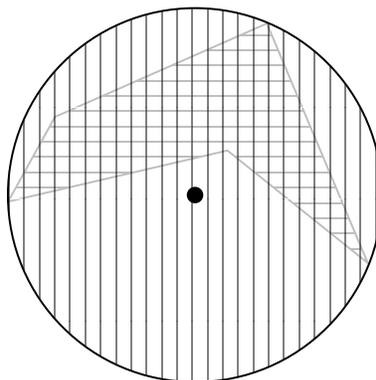
Of crucial importance is that the representative coordinates describing a location are not adversely altered in the shape mapping. Although intuitive, there are cases where such a condition could inadvertently arise, albeit with potentially significant consequences, by either mathematical or geometric operations. A description of how this could occur follows.

A shape which minimally encompasses the original but whose geometric center, or centroid, varies from that of the original, can exist. A 3GPP polygon upon mapping into an E2-compliant circle may produce such a result. This is evidenced by circumscribing an irregular polygon with a minimum bounding circle. More significantly, the resulting circle's center could be entirely outside of the original uncertainty polygon.



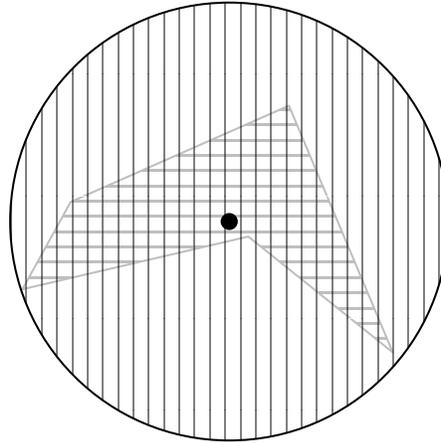
**Figure 7.5: A Polygonal Uncertainty**

Again, when taking the approach of ensuring the entirety of the original shape is covered by the new one, a minimum bounding circle may be employed. However, in this case, doing so is problematic because it locates the representative coordinates (described by the circle's center) outside of the original search area.



**Figure 7.6: Resultant Shape Places Defining Coordinates Outside of the Original**

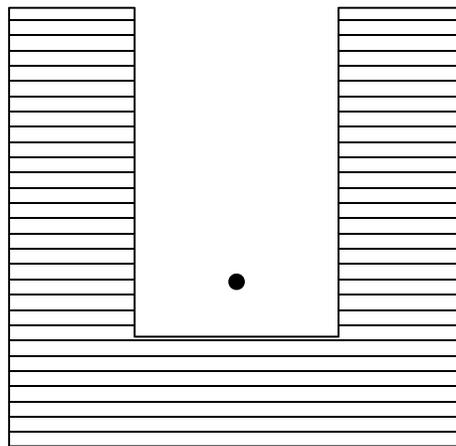
The approach shown in Figure 7.6 is discouraged because the principal information defining the location, being the latitude and longitude, is now outside of the original area of uncertainty. A better approach in this case would utilize the centroid of the polygon as the center of the circle and then increase its radius to minimally cover the original shape.



**Figure 7.7: Resultant Shape Contains the Original with a Common Centroid**

Figure 7.7 renders a circle which entirely contains the original polygon and whose center is located at the geometric center of the original area of uncertainty. In highly irregular shapes, special consideration may need to be given by ‘clipping’ extended protrusions of the original shape.

An edge case exists which should be mentioned here. This occurs when the geometric center of the original shape is outside of the shape itself. This can easily occur for uncertainty polygons in the shape of an “L” or “U” as could be envisioned for certain in-building location technologies.



**Figure 7.8: U-Shaped Polygon with Its Centroid Depicted**

Figure 7.8 depicts a U-shaped polygon and its centroid. In this case, the shape’s geometric center is outside of the uncertainty area specified by the polygon. When converting this shape into another form, it is recommended that the single descriptive point around which shapes are commonly defined be located within the original area of uncertainty. For consistency, a circle will again be used to describe a suitable mapping methodology for this condition.

As it is desirable to represent the new shape by coordinates located within the original, the point nearest the original uncertainty centroid yet within the original uncertainty shape is identified. In this case, this is represented by a point on the surface immediately below the centroid. From this point the shortest radius is used to cover the original polygon, resulting in a minimal bounding circle whose center is located within the original uncertainty shape nearest to the original shape's centroid.

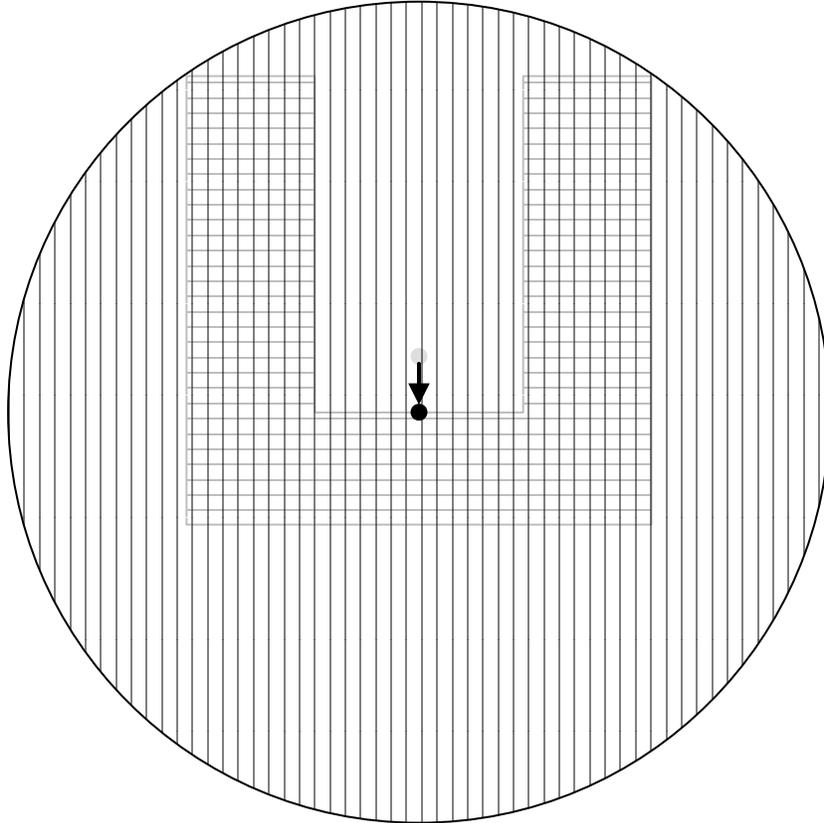


Figure 7.9: Resultant Circle Contains the Polygon having its Center within the Polygon

### 7.2.3 3D Considerations

Similar principles are in effect when Z-axis information is included in the shape description. Below is an example of mapping an ellipsoidal uncertainty to that of a cylinder as could also be required when conveying location information across 3GPP and E2 components.

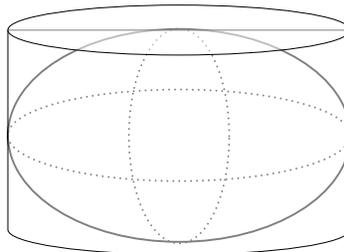


Figure 7.10: Resultant Cylinder Contains Original Ellipsoid

In this example the resultant cylinder, being an extrusion of a two-dimensional circle or ellipse, fully contains the original ellipsoid while the geometric centers, or centroids, are the same. This results in the base coordinates being unchanged between the two representations.

### 7.3 Mapping from 3GPP Originated Location to E2 Location

Some mappings from 3GPP originating networks are straightforward, while other mapping approaches require assumptions to be verified. Table 7-2 further describes the mapping required.

**Table 7-2: Mapping from 3GPP Originated Location to E2 Location**

3GPP location shape type	Recommended E2 location shape type	Comments
Ellipsoid Point (GAD Shape 0)	Ellipsoid Point	Equivalent mapping
Ellipsoid point with uncertainty circle (GAD Shape 1) (defined to not include confidence)	Ellipsoid Point with Uncertainty	Confidence is supplied with a value of '0'.
Ellipsoid point with uncertainty ellipse (GAD Shape 3) (defined to include confidence)	Ellipsoid Point with Uncertainty	The horizontal uncertainty reduces to a single radius value. Use the semi-major value for this single value.
Polygon (GAD Shape 5)	Ellipsoid Point with Uncertainty	Center the circle at the polygon's centroid and extend the circle's radius to the minimal length needed to cover the entire polygon. Note special conditions in section 7.2.2.
Ellipsoid point with altitude (GAD Shape 8)	Ellipsoid Point	3D Point w/o Uncertainty.
Ellipsoid point with altitude and uncertainty ellipse (GAD Shape 9)	Ellipsoid Point with Altitude and Uncertainty	The horizontal uncertainty reduces to a single radius value. Use the semi-major value for this single value. The vertical uncertainty should simply be retained in the new shape description.
Ellipsoid Arc (GAD Shape 10)	Ellipsoid Point with Uncertainty	Center the circle at the arc's centroid and extend the circle's radius to the minimal length needed to cover the entire arc. Note special conditions in section 7.2.2.
High Accuracy Ellipsoid point with uncertainty ellipse (GAD Shape 11)	Ellipsoid Point with Uncertainty	The horizontal uncertainty reduces to a single radius value. Use the semi-major value for this single value.
High Accuracy Ellipsoid point with altitude and uncertainty ellipse (GAD Shape 12)	Ellipsoid Point with Altitude and Uncertainty	The horizontal uncertainty reduces to a single radius value. Use the semi-major value for this single value. The vertical uncertainty should simply be retained in the new shape description.

### 7.4 Mapping from 3GPP Originated Location to PIDF-LO Location

Some mappings from 3GPP originating networks are straightforward, while other mapping approaches require assumptions to be verified. Table 7-3 further describes the mapping required.

**Table 7-3: Mapping from 3GPP Originated Location to PIDF-LO Location**

3GPP location shape type	Recommended PIDF-LO location shape type	Description of Mapping
Ellipsoid Point	Point	Equivalent mapping
Ellipsoid point with uncertainty circle	Circle	Equivalent mapping
Ellipsoid point with uncertainty ellipse	Ellipse	Equivalent mapping
Polygon	Polygon	Equivalent mapping
Ellipsoid point with altitude	Point	Equivalent mapping
Ellipsoid point with altitude and uncertainty ellipsoid	Ellipsoid	Equivalent mapping
Ellipsoid Arc	Arc Band	Equivalent mapping
High Accuracy Ellipsoid point with uncertainty ellipse	Ellipse	Potentially reduced resolution
High Accuracy Ellipsoid point with altitude and uncertainty ellipsoid	Ellipsoid	Potentially reduced resolution

### 7.5 Mapping from PIDF-LO Originated Location to E2 Location

Some mappings from 3GPP originating networks are straightforward, while other mapping approaches require assumptions to be verified. Table 7-4 further describes the mapping required.

**Table 7-4: Mapping from PIDF-LO Originated Location to E2 Location**

PIDF-LO location shape type	Recommended E2 location shape type	Description of Mapping
Point	Ellipsoid Point	This reduces to a 2D point.
Circle	Ellipsoid Point with Uncertainty	Equivalent mapping. It is assumed that the confidence value is provided in PIDF-LO per RFC 7459 [Ref 106].
Ellipse	Ellipsoid Point with Uncertainty	The horizontal uncertainty reduces to a single radius value. Use the semi-major value for this single value.
Prism	Ellipsoid Point with Altitude and Uncertainty	Center the cylinder at the prism’s centroid, extend the cylinder’s radius to the minimal length needed to cover the entire prism on the horizontal plane and identify the minimal vertical uncertainty needed to encompass the prism from the elevation of the object’s centroid (which should be half the height of the prism). Note special conditions in section 7.2.2.
Sphere	Ellipsoid Point with Altitude and Uncertainty	The resultant shape minimally contains the original, with their centroids being coincident.
Ellipsoid	Ellipsoid Point with Altitude and Uncertainty	The resultant shape minimally contains the original, with their centroids being coincident.
Arc Band	Ellipsoid Point with Uncertainty	The resultant shape minimally contains the original, with their centroids being coincident.

## 8 Recommendations

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This Technical Report has provided a summary of the related standards where reporting formats are defined for location conveyance of 2D and 3D location estimates for wireless emergency calls. This Technical Report's first goal was to determine if gaps existed in the end-to-end aspects of location conveyance standards. In general, no gaps of significance (i.e., where no mappings were possible) were identified. Most standards support most shapes, so deployments are not hindered by any standard. It is shown that end-to-end solutions are possible where the position is never modified once generated (i.e., PIDF-LO from device to PSAP). It is also shown that for the common deployments of today there is an ideal, or near ideal, shape to be selected, if a protocol conversion is required. The various tables show the specific recommendations and the implications of how the downstream entity is impacted and how the information is modified (e.g., GAD Shape 9's uncertainty ellipsoid with semi-major and minor axes being converted to a simple radius). If new shapes are introduced in the future, this Technical Report has a full set of recommendations for reporting two-dimensional and three-dimensional shapes and best practices for propagating the shapes to minimize the accumulation of errors.

This Technical Report should be used by wireless carriers, infrastructure vendors, handset manufacturers, and public safety to: (1) implement best practices, and (2) understand where information conversion can occur and could introduce some additional error in the position estimates.