LiDAR for z-axis Dispatchable Location

Business Case

June 2023

National 911 Program

About the National 911 Program

The National Highway Traffic Safety Administration (NHTSA) National 911 Program (Program), in the Office of Emergency Medical Services (OEMS) at the United States (U.S.) Department of Transportation (DOT), provides leadership and coordination of federal efforts that support 911 across the nation. A seamless interoperable 911 system-of-systems across the U.S. advances NHTSA's mission to eliminate fatalities, illness, and injuries from motor vehicle crashes and improve post-crash care.

The Program works with many stakeholders—including federal, state, local, tribal, and territorial (FSLTT) governments, technology vendors, public safety officials, and 911 professionals—toward a goal of advancing 911 that takes advantage of existing and emerging communications technologies, improving response times and information available to first responders prior to and during a 911 incident.

About this Document

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Executive Summary

The Next Generation 911 (NG911) migration depends on accurate location data generated from geographic information systems (GIS) to route an emergency call to the appropriate public safety answering point (PSAP). Horizontal as well vertical accuracy of an emergency caller can determine the time it takes a first responder to reach an incident. Vertical elevation, known as z-axis, is being formally recognized as a part of the NG911 environment and many federal, state, local, tribal, and territorial (FSLTT) jurisdictions are seeking ways to implement this lifesaving technology.

The Federal Communications Commission (FCC) recognizes this need as well and has published a vertical accuracy benchmark known as z-axis as part of the Fifth Report and Order FCC-19-124[1]. This report, published in 2019, outlines the accuracy requirements for vertical locations equating to three meters above or below the handset of wireless callers. Many PSAPs already have begun to receive elevation data as part of their automatic location identification (ALI) spill from service providers. At this time, a vast majority of PSAPs are not fully prepared to ingest and read this elevation data since sophisticated software algorithms are needed to properly convert the raw elevation to intelligible, dispatchable location information that can be easily understood and read by 911 telecommunicators. In preparation for testing three-dimensional (3D) backend solutions, GIS data must be developed to support this new vertical environment. Light detection and ranging (LiDAR) can support GIS data development by providing accurate and precise elevation information for building footprints. Collection and classification of LiDAR data provides a 3D landscape of the terrain from which base elevations are derived. Combining this elevation information with GIS data will allow FSLTT 911 authorities to utilize z-axis technology.

This business case is meant to assist FSLTT jurisdictions with justifying the purchase of LiDAR products for establishing base elevation and building heights necessary for properly interpreting the z-axis data provided by wireless carriers and identifying partnering solutions to lessen the financial burden of collection and increase the sustainability of the program year-over-year.

[1] Indoor Location Accuracy Timeline and Live Call Data Reporting Template | Federal Communications Commission (fcc.gov)

1 Z-axis Reconciliation Project Definition

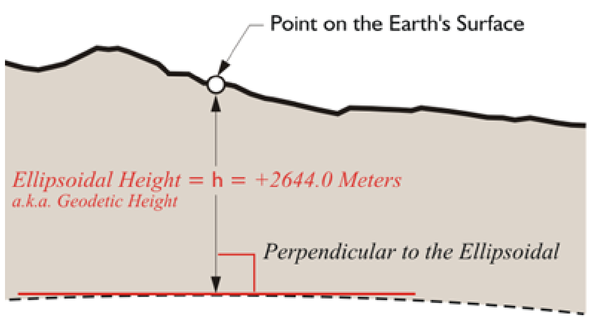
1.1 Problem Statement

Location information for wireless callers to 911 now is being provided to public safety answering points (PSAPs) with both horizontal (longitude and latitude) and vertical (z-axis or height above ellipsoid) values. PSAPs have been interpreting the horizontal location information for decades and placing the caller's location on a two-dimensional map. The introduction of the vertical location information provides PSAPs z-axis information without a base height reference as context for calculating the elevation above the ground or height above terrain. In current PSAP mapping environments, the Height Above Ellipsoid (HAE) alone adds little to no value to the emergency response process.

1.2 Background Information

The Federal Communications Commission (FCC) identified the need to locate 911 callers both horizontally as well as vertically. In 2019, the Fifth Report and Order on Reconsideration—building on the FCC's rules for transmitting z-axis location[2] with wireless 911 calls—became effective for the top 25 cellular markets in the United States (U.S.)[3] Most states are scrambling to implement solutions to operationalize the intelligence provided by this technology rollout.

Geographic information systems (GIS) are used to create and maintain the maps relied on by 911 centers to provide telecommunicators and first responders with a visual reference for location information. This has traditionally been displayed with a two-dimensional map. GIS data is required to translate the three-dimensional (3D) location of the 911 caller to a position on a map, including building floor information. Mapping in three dimensions requires more sophisticated data collection and classification along with complex software processes to support this type of visual aid.



Light detection and ranging (LiDAR)[4] is a process used for collecting elevation information from a sensor and classifying that data—known as a point cloud—based on bare earth, vegetative, transportation, and building features. Most PSAP mapping systems can not readily ingest LiDAR point clouds due to the size and complexity of the data. Therefore, the final data product is exported to a GIS format that is more readily consumed by PSAP mapping applications.

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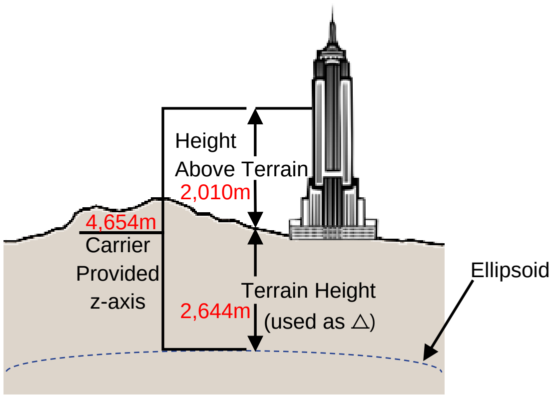
2 https://docs.fcc.gov/public/attachments/FCC-20-98A1_Rcd.pdf
3 The top 50 cellular markets are listed in Appendix B.
4 https://www.usgs.gov/faqs/what-lidar-data-and-where-can-i-download-it

Currently the horizontal location, within 50 meters for 80% of all 911 cellular calls[5], should be delivered to the PSAP as part of the FCC accuracy requirements of the Fifth Report and Order enacted in 2019. The FCC, in that same Report and Order, also required the provisioning of the z-axis location of the caller within three meters above and below from the calling device for 80% of all wireless 911 calls. Commercial mobile radio services (CMRS) providers, otherwise known as wireless carriers, are required to deliver elevation data with confidence and uncertainty levels to a PSAP per call. There is no requirement for the delivery of the elevation data to be translated from HAE to Mean Sea Level (MSL) or height above terrain—making this information non-intelligible for 911 telecommunicators or first responders without additional GIS data.

1.3 Project Overview

Federal, state, local, tribal, and territorial (FSLTT) 911 authorities seeking to provide intelligible, dispatchable information to PSAPs must translate the HAE provided by wireless carriers into the height above terrain within a 911 center's mapping solution. From the example to the right, if the ellipsoidal height is increased by moving the caller's location from the Earth's surface to an upper floor of a multistory building, the carrier-provided z-axis information will not provide actionable intelligence without a delta value—terrain height—to be subtracted from the overall height—the HAE—to determine the height above terrain of the caller—the actionable height.



Using LiDAR to build a terrain model and extracting building heights from the first return LiDAR, FSLTT 911 authorities can construct a 3D representation of all buildings (four or more stories as required by the FCC) and the immediate surrounding areas. The resultant products can be provided to the appropriate PSAPs for inclusion in mapping solutions where the carrier-provided z-axis now can be translated into elevation within a building.

1.4 Collection Options

There essentially are three options for collecting 3D data:

- **Option 1**: Local, independent collection of 3D data and development of the z-axis dataset
- **Option 2**: Use the existing 3D Elevation Program (3DEP)[6] QL2 LiDAR data with building height classification (i.e., building heights are obtained with minimal structure details)
- **Option 3**: Buy-up to QL1 or QL0 LiDAR data with building height classification (i.e., building heights are obtained with substantial structure details)

[5] Horizontal Location Accuracy Benchmark**:** Nationwide providers must achieve 50-meter horizontal accuracy (x/y location within 50 meters) or provide dispatchable location for 80 percent of all wireless 911 calls. (47 CFR § 9.10(i)(2)(i)(A)(4))
[6] What is 3DEP? | U.S. Geological Survey (usgs.gov)

The following table denotes the differences between the three options.

Table 1: Options Comparison

	Option 1: Local, Independent Collection	Option 2: Use Existing 3DEP QL2 Data	Option 3: Buy-up to QL1 or QL0 Data
Specifications	Set by each jurisdiction or by the LiDAR vendor	USGS[7] 3DEP Base Spec at QL2 or better 10cm vertical accuracy 71cm pulse spacing 2pts/m^2 pulse density 1m DEM[8]	10cm (QL1) or 5cm (QL0) vertical accuracy 35cm pulse spacing 8pts/m^2 pulse density 0.5m DEM
Benefits	Full control over the process	No cost to acquire or use Limited participation in collection planning, scheduling, and update frequency	Highly accurate model Detailed buildings Detailed vegetation Better definition of features and the ground Improved feature extraction capabilities Participation in collection planning, scheduling, and update frequency
Disadvantages	Non-standardized collection may negatively impact overall data integrity and the ability to share data Substantially higher cost Requires sustained funding	A-line roofs and other building structures make it difficult to apply floor levels	Requires participation in governance working group(s) and sustained funding
Timescale	Dependent upon each jurisdiction's resources and approach	Set by USGS and partners	Can influence frequency and schedule through participation in working group(s)
Costs	Dependent upon each jurisdiction's resources and approach	No cost	Investment varies by number of partners Substantially less than independent collection

[7] Unites States Geological Survey
[8] Digital Elevation Model

1.4.1 Project Exclusions

Use in 911 only requires collection of LiDAR for areas including or immediately surrounding buildings of four or more stories per the FCC order. However, FSLTT jurisdictions can purchase LiDAR products under this contract not related to 911 needs with local, non-911 funds per federal regulations.

1.5 Benefits and Limitations

The collection of LiDAR data can be of great value to a wide range of government agencies beyond 911—from hydrodynamic modeling of streams, rivers, or coastal areas to forensic and archeologic studies to farming with precision agriculture. The potential for cost sharing across multiple agencies and the multiple grant opportunities available to each use for LiDAR data can reduce or even completely cover local costs to upgrade the 3DEP QL2 LiDAR.

Budgeting for local buy-ups can present some challenges since the LiDAR collection is not performed yearly. Education and outreach to elected officials and budgeting authorities likely will be necessary to ensure that off-years do not affect the ability to secure funding for future LiDAR updates.

1.6 Scope and Interdependencies

The FCC has created the expectation that PSAPs now should know the floor location of a 911 caller without any action by the caller. The z-axis information being provided to PSAPs, however, only is actionable with the addition of reference data developed from the acquisition of LiDAR.

Computer-aided dispatch (CAD) systems currently marketed in the industry cannot process three-dimensional GIS data. The resultant products to support the use of z-axis information must be compatible with call-handling equipment (CHE) that provides the vertical location.

Certain prerequisites are assumed in this document and are detailed in the *NENA Requirements for 3D Location Data for E9-1-1 and NG9-1-1* (NENA-REQ-003.1-2022).[9] Variables outside of these will alter the output and/or accuracy of the data and likely will negatively impact the outcome. These steps generally are intended to integrate 3D data at rudimentary through full end-state levels.

All data should natively be in the World Geodetic System of 1984 (WGS84)[10]. Any transformations or reprojections between coordinate systems and datums could potentially alter the viability of the end product.

Address points should not be road centerline geocoded. To utilize the attribute “join,” detailed in the workflow processes, all address points must be placed on building rooftops.

Schema designations in this business case are based on NENA-STA-006.2a-2022[11].

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[9] https://www.nena.org/resource/resmgr/standards/nena-req-003.1-2022_3d_gis_2.pdf
[10] https://gis-lab.info/docs/nima-tr8350.2-wgs84fin.pdf
[11] https://www.nena.org/resource/resmgr/standards/nena-sta-006.2a_ng9-1-1_gis_.pdf

1.7 Workflow Processes

The following steps present an optional workflow to create operational 3D data. The maintenance phase would follow a similar path, but for more targeted areas or geometries. Further discussion on identifying areas of upkeep is canvassed in the Maintenance section.

1.7.1 Building Footprints

The use of open-source data such as Microsoft Building Footprints[12] as a base data source will allow jurisdictions to minimize the cost of creating these data from scratch. Microsoft Building Footprints allows jurisdictions to be immediately presented with a large coverage area of building footprint information. While most data captured dates back to 2012, certain areas of the country were updated in 2019–2020. (See Figure 1)

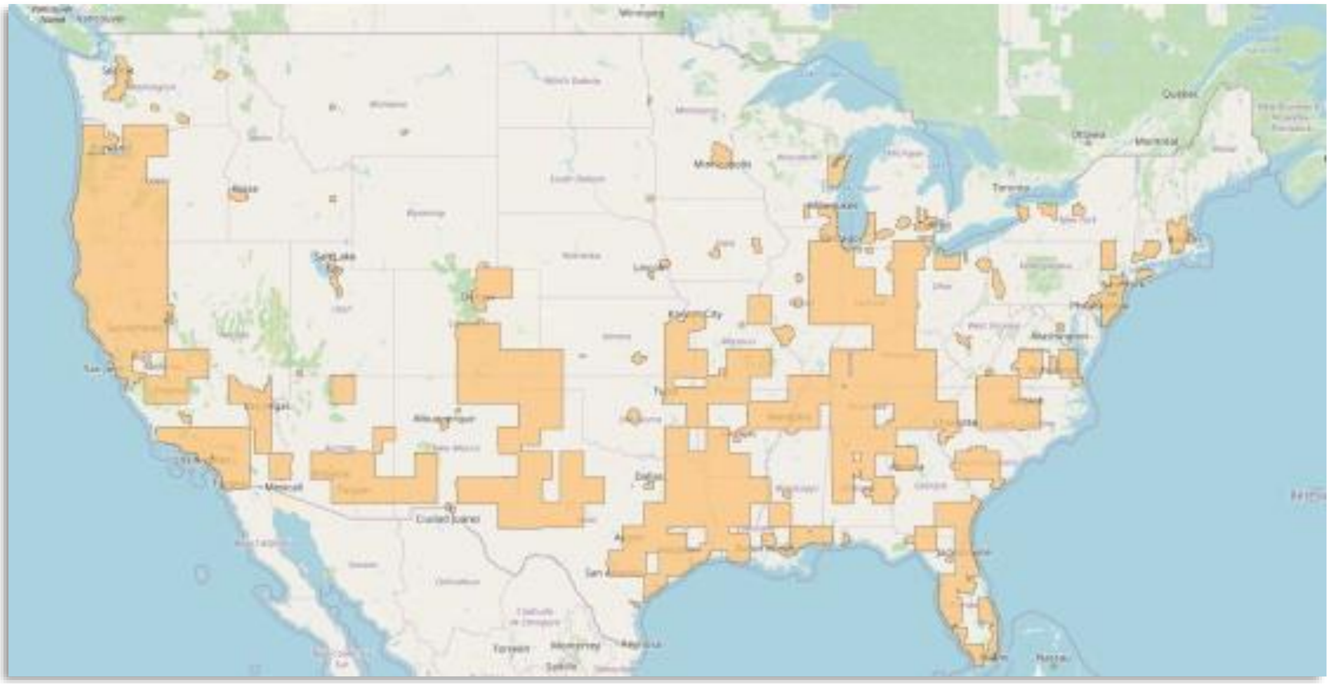

Figure 1: Microsoft Building Footprint Updates (2019–2020)

These footprints were used to update the open-source OpenStreetMap (OSM)[13] product and an export of this dataset can be downloaded for comparison. Depending on the locality, OSM building footprints may be a more viable solution since it is a crowd-sourced dataset. OSM data provides minimal attributes whereas the Microsoft data is just the footprint geometry with only release and capture date attributes.

[12] GitHub - microsoft/USBuildingFootprints: Computer generated building footprints for the United States
[13] https://www.openstreetmap.org/#map=5/38.007/-95.844

Some descriptive place names could be linked to the Complete Landmark Name[14] attribute, and some generalized OSM types could be linked to the Place Type[15] attribute with a translation table.

Both data sources already contain z-axis information (Polygon Z).

1.7.2 Data Review

After downloading open-source data, a thorough data review is necessary to find and correct potential errors before processing. It may be best to grid off the jurisdictional area and review methodically so that no areas are missed.

Examples of the error types that must be handled are provided in the sections that follow.

Missing Structures

Omission is the most frequent error for data not updated over several years. Missing structures can be due to a variety of reasons—the most common being new construction or algorithmic issues in either interpreting the raster or constructing the geometry when the initial dataset was compiled.

Figure 2 shows an example of an apartment complex where structures are missing.

[14] NENA: The 9-1-1 Association. (2018, June 18). NENA-STA-006.1-2018 § 4.29. Alexandria, VA.
[15] Ibid., § 4.90

Figure 2: Missing Apartment Complex Structure

New buildings can be digitized from freely available 3DEP products, but the OSM building footprints should be referenced first to see if they have already been added through crowdsourcing.

Figure 3 shows an area of new construction. The Microsoft data has not yet captured any footprints, but OSM already has a few buildings in place (green polygons). These can easily be selected and exported to integrate into the larger footprint dataset.

Figure 3: OSM Augmentation of Building Footprints Not Present in the Microsoft Building Footprints

By importing the Microsoft and OSM building footprint data, the time and cost of the project has been greatly reduced; updating an existing dataset with some missing buildings is far less labor-intensive than creating a dataset of hundreds or even thousands of buildings from scratch.

Older or Misaligned Structures

Other issues in the data may result from older buildings that have not been updated and, therefore, have a skewed presentation.

Figure 4 shows an older building structure that would need to be deleted and the new structure extracted from the 3DEP LiDAR.

Figure 4: Older Building Footprint with Newer Raster Overlay

Tutorials and training are available from multiple sources to guide jurisdictions through updating building footprint data from LiDAR[16] or many qualified photogrammetry and GIS companies can be contracted to perform the work using the General Services Administration (GSA) Schedule[17] by searching Geographic Information Systems in the GSA eLibrary.

[16] Extract 3D buildings from lidar data | Learn ArcGIS
[17] GSA eLibrary Search Results Summary

Artifacts

Depending on the capture method, some algorithms will detect things in the raster that are interpreted as structures but are not. These can appear more organic than the usual blocky geometries generated from true buildings.

Figure 5 shows an example of this; there may have been flooding in portions of this field that was interpreted as structures.

Figure 5: Artifacts in the Microsoft Building Footprints

1.7.3 Attribution

It is necessary to enhance the building footprint data—derived from open-source or 3DEP products—by incorporating additional attributes for addressing, building height, and landmark values, which quickly can be absorbed from intersecting object classes such as address points or tax data.

Spatial joins between the building footprints and other datasets that already contain the desired attributes can populate most attribute fields required by NG911. A spatial join uses spatial context (intersect or within) to migrate attributes from one set of geometry to another. The entire attribute can be joined, or only certain fields can be migrated using a field map.

This section discusses attributional enhancements and options involved with attaching them to the footprint layer.

Addressing

It is important for the building footprints, and eventually 3D geometry, to have relevant attribution. The most beneficial primary attribute set in a PSAP environment is the civic address information. At a bare minimum, fields that match the master street address guide (MSAG)—the legacy table of all valid addresses in a jurisdiction—should be added. Ideally, the site structure address point (SSAP) data schema should conform to the latest published version of the *NENA Standard for NG9-1-1 GIS Data Model* (NENA-STA-006), but these datasets must be usable in PSAP operations as well. Vendor software such as CAD may impact what fields are implemented. It is recommended to use the NENA schema as a base and add any additional fields necessary for applications beyond NG911. There are several options (i.e., scripting or toolsets) that would help with redundant fields so that data entry is not impacted.

Depending on the accuracy and fitness of the SSAP dataset, a spatial join can be used to acquire basic MSAG-level attribution. For this to be successful, the SSAP should be placed on the rooftop so an intersect with the building footprint can occur. Mailbox placement will not work for this exercise, and even address points derived from a road centerline geocode with a prescribed offset can yield such a high percentage of non-intersects that it renders the data useless (see Figure 6).

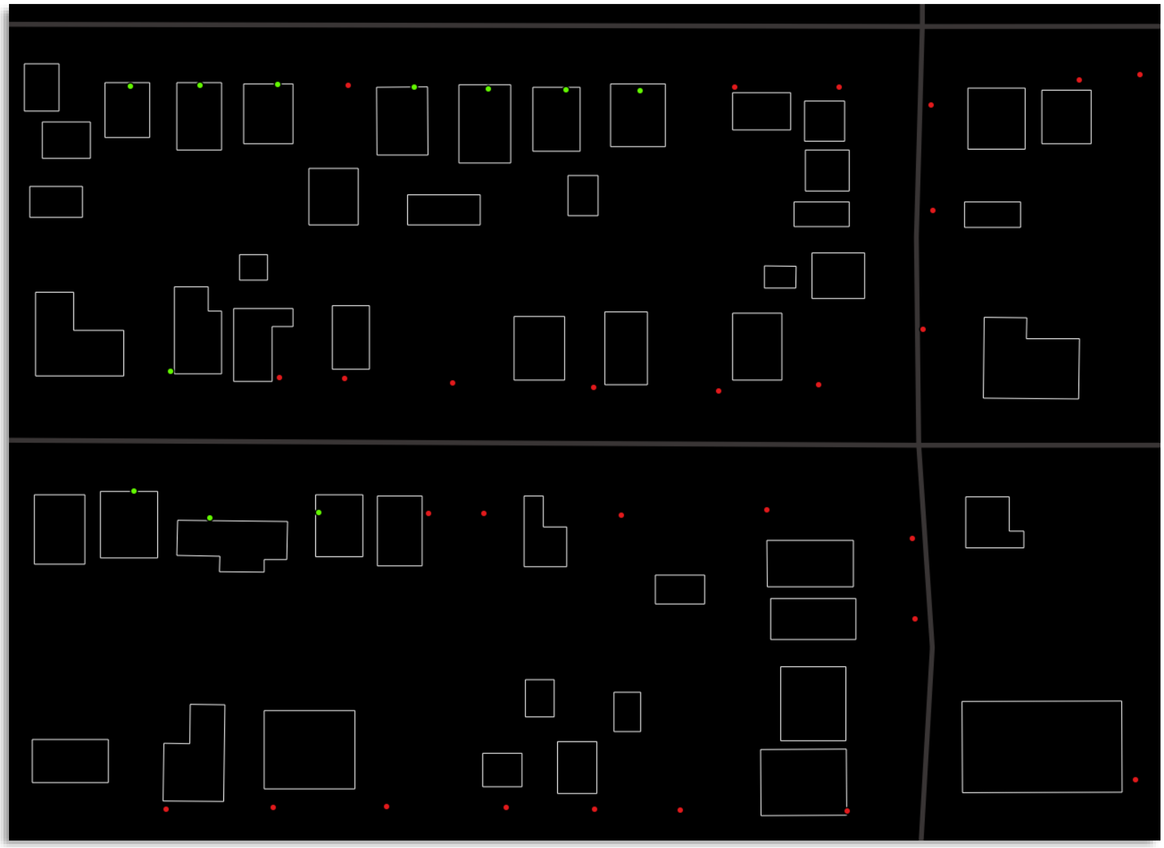

Figure 6: Intersection of Offset Centerline-Geocoded Civic Addresses with Building Footprints

After the spatial join is performed, two queries should be run to isolate edits and missing features.

- An attribute selection on the building footprints should be performed to isolate those records that did not acquire address attribution. This should identify issues like artifacts or older structure geometries that may need to be deleted or edited. This may also identify structures in the data that legitimately do not have addressing assigned (e.g., barns). The following query should suffice to select these features: St_Name = '' OR St_Name IS NULL
- A spatial selection should be performed to isolate those address points that did not intersect a building footprint. This should identify missing building structures and erroneously placed address points (e.g., points that were originally placed at the mailbox or centerline geocoded and were never moved to the rooftop). Areas of new construction will also probably be identified where new footprint geometry has not been generated.

These query results should be saved for future maintenance work. Once the query is run, the selection set can be exported as a new layer to be referenced when augmenting the building footprint layer. Adding a field to track progress can quickly create a spatial project tracking mechanism.

Landmark Namespace

Understanding the "what" about the "where" is just as important for emergency response. Quickly assessing the type and/or name of the facility first responders may be going to can aid in preparation for that response. Free options such as OpenStreetMap and ArcGIS Hub[18] from Esri are available to collect vanity and categorization data to help in this regard.

OpenStreetMap[19] contains multiple crowd-sourced layers for locations all over the planet. Some major corporations also contribute to the data amalgam. For instance, Esri contributes to various layers in the dataset[20], has developed editing tools for integration into ArcGIS Desktop[21], and consumes OSM data in its application environment[22]. Building footprints are also a part of this extensive dataset. These geometries come with some standard attribution including building name and type, and some products have the building height and number of levels. Attributes can be assigned using the same methodology outlined in Section 1.7.3. A spatial join to capture any additional attributes is the easiest method if the features overlap.

To isolate appropriate structures from the OSM data, it is useful to understand how features are categorized. OSM uses a free tagging system that consists of a key and a value.[23] To isolate addressable structures, use the "building" key to extract applicable structures. Multiple tags can be used to add descriptions such as the type, material, color, and even the number of floors, ingress/egress, and height. Distinguishing structures that have been abandoned or repurposed from active or current use are tagged with either "building:use=*" or with an "amenity" key. For additional information on accepted tagging specific to buildings, please refer to the Key:building wiki page.[24]

Crowdsourcing GIS data can create a risk to attribute population not conforming to the prescribed standard. Care should be taken to isolate all possible variations used to tag a building and remove any attributes that are not mappable. It may also be helpful to understand that since this is crowd-sourced data, and many places in the world do not have up-to-date aerial imagery to capture polygonal representations of structure footprints, in some localities, buildings may be captured as nodes with the appropriate tagging.

A useful ArcGIS Feature Service[25], published and updated regularly, affords access to attributes such as address information, postal code, amenity, building type, vanity name, and branding.

1.8 Maintenance

Continuously updating the LiDAR data in sync with new development is equally as important as maintaining the GIS data necessary to support Next Generation Core Services (NGCS). However, LiDAR data only is necessary for buildings over three stories tall. It is not necessary to reacquire an entire jurisdiction to accommodate new multistory buildings; the same collaborative network used to collect the initial LiDAR products also can be used to supplement the data between collection events. It likely will be beneficial in urban and suburban areas to perform a complete LiDAR refresh every two to three

[18] https://hub.arcgis.com/maps/462b08b0811c4a77aa09afc36c4f4b73
[19] OpenStreetMap
[20] ArcGIS Datasets in OpenStreetMap (esri.com)
[21] ArcGIS Editor for OpenStreetMap | OSM Editor - Access, Edit & Analyze Data (esri.com)
[22] Live OpenStreetMap Data in ArcGIS (esri.com)
[23] Tags - OpenStreetMap Wiki
[24] Key:building - OpenStreetMap Wiki
[25] OSM_Buildings_NA (FeatureServer) (arcgis.com)

years, depending on growth and budgetary constraints. LiDAR collection also should be done in tandem with orthoimagery collection since the sensors and imagery capture equipment can coexist on the same plane.

1.9 Strategic Milestones

Establishing strategic milestones for this project will help guide a jurisdiction through the processes. Well-defined metrics also provide a gauge for incremental success and highlight project issues early—before the risk becomes a blocking issue. The following milestones and metrics have been identified for a LiDAR project; not all milestones will apply to every jurisdiction.

Table 2: Milestones and Metrics

Strategic Milestones	Success Metrics
Acquire existing LiDAR products	Baseline dataset acquired
Develop/acquire 3D buildings dataset	Baseline dataset acquired
Perform gap analysis of 3D buildings	Establish level of effort to bring data current
Establish interest/partnerships	Project team meets regularly
Develop cost model/buy-up needs	Funding plan developed
Acquire funding	Funding approved
Update scope of work for current vendor or prepare request for proposal (RFP) for new contract	Contractual modifications for current vendor or RFP awarded
Research and vet vendor backend capabilities for ingestion and utilization of z-axis data	Vendor selected for beta-testing of backend solution
Investigate existing LiDAR datasets and upcoming LiDAR flights for building footprint capture with elevation values Focus should be on buildings over three stories Finalize building footprint data to be incorporated with the pilot program(s)	Density analysis along with the FCC top 50 cellular market areas determines the focus areas Pilot program(s) underway
Recruit beta testers for backend z-axis solution	PSAP(s) selected for pilot testing of z-axis solution with recent LiDAR building footprints with z-axis
Train GIS staff on z-axis data	Documentation is developed to support z-axis understanding and editing of 3D NG911 GIS
Train 911 staff on z-axis data	Documentation is developed to support understanding of confidence and uncertainty levels of z-axis data
Create a maintenance plan for 3D GIS data	3D GIS maintenance plan is created for jurisdictions
Delivery of point cloud, which has been through quality control, and 3D GIS dataset	Data accepted
Delivery of the 3D GIS data to the jurisdictions	Accepted by the jurisdictions
Beta testing of GIS in the backend environment	Successful beta testing, followed by a move to fully implement in pilot PSAP(s)
Draft report on metrics/successes/lessons learned	Draft report

2 Finance

2.1 Financial Appraisal

The collection of 3D elevation data can be both expensive and complicated to manage. The USGS manages the 3DEP to respond to growing needs for high-quality topographic data and a wide range of other 3D representations of the nation's natural and constructed features. 3DEP informs "critical decisions made across our Nation every day that depend on elevation data, ranging from immediate safety of life, property, and environment to long term planning for infrastructure projects."[26] This program is funded by Congress and allows FSLTT partners to "buy-up" to higher quality LiDAR at a fraction of the cost of individual collection by any one jurisdiction. The average cost of 3DEP high-quality LiDAR remains under $800 per square mile and the federal government has funded at least 75% of the costs[27] depending on several factors such as the planned collection area, population density of the area to be collected, and the needs of federal agencies. Figure 7 depicts the investments in LiDAR year-over-year.

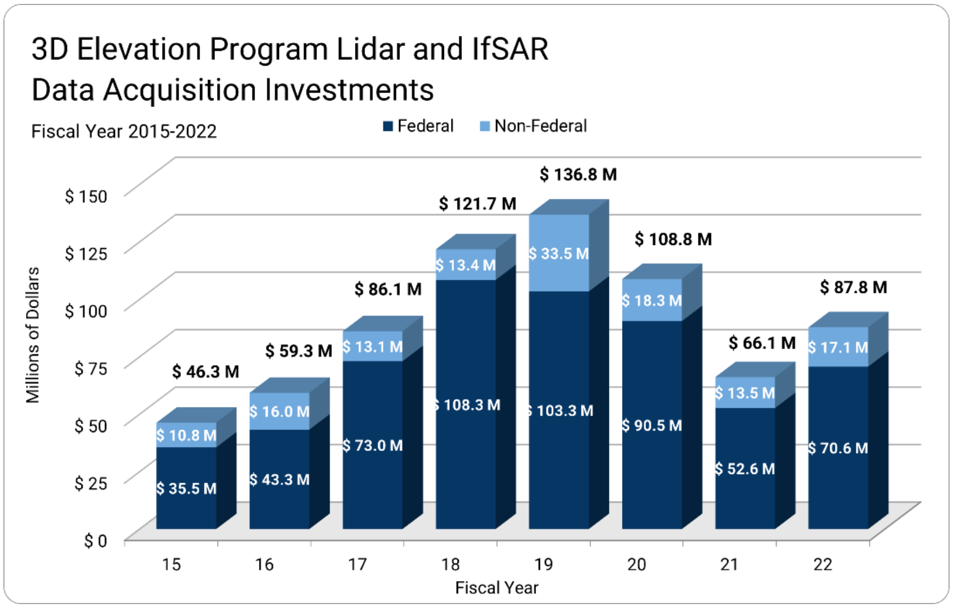

Figure 7: Investments in LiDAR

The broad use of LiDAR also has increased the pool of potential funding partners to include stormwater, urban planning, forestry, broadband and internet access, and many others with whom the USGS coordinates these efforts. The ideal end state, according to the USGS, is substantially benefitting partners and taxpayers while ensuring the project is affordable to every community in the U.S.

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26 3DEP By The Numbers | U.S. Geological Survey (usgs.gov)
27 3DEP Lidar and IfSAR Data Acquisition Investments | U.S. Geological Survey (usgs.gov)

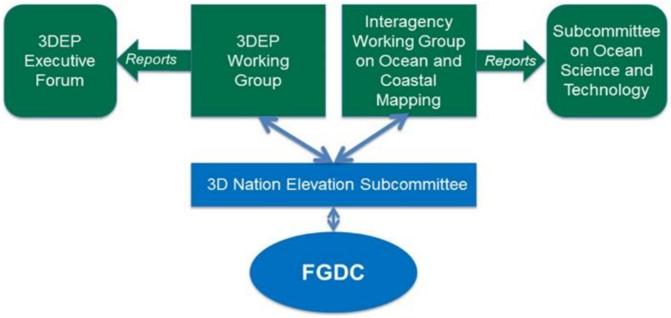
The broad use of 3DEP products increases the value over expense of acquiring these data. The USGS estimates a 5:1 return on investment for the 3DEP efforts since 2015. According to the Fiscal Year 2014 National Enhanced Elevation Assessment report: "At the full funding level, 3DEP could return more than $690 million annually in new benefits directly to the private sector and indirectly to citizens through improved government program services. "[28]

> *This would result in a nearly 5:1 return on investment, informing critical decisions that are made across our Nation every day that depend on elevation data, ranging from immediate safety of life, property, and environment to long term planning for infrastructure projects.*[29]

2.2 Sensitivity Analysis

The most prominent risk of implementing 3D data for 911 emergency response is maintaining these data in synchronization with real-world development. LiDAR data will not be available for buildings under construction or may show old infrastructure that since has been removed. To be truly effective, 3D data must be maintained as development and redevelopment occur, which requires dedicated annual funding.

Funding for 3DEP is governed through two working groups reporting to the 3D Nation Elevation Subcommittee of the Federal Geospatial Data Committee (FGDC). FSLTT partners wishing to participate in 3DEP must:



- Sign the 3DEP governance memorandum of understanding
- Assign agency representatives to the 3DEP Executive Forum and Working Group
- Acquire data through the 3DEP data acquisition process and participate in the 3DEP multiyear planning process
- Implement local policy to work within the Unified Federal 3DEP plan for data acquisition and sharing
- Coordinate internally to link regional/field offices into 3DEP and data acquisition processes
- Provide input and support to improve the acquisition process
- When datasets are acquired outside of the 3DEP process, ensure that data meet 3DEP specifications, are publicly shareable (unlicensed), and are contributed to national holdings
- Participate in 3DEP budget initiatives and establish a 3DEP budget line item

[28] 3DEP By The Numbers | U.S. Geological Survey (usgs.gov)
[29] Ibid.

- Report 3DEP investments to budget crosscut (nine participating agencies)
- Promote 3DEP to agency constituents to participate in or support the national 3DEP effort
- Participate in assessments and adoption of new technologies to advance national 3DEP goals
- Encourage or require that federal grant monies used for elevation data acquisition result in the data being collected to 3DEP standards and contributed to the national holdings
- Participate in the 3D Nation Elevation Requirements and Benefits Study and other studies to document needs for the next generations of 3DEP

Participation in 3DEP requires a higher level of dedication from every partner jurisdiction to commit funding and personnel to ensuring the success of the project every update cycle. Nonconsecutive funding cycles generally are met with more scrutiny and are less likely to be sustainable than dedicated annual funding models.

3 Project Oversight

3.1 Governance

The agencies participating in the LiDAR acquisition project at a minimum should constitute the governance body. The role of the governance body will include oversight in the collection of elevation data and assurance data is being collected within specifications for NG911 purposes. To ensure the highest return on investment, LiDAR data should be openly shared with all interested parties.

3.2 Risk Management

The deployment of 3D technology in the PSAP environment for mapping z-axis is relatively new and therefore limited in best practices. The greatest risks to this project are outlined below:

- Limited availability of technology on the backend to support z-axis in the PSAP environment or 2D with enhancements
- Currency of LiDAR data once delivered
- Maintenance of LiDAR data once delivered

4 Conclusion

The dispatchable location or vertical location of wireless callers can be valuable information to 911 but only if the information can be converted into actionable intelligence. Of the many PSAPs receiving elevation data as part of their ALI spill from service providers, only a very few are able to act upon the information. The GIS data necessary to support this new vertical environment likely exists for urban and some suburban environments, but smaller cities and towns with a handful of four-story or taller buildings may not even have the requisite GIS data to operationalize the location information.

Combining LiDAR elevation information with GIS data will allow FSLTT 911 authorities to utilize z-axis technology. With the opportunity for partnerships between multiple agencies and the federal government, the cost for this approach to z-axis integration with PSAP operations can be far less prohibitive than other commercial solutions.

Glossary of Terms

Term	Definition
3D	A three-dimensional representation of geographic data typically represented in a computer environment. Three-dimensional features will have spatial dimensions for length, width, and depth providing the user with a more realistic perspective.
Altitude	The vertical distance between a datum line and the geographic location of an object considered above that line.
Elevation	The vertical distance between a fixed plane or reference and the geographic location of an object. This could be Mean Sea Level, geoid, or other reference areas.
Ellipsoid	A simplified 3D spherical representation of the earth used to measure distances across earth's surface.
Height Above Ellipsoid (HAE)	The vertical distance between a mathematical model of the earth, also known as an ellipsoid, and the geographic location of an object. The most used ellipsoid is WGS84 coordinate reference system. Ellipsoid height is the difference between the ellipsoid and a point on the Earth's surface.
Height Above Ground Level	Vertical distance between the Earth's surface and the geographic location of an object.
Horizontal Accuracy	Horizontal accuracies are compared against existing ground control points with known, surveyed positions. These known positions are surveyed against a known referenced geodetic datum.
Light Detection and Ranging (LiDAR)	A remote sensing method that uses pulses of light from a sensor to measure distance ranges to the earth. Combined with other data, LiDAR can create a precise 3D landscape of the earth.
Mean Sea Level	As cited by NOAA "Average height of the surface of the sea for all stages of the tide over a 19-year period."
Quality Control (QC)	At its most basic level, quality control of collected LiDAR point clouds are compared to control points, or known heights. Advance analysis can provide statistics about the LiDAR data collection including RMSE, and absolute and average differences between control points and the dataset.
Quality Level (QL)	QL represents topographic quality levels as defined by the 3DEP LiDAR Based Specifications.[30] Point density and vertical accuracy are two major factors when considering QL. Point density is the average number of points captured per square unit. Vertical accuracy is expressed as the RMSE (Root Mean Square Error).
Root Mean Square Error (RMSE)	RMSE is a measurement of error differences between a known, true value versus a predicted or estimated value.
Vertical Accuracy	Vertical accuracy of elevation data is the height difference between the referenced model height and the actual height of the land. The referenced model can be either an ellipsoid, such as the WGS84 coordinate reference system or a geoid.
Z-Axis	Based off z-axis technology, vertical location accuracy data that are required to be delivered from the handset of a wireless device in Height Above Ellipsoid.
Z-Value	z-axis are typically used in mapping environments to express the elevation of a feature in relation to the ground/terrain surface.

[30] https://www.usgs.gov/ngp-standards-and-specifications/lidar-base-specification-tables

Appendix B: Top 50 Most Populous Cellular Market Areas

"The Cellular Market Areas (CMAs) were created from the Metropolitan Statistical Areas (MSAs) defined by the Office of Management and Budget (1-305), the Gulf of Mexico (306), and Rural Service Areas (RSAs) established by the FCC which do not cross state borders (307-734). These RSAs include parts of Puerto Rico not already in an MSA (723-729), U.S. Virgin Islands (730-731), Guam (732), American Samoa (733), and Northern Mariana Islands (734)"[31]

1. New York-Northern New Jersey-Long Island, NY-NJ-PA
2. Los Angeles-Long Beach-Santa Ana, CA
3. Chicago-Joliet-Naperville, IL-IN-WI
4. Dallas-Fort Worth-Arlington, TX
5. Philadelphia-Camden-Wilmington, PANJ-DE-MD
6. Houston-Sugar Land-Baytown, TX
7. Washington-Arlington-Alexandria, DCVA-MD-WV
8. Miami-Fort Lauderdale-Pompano Beach, FL
9. Atlanta-Sandy Springs-Marietta, GA
10. Boston-Cambridge-Quincy, MA-NH
11. San Francisco-Oakland-Fremont, CA
12. Detroit-Warren-Livonia, MI
13. Riverside-San Bernardino-Ontario, CA
14. Phoenix-Mesa-Glendale, AZ
15. Seattle-Tacoma-Bellevue, WA
16. Minneapolis-St. Paul-Bloomington, MN-WI
17. San Diego-Carlsbad-San Marcos, CA
18. St. Louis, MO-IL
19. Tampa-St. Petersburg-Clearwater, FL
20. Baltimore-Towson, MD
21. Denver-Aurora-Broomfield, CO
22. Pittsburgh, PA
23. Portland-Vancouver-Hillsboro, OR-WA
24. Sacramento-Arden-Arcade-Roseville, CA
25. San Antonio-New Braunfels, TX
26. Orlando-Kissimmee-Sanford, FL
27. Cincinnati-Middletown, OH-KY-IN
28. Cleveland-Elyria-Mentor, OH
29. Kansas City, MO-KS
30. Las Vegas-Paradise, NV
31. San Jose-Sunnyvale-Santa Clara, CA
32. Columbus, OH
33. Charlotte-Gastonia-Rock Hill, NC-SC
34. Indianapolis-Carmel, IN
35. Austin-Round Rock-San Marcos, TX
36. Virginia Beach-Norfolk-Newport News, VA-NC
37. Providence-New Bedford-Fall River, RI-MA
38. Nashville-Davidson-Murfreesboro-Franklin, TN
39. Milwaukee-Waukesha-West Allis, WI
40. Jacksonville, FL
41. Memphis, TN-MS-AR
42. Louisville/Jefferson County, KY-IN
43. Richmond, VA
44. Oklahoma City, OK
45. Hartford-West Hartford-East Hartford, CT
46. New Orleans-Metairie-Kenner, LA
47. Buffalo-Niagara Falls, NY
48. Raleigh-Cary, NC
49. Birmingham-Hoover, AL
50. Salt Lake City, UT

[31] https://www.fcc.gov/oet/maps/areas