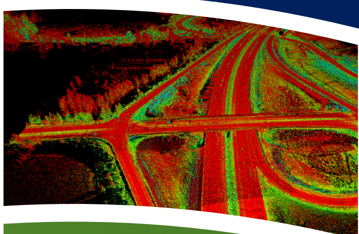
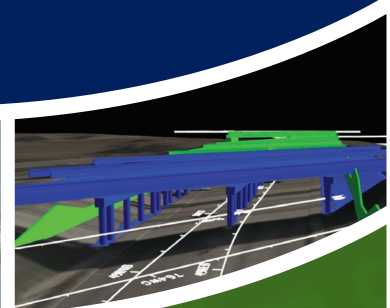
Guide for

Efficient and Effective Utility Asset Data Collection Using Geospatial 3D Techniques

Summer 2016





3D Engineered Models:

Schedule, Cost, and Post-Construction

*An **Every Day Counts** Innovation*

U.S. Department of Transportation
Federal Highway Administration

Contents

Efficient and Effective Utility Asset Data Collection Using Geospatial 3D Techniques

Introduction

There is an increasing emphasis on shifting asset management practices toward cradle-to-cradle approaches (as opposed to cradle-to-grave approaches), where assets are not discarded at the end of their useful life but instead are consistently and systematically transformed into newer assets of equal or greater value. Such a continuous upgrade of the system, however, is only possible through thorough performance monitoring and service life assessments at various time intervals, for which clear information requirements first need to be established.

Utilities in the rights-of-way pose unique challenges as many are owned and maintained by other parties, yet they have significant effects on roadway element life-cycle performance. Additionally, state transportation agencies (STAs) find themselves owning and maintaining an increasing array of infrastructure, such as drainage, traffic control, lighting, and visual monitoring systems, for which long-term asset performance is desired. Integrating data from legacy utilities owned by multiple parties with newly installed utilities as part of a highway or utility project is a step toward understanding these interrelated systems and their mutual effects on STA assets.

Geospatial, three-dimensional (3D), as-found utility survey technologies are key to achieving this asset management vision. These surveys integrate existing legacy utility data with new utility asset data collected with a variety of new survey technologies. When specified, integrated, and used correctly, 3D utility data can result in efficient workflows for agencies.

While transportation agencies may already be collecting data for various purposes and at various times, often these efforts are duplicated or in silos within various agency functions or divisions using a variety of collection methods and standards. As-found surveys help consolidate and standardize resources, thus maximizing funding and enhancing the accuracy of information integration. There are also safety benefits, as some traditional practices could expose survey staff to unsafe conditions and create unnecessary traffic delays for the traveling public.

Most STAs conduct as-found surveys as part of the project delivery process, which, in most cases, is completely detached from asset inventory and management workflows. While the process for implementing geospatial 3D as-found utility surveys will depend on a number of factors—most notably the agency's current asset inventory practices, utility project development processes, asset inventory maturity, internal technical resources, and available funding—this guide draws the decision makers' attention to the key issues that must be addressed for the utility asset inventory program to succeed, including:

- developing information requirements
- preparating data integration into the system
- implementing the data collection program

These aforementioned aspects of a successful utility asset inventory program share many common traits with other agency-wide asset data collection programs. As such, integrating the utility data collection program with an agency's larger data collection effort will result in cost and time savings and will ensure that data collection methods and common data elements are apropriately shared between the various data silos.

Program Planning: Develop Information Requirements

The information requirements are the foundation of any inventory and condition assessment program. They define what an agency needs to know (i.e., to collect) in order to support the work of its various divisions. These divisions, however, tend to work with different terminologies, domains, and applications. As a result, information requirements within the agency vary depending on who is going to use the information and how.

As stated previously, as-found utility surveys provide a unique opportunity to consolidate resources through compatible collection efforts. In exchange, however, they require relevant divisions to define a common set of information requirements (Figure 1). Most asset management programs have a wide range of condition assessment data elements, which should be captured in information requirement documents.

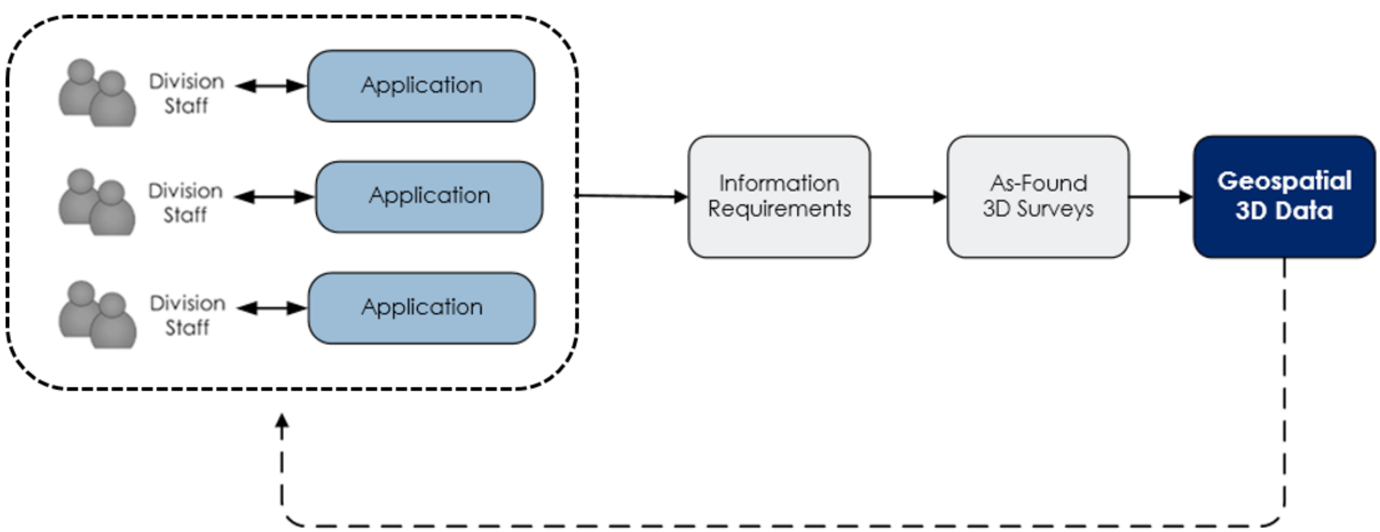


Figure 1: Development of Information Requirements for As-Found Utility Surveys

This set of information requirements is not only paramount for the success of the data collection effort, but also critical for the realization of the aforementioned cradle-to-cradle asset management vision. Cradle-to-cradle asset management can only be achieved if information is integrated and interoperable, and as-found surveys are key to beginning to overcome this challenge.

First, there needs to be a very clear understanding of two things: the vision, and the data elements needed to support that vision. After developing this understanding and before initiating the data collection process, relevant divisions within any given agency must collaboratively develop a unified set of information requirements that will guide data collection so that it satisfies everyone's operational needs. Such a set will include, at minimum, data dictionaries, data deliverables, and data formats.

Data Modeling and Dictionaries

For robust data implementations, there should be a formal data modeling process. Good data modeling software enables data modelers to produce data dictionaries based on the results of the data modeling exercise. A data model consolidates all the requirements necessary to develop an adequate utility asset inventory. It details the assets to be collected, the features to be recorded for each particular asset, and the descriptors or identifiers to be used when recording each specific feature.

Utility assets to be collected can be divided into three major groups: legacy underground (hidden) utilities and their surface appurtenances (hydrants, valve boxes, etc.), legacy overhead (visible) utilities and their structures (poles, towers, etc.), and utilities under construction/installation. Due to the geometric, material, ownership, positional uncertainty, and other complexities of utilities, this unified utility data model and dictionary effort is a critical step in collecting and managing utility data between departments.

For each utility asset, different groups of objects and attributes can be collected. These include, but are not limited to, characterization (ID number, subtype), location (route, coordinates[1]), geometry (width, height), Utility Quality Level (legacy underground utilities) or Accuracy Level (utility data captured during installation and/or visible and aboveground), and condition.

The American Society of Civil Engineers has two standards detailing guidance for collecting and depicting utility assets. CI/ASCE 38-02 (soon to be updated) "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data" and ASCE XX (anticipated publish date 2017) "Collection, Administration, and Exchange of Utility Infrastructure Data Standard" work in harmony to identify these objects and attributes.

Data Deliverables

Data deliverables establish the set of specific products that will result from the data collection effort. Such deliverables will include raw data and processed data.[2]

Raw data refers to the LiDAR (light detection and ranging) point clouds[3], images, and videos produced automatically as data is captured from multi-sensor systems. It also refers to data

1 The agency will need to define the geodetic information (coordinate system, geodetic datum, etc.) with which they want to work.

2 It is assumed that the agency already owns a geospatial database or will develop one as part of the asset inventory program.

3 While the point cloud is automatically captured, point clouds should be geo-referenced, sanitized (noise removed), and classified using industry standards. Depending on the intended data use, a user can extract additional derived products from point clouds, such as digital terrain models (DTMs), using specific applications that are native to the user. Likewise, an agency might want to obtain a footprint of the point cloud and imagery tiles.

captured by traditional utility investigation and survey methods, and from new automated construction positioning methods.

Alternatively, processed data refers to geographic information systems (GIS) data in the form of points and linear features and database information such as tables and metadata. GIS data is stored in database tables, which, depending on the implementation, could be standalone (e.g., a file geodatabase) or enterprise. Both classes are linked by their geospatial characteristics.

Additional Considerations: Data Cross-Utilization

While the focus of geospatial as-found utility surveys is on inventory of existing assets, agencies can also use project-specific implementation of geospatial as-built surveys to enhance their asset inventory database. Data cross-utilization from both efforts can allow agencies to identify the most efficient data acquisition system in place. Agencies, however, must ensure that information requirements for collecting data on new assets align with those defined for collecting data on existing assets.

Geospatial as-found utility surveys can also be tied to 3D design data. Design 3D models are generated through computer-aided design and drafting (CADD) systems, while asset management inventory databases are GIS-based. Thus, significant consideration should be given to ensuring geospatial utility survey data can be used for both asset inventory and future design applications. The metadata fields created for the GIS database should match the properties of the 3D survey and design CADD libraries.

Additional Considerations: LiDAR System Accuracy

Today, mobile LiDAR systems have two types of accuracies: mapping grade and survey/engineering grade. The distinction is significant given its applicability. Mapping grade accuracy is cheaper but only acceptable for applications requiring accuracies within a couple of feet, such as asset management and inventory mapping[4]. On the contrary, survey/engineering grade accuracy is needed for applications requiring inch and sub-inch accuracy, such as engineering surveys or engineering design[5], and it is also more expensive.

The need for the survey type is driven by the information requirements set up front by the agency during the planning process. Greater accuracy generally results in more costs for data collection, processing, and storage. However, once utilities are hidden from view, it is time-consuming and expensive to attempt to find them again. There will also be inherent uncertainties in their locations that are impossible to quantify. Therefore, it is prudent to use survey-grade accuracies for the survey portion of documenting exposed underground utilities whenever the opportunity arises.

Data Formats

So that data collected can be shared by many systems and applications, the agency must require that data deliverables be provided in compatible, industry standard file formats. Table 1 provides some examples.

4 Other applications include traffic congestion, emergency response, environmental assessment, billboard management, or land use.

5 Other applications include machine control, structural clearances, structural and pavement analysis, quantity calculations, and project as-built surveys.

Table 1: Sample Data Formats by Deliverable

Data Deliverables	Raw Data			Processed Data		
	LiDAR Point Cloud	Images	Video	GIS Data	Database	CADD Data
Data Formats	LASer File Format Exchange (.LAS), LAZ*, or ASTM E57	Geographic Tagged Image File Format (GeoTIFF) or System Compatible File Format	Audio Video Interleave (.avi), MPEG-4 Video File (.mp4), Windows Media File (.mvw), or System Compatible File Format	Geodatabase, Shape File (.shp) or System Compatible File Format	Comma Separated Value (.csv) or System Compatible File Format	3D Geometry (.dgn, .dwg)

Program Planning: Prepare Data Integration

Before data collection begins, an agency must provide the right storage and collaboration platforms, as well as software applications, that allow for efficient use of collected data. Ideally, as depicted in Figure 2, raw data for newly installed utilities and overhead utilities (point clouds, images, and video) will flow from the collection vehicle to a central data storage location.[6]

From there, it can be merged with any legacy utility data already in the enterprise central database. However, this is not easy. In fact, lack of compatibility between legacy databases and "new" databases is a major source of frustration because, inevitably, agencies may only allocate funding to support the development and implementation of the new system.

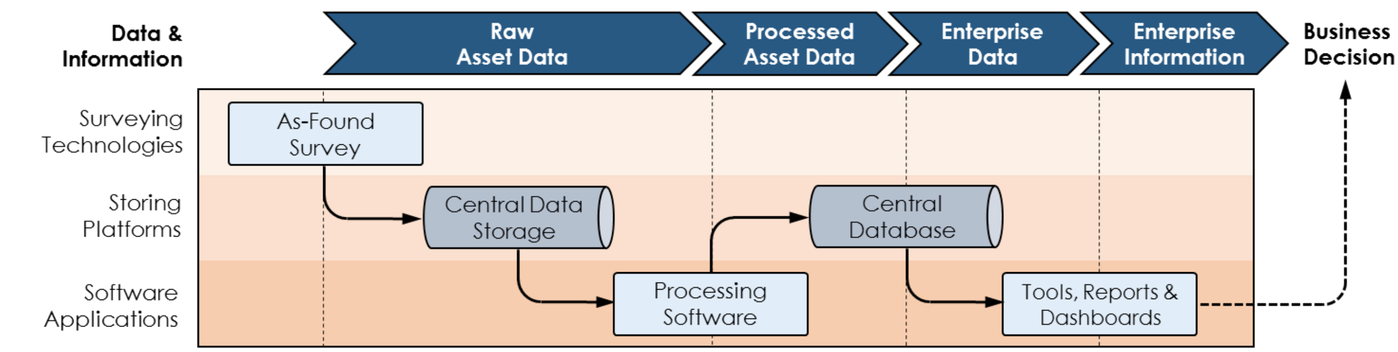


Figure 2: Data Flow and Data Evolution from As-Found Survey to Business Decision

Next, specific software will be used to extract processed data (i.e., GIS data and databases) from raw data[7]. The extracted data will undergo some sort of professional judgment processing, after which the newly processed data will flow into a central database, where divisions across the agency will also be storing their own data. From the central warehouse, divisions will be able to withdraw enterprise data and use it as input for visualization and Business Intelligence (BI) tools, dashboards, and reports that help to better communicate processed data or directly transform it into meaningful information. This information permits management to make key decisions and develop performance-based business plans that allow for truly lean asset management.

6 This data storage can be an internal or external network server or a cloud service provided by the IT responsible authority.

7 For more information on data post-processing, NCHRP 15-44 (2013) outlines a workflow for data acquisition and post-processing activities (pg. 28), including geo-referencing, post-processing, computation/analysis, and packaging and delivery.

Program Implementation: Collect Asset Data

Once information requirements are established and data integration is planned, the agency must evaluate and decide whether the as-found utility survey will be conducted using internal resources, contracted services, or a combination of both. Regardless of the approach, there are a number of common considerations that agencies should keep in mind during data collection.

Legacy Utility Data

Legacy utility data for either overhead or underground facilities may exist in the form of utility company records, GIS databases, or previous project plans. Another increasingly used option is to utilize a "designer" One-Call ticket, when respective state statutes allow, and subsequently survey the marks placed on the ground by the utility owner. Both records and surveyed One-Call marks can result in no better than Utility Quality Level D (QLD) data, according to ASCE 38-02. In other words, while there may be a high degree of certainty regarding the position of the marks representing the utilities, the marks themselves are highly uncertain, leading to a cumulative high degree of uncertainty regarding the actual position of the asset.

One Call was originally developed for damage prevention purposes during construction, not asset management. When looked at from the point of view of damage prevention, One Call is actually a very successful program (judging by the annual incident statistics and trends). The problem arises when data intended for one application (damage prevention during construction) is used for a completely different application that has more stringent requirements (design-grade data).

Survey Equipment

The equipment needed to perform as-found utility surveys is quite varied. For detection of underground utilities, a suite of geophysical equipment with either concurrent ground control surveying or more traditional positioning methods is required. For overhead and some newly installed utilities, a Mobile Laser Scan (MLS) may be ideal. An MLS includes three different components: (1) vehicle type, (2) on-board sensors (laser scanner, inertial measuring unit (IMU), Global Navigation Satellite System (GNSS), traditional and/or 3D cameras), and (3) computer equipment for data storage and running the data collection software.

While an MLS is the core component of any asset inventory program that plans to utilize rapid, large area coverage tools, it is not the only one. An agency must also either subscribe to a GNSS network or own multiple base stations and all associated software.[8] [9]

Surveying Conditions

As-found utility surveys should only be conducted under conditions that allow the MLS to capture accurate and readable data. Thus, the MLS must collect data during a time of the year that provides a level of detail within the required specifications (e.g., dry pavement for pavement surveys). Regardless of external conditions, the MLS must also collect data in both directions to increase accuracy and reduce rework.

8 Note that besides purchase or procurement of equipment, there are other costs associated with the data collection process, namely labor expenses, but also costs associated with pre-mission planning, setting ground control, conducting quality control, and coordinating and setting traffic control.

9 For a more detailed review of costs associated with as-found surveys, Yen et al. (2011) investigates the costs and benefits of mobile LiDAR technology to business processes, as well as the best deployment option to achieve maximum benefit.

Quality Assurance

The quality of data captured by a combination of any means will largely determine the quality of the business decisions made from it. For instance, if a combination of geophysical instrumentation and MLS is used to collect asset data, the data should be subject to thorough quality assurance (QA). However, given the large amount of data at hand (likely in the order of tens of terabytes), QA cannot only occur at the end of the data collection exercise—redundancy of checks in the QA process is paramount. Therefore, an agency should not only designate a competent team to review and ensure that the deliverables meet the requirements, but also secure the services of a qualified and independent team to verify that the work product is compliant with the specifications.

The same considerations apply if an agency decides to outsource its inventory program. In such a case, however, the contractor should also be required to provide a quality control (QC) plan that explains how accurate and high-quality data will be achieved and maintained and how any deficiencies will be remedied. To further encourage delivery of high-quality data, incentive and disincentive clauses can be considered in the contract letting process based on independent checks conducted at designated road sections.[10]

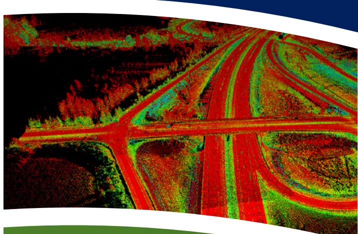
Conclusion

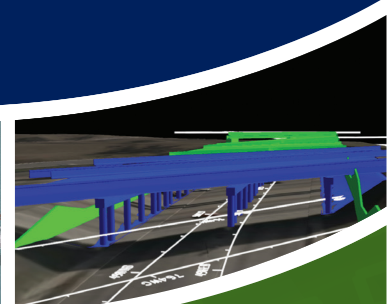
Geospatial 3D data collection methods offer an opportunity to combine resources while acquiring valuable information that can be shared with multiple stakeholders. New surveying techniques are making it possible to collect high-accuracy utility asset data that can be integrated with GIS-based asset inventory systems for enterprise accessibility. While efficient use of geospatial 3D data collection for utilities is in its infancy, recent research efforts provide documented case studies for updating existing guidelines and creating new ones.

This guide can be used as a starting point for developing agency implementation plans that can be augmented with other specifications that are soon to be released, such as the updated CI/ASCE 38-02 "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data" and ASCE XX "Collection, Administration, and Exchange of Utility Infrastructure Data Standard." Agencies can optimize their current geospatial acquisition practices to successfully implement utility asset data collection that can be integrated with enterprise asset management plans and 3D engineering design practices[11].

10 Each check would involve a comparison between values measured by the agency and values measured by the contractor for a particular feature. The overall potential for incentives/disincentives should be around 10% of the total contract value.

11 Refer to FHWA's Guide for Efficient Geospatial Data Acquisition using LiDAR Surveying Technology for more details on enterprise geospatial data acquisition. The guide is located at *http://www.fhwa.dot.gov/construction/3d/hif16010.pdf*.





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