A Sempra Energy utility®

EPIC Final Report

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Administrator	**San Diego Gas & Electric Company®**
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Attribution

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Executive Summary

This summary provides an overview Module 3 of SDG&E's Project 2 on "Visualization and Situational Awareness Demonstrations", which was funded by the first triennial cycle of the Electric Program Investment Charge (EPIC-1). The objectives of Project 2 were:

- Examine how data currently unexploited and separately processed can be integrated and visually presented for strategic use by system operators.
- Demonstrate how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances utility system monitoring and situational awareness.

Module 3 of this project explored how Unmanned Aircraft Systems (UAS) can be used for advanced image collection, ingestion and storage of UAS data, and how advanced data analytics could be conducted through means of a platform especially adapted to meet SDG&E's organizational requirements. A common theme identified by SDG&E stakeholders was the lack of a single, centralized data repository to store, visualize and analyze the large quantities of data collected by SDG&E. Currently, stakeholder groups collect, ingest, manage and maintain their own data resulting in little to no data sharing capability.

The stakeholder requirements were split into the following groups: Infrastructure, Vegetation Management and Environmental Services. The following test cases were demonstrated:

Infrastructure

1. Implementation of a Centralized Repository for Data Management
   Demonstrate how the vendor tool could be used as a centralized repository for full data lifecycle management for design and construction projects.
2. Export Results for Downstream System Integration with GIS
   Demonstrate how the vendor tool could be integrated with SDG&E's in-house GIS system.

Vegetation Management

3. Identifying Tree Growth Patterns
   Evaluate how advanced data analytics can be used to make tree growth forecasts to assist SDG&E in planning tree maintenance and cutting works.

4. Identifying Areas of Tree Health

   Explore how advanced data analytics can be used to assess tree health. Dead and dying trees can pose a severe fire risk and must be managed according to industry standards.

5. Identifying Changes in Pole Lean

   Identify poles that have begun to lean through advanced data analytics. Identifying leaning poles allows rectification works to be conducted and reduces non-compliances.

6. Maintenance Audit

   Evaluate how advanced data analytics can be used to check that maintenance works have been completed on schedule and per the required specifications.

Environmental Services

7. Identification of Water Bodies

   Demonstrate how advanced analytics can be used to calculate the proximity of an existing and/or proposed pole site with a body of water.

8. Pole Accessibility from Roadway

   Demonstrate how advanced data analytics can be used calculate the distance from a roadway to a pole and determine the type of terrain in between.

9. Capture of Pole Accessibility Field Notes

   Demonstrate how the vendor system's mobile capability can be used to capture pole accessibility notes whilst out in the field.

The work demonstrated the value of having a central repository to store, catalog, and sort data that could be visualized by multiple stakeholders concurrently. It allows the stakeholders to create custom views for their area of operations and to perform deep learning analytics on the vast amount of data to provide actionable results to important test cases, ranging from automatic identification of equipment on poles to tracking vegetation encroachment on power lines.

These are just some of the use cases that the data captured from UAS will enable stakeholders to leverage. All these scenarios will enable the utilities to perform virtual asset inspection that enhances safety and reliability of power system equipment. Additional evaluation is recommended before making decisions about commercial deployment of any specific data management platform.

Table of Contents

1.0 Introduction 13
1.1 Focus of Module 3 of EPIC-1, Project 2 13
1.2 Project Task Summary 14
2.0 Stakeholder Analysis 18
2.1 Infrastructure Stakeholder Group 18
2.1.1 Responsibilities 18
2.1.2 Problem Statement 19
2.2 Vegetation Management Stakeholder Group 20
2.2.1 Responsibilities 20
2.2.2 Problem Statement 21
2.3 Environmental Services Stakeholder Group 22
2.3.1 Responsibilities 22
2.3.2 Problem Statement 23
3.0 Use Case Summary 24
3.1 Infrastructure Use Cases 25
3.1.1 Data Collection 26
3.1.2 Data Ingestion 29
3.1.3 Data Storage 31
3.1.4 Data Visualization 32
3.1.5 Data Retention 32
3.1.6 Data Removal 33
3.2 Vegetation Management Use Cases 34
3.2.1 Identifying Hardware and Firebreaks 34

3.2.2 Identifying Tree Growth Patterns 37
3.2.3 Identifying Areas of Tree Health 38
3.2.4 Identifying Changes in Pole Lean 40
3.2.5 Maintenance Audit 42
3.3 Environmental Services Use Cases 42
3.3.1 Identification of Potential Pole Sites 43
3.3.2 Identification of Water Bodies 44
3.3.3 Identification of Vegetation Community 44
3.3.4 Identification of Birds' Nests in Vegetation 45
3.3.5 Identification of Noxious Weeds and Invasive Species 46
3.3.6 Identification of Staging Yards 47
3.3.7 Comparison of Pre- and Post-Construction Work Areas 48
3.3.8 Pole Accessibility from Road 49
3.3.9 Capture of Pole Accessibility Field Notes 52
4.0 Test Case Summary 53
4.1 Test Cases - Vendor A 54
4.1.1 Infrastructure 54
4.1.2 Vegetation Management 54
4.1.3 Environmental 54
4.2 Test Cases - Vendor B 54
4.2.1 Infrastructure 54
4.2.2 Vegetation Management 54
4.2.3 Environmental 55
4.3 Baseline Data Set 55
5.0 Vendor Tool Demonstration System Design, Development and Setup 56

5.1 Vendor A – Vendor A Tool ... 56
5.1.1 Vendor A Tool System Summary ... 56
5.1.2 Vendor A Tool Feature Summary ... 56
5.1.3 Platform Compatibility ... 57
5.1.4 Deployment Options ... 58
5.2 Vendor B – Vendor B Tool ... 58
5.2.1 Vendor B Tool System Summary ... 58
5.2.2 Vendor B Tool Interface Overview ... 59
5.2.3 Vendor B Tool System Requirements ... 62
5.2.4 Vendor B Tool System Architecture ... 65
6.0 Vendor Test System Demonstration Approach, Results and Recommendations ... 68
6.1 Vendor A Test Case Results ... 68
6.1.1 Infrastructure ... 68
6.1.2 Vegetation Management ... 77
6.1.3 Environmental ... 86
6.1.4 Documented Use Case Recommendations ... 95
6.1.5 Vendor A System Recommendations ... 98
6.1.6 Vendor A Project Summary ... 99
6.2 Vendor B Test Case Results ... 99
6.2.1 Infrastructure ... 99
6.2.2 Vegetation Management ... 103
6.2.3 Environmental ... 111
6.2.4 Documented Use Case Recommendations ... 115
6.2.5 Vendor B System Recommendations ... 117
6.2.6 Vendor B Project Summary ... 119

7.0 Requirements for Prospective SDG&E System 119
7.1 Requirements Specification 120
7.1.1 Functional Requirements - General 120
7.1.2 Functional Requirements – System Services 122
7.1.3 Functional Requirements – Mobile Data Capture 123
7.1.4 Functional Requirements – Advanced Data Analytics 123
7.1.5 Non-Functional Requirements 126
7.1.6 Collection Requirements 129
8.0 Project Outcome 129
8.1 Recommendations 129
8.1.1 General Recommendations 129
8.1.2 Recommendations for Vendor-Agnostic System 131
8.2 Next Steps 133
9.0 Technology Transfer Plan 134
9.1 SDG&E Technology Transfer Plan for Project Results 134
9.2 Applicability to Other Utilities and Industry 135
10.0 Metrics and Value Proposition 135
10.1 Metrics 135
10.2 Value Proposition 137
11.0 Appendices 139
11.1 Appendix A – Infrastructure Current Workflow 139
11.2 Appendix B – Vegetation Management Current Workflow 140
11.3 Appendix C – Environmental Services Current Workflow 141
11.4 Appendix D - Infrastructure Future Workflow 142
11.5 Appendix E - Vegetation Management Future Workflow 143

11.6 Appendix F – Environmental Services Future Workflow ... 144
11.7 Appendix G – Vendor / Stakeholder Use Case Matrix ... 145

List of Tables

Table 1: Example of Pole Accessibility Field Notes ... 50
Table 2: Vendor B Tool System Requirements ... 65
Table 3: Vendor B Tool Operating System Specification ... 66
Table 4: Pole Data CSV Example ... 69
Table 5: Boring and Seismic CSV Format Examples ... 72
Table 6: Pole Lean Conditions ... 77
Table 7: Accuracy Results ... 81
Table 8: Firebreak Severity Matrix ... 84
Table 9: Water Body Conditions ... 87
Table 10: Pole Accessibility Criteria ... 90

List of Figures

Figure 1: Data Lifecycle ... 26
Figure 2: Firebreak Examples (Plan View at Ground Level) ... 36
Figure 3: Firebreak Clearance Requirements Around Poles and Towers ... 40
Figure 4: Option for Displaying Pole Accessibility Information ... 51
Figure 5: Vendor A Tool Workflow Overview ... 56
Figure 6: Vendor B Tool 'Explorer' Tab ... 59
Figure 7: Vendor B Tool 'Config' Tab ... 60
Figure 8: Vendor B Tool Map Controls ... 60
Figure 9: Vendor B Tool Map Layers Sidebar ... 61
Figure 10: Vendor B Tool Work Searches Sidebar ... 62
Figure 11: Attachments ... 71
Figure 12: Leaning Pole Details ... 78
Figure 13: Search and Filter by Pole Lean ... 79

Figure 14: Point Cloud Viewer ... 79
Figure 15: Calculated Best Fit Line ... 80
Figure 16: Outside Radius Points Used to Calculate Best Fit ... 81
Figure 17: Vegetation Points Detected within a Firebreak ... 83
Figure 19: Search and Filter for Firebreak Maintenance Audits ... 84
Figure 20: Vegetation within Firebreak ... 85
Figure 21: Asset Details View – Distance to Water ... 87
Figure 22: Search and Filter by Water Proximity ... 88
Figure 23: Terrain Details ... 89
Figure 24: Terrain Profile ... 90
Figure 25: Search and Filter by Pole Accessibility ... 91
Figure 26: Terrain Profile Map View ... 92
Figure 27: Google Street View ... 92
Figure 28: Save Imagery for Inclusion in Project Documentation ... 92
Figure 29: Pole Access Export for Field Notes ... 93
Figure 30: Alternative Path Analysis ... 95
Figure 31: Surface Normal Model ... 97
Figure 32: Potential Staging Yards ... 98
Figure 33: Grow-in Measurement Diagram ... 104
Figure 34: Fall-in Measurement Diagram ... 104
Figure 35: Violation Height ... 105
Figure 36: Vegetation Encroachment Results ... 106
Figure 37: LiDAR View of the Encroachment ... 107
Figure 38: Tree Health Map ... 108
Figure 39: Healthy Vegetation Infrared Absorption and Reflection ... 109
Figure 40: Pole Lean Results ... 111
Figure 41: Pole Accessibility from Road ... 112
Figure 42: Field Notes Example ... 114
Figure 43: Terrain Profile and Grade from Pole to Nearest Roadway ... 118

Abbreviations & Acronyms

Acronym	Definition
API	Application Programming Interface
ASD	Aviation Services Department
ASPRS	American Society for Photogrammetry and Remote Sensing
CMP	Corrective Maintenance Program
CPU	Central Processing Unit
CPUC	California Public Utilities Commission
CSV	Comma Separated Values
DEM	Digital Elevation Model
DSM	Data Source Modeler
DWG	AutoCAD Drawing Database file
DXF	Drawing Exchange Format
EA	Enterprise Architecture
EPIC	Electric Program Investment Charge
EPP	Environmental Project Planning
ESPG	European Petroleum Survey Group
ESRI	Environmental Systems Research Institute
ETS	Environmental Tracking System
EXIF	Exchangeable Image File
FiRM	Fire Risk Mitigation
FTP	Fire Transfer Protocol
GB	Gigabyte
GHz	Gigahertz
GIS	Geographic Information System
GPS	Global Positioning System
GPU	Graphics Processing Unit
IR	Infrared
IT	Information Technology
JSON	JavaScript Object Notation
KMZ	Keyhole Markup Language Zipped files
kV	Kilovolt
LAS	Log ASCII Standard
LiDAR	Light Imaging Detection and Ranging

MB	Megabyte
MVCD	Minimum Vegetation Clearance Distance
NIST	National Institute of Standards and Technology
OGC	Open Geospatial Consortium
PC	Personal Computer
PDF	Portable Document Format
PG&E	Pacific Gas and Electric
PIDS	Pole Information Data System
PLS-CADD	Power Line Systems - Computer Aided Design and Drafting
QC	Quality Control
RAM	Random Access Memory
RANSAC	Random Sample Consensus
RBAC	Role-Based Access Control
RGB	Red, Green, Blue
ROV	Remotely Operated Vehicle
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SMART	Specific, Measurable, Achievable, Realistic, Timely
SME	Subject Matter Expert
SoCalGas	Southern California Gas
SSL	Secure Sockets Layer
TCM	Transmission Construction and Maintenance
TCP/IP	Transmission Control Protocol/Internet Protocol
TED	Transmission Engineering and Design
TLS	Transport Layer Security
UAS	Unmanned Aircraft System
USGS	United States Geological Survey
UV	Ultraviolet
WFS	Web Feature Services
WMS	Web Map Services
XLS	Microsoft Excel Spreadsheet file

1.0 Introduction

The California Public Utilities Commission (CPUC) established the Electric Program Investment Charge (EPIC) to provide public interest investments in research and development of clean energy technologies.

This report documents the work done in Module 3 of SDG&E's Project 2 (Visualization and Situational Awareness Demonstrations) in the first EPIC triennial cycle (EPIC-1). For more background on the structure and requirements of EPIC and on SDG&E's EPIC projects, the reader is referred to the SDG&E public EPIC website.[1]

The objectives of EPIC-1, Project 2 were:

- Examine how data currently unexploited and separately processed can be integrated and visually presented for strategic use by system operators
- Demonstrate how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances utility system monitoring and situational awareness

1.1 Focus of Module 3 of EPIC-1, Project 2

This module of the project focused on pre-commercial demonstrations of vendor tools to investigate the benefits of advanced data analytics conducted on LiDAR and imagery data collected via Unmanned Aircraft Systems (UAS). The knowledge created in the demonstrations was intended for use in decision making regarding what prospective solutions might be adopted commercially.

Several stakeholder meetings took place to discuss inefficiencies with their current workflows and to determine how these inefficiencies could be mitigated by introducing advanced data analytics and improved data collection techniques by utilizing UAS data.

[1] SDG&E Electric Program Investment Charge (EPIC) website found at www.sdge.com/EPIC

Thought was also given to how this collected data could be ingested, stored, visualized and retained on a single centralized repository to improve data sharing between stakeholder groups.

The overall goal was to identify process improvements which can result in reduced costs, process efficiency, heightened resource productivity, improved safety and electricity ratepayer benefits for customers.

Two vendors were selected to conduct the advanced data analytics and demonstrate how their platforms can manage this data in a centralized repository throughout the full data lifecycle. These vendors will be referred to as Vendor A and Vendor B throughout this report.

1.2 Project Task Summary

The project was split into five distinct task phases. The following is a description of each phase of work assigned to the EPIC Project Team and the expected deliverables.

Task 1 - Project Kickoff and Work Plan

- Develop final report outline based on interaction with SDG&E, vendors, EPIC guidelines and overall project tasks
- Create project timeline showing key milestones and high-level tasks
- Develop stakeholder and use case information forms for use in the one-to-one stakeholder use case meetings
- Attend and compile summaries of the vendor kick-off meetings

Deliverables:

1. Final report outline
2. Project timeline
3. Stakeholder information form
4. Use case information form
5. Vendor kickoff meeting summaries

Task 2 - Use Case Development

- Conduct one-to-one meetings with each of the participating stakeholders and vendors to develop use cases that define visualization and situational awareness using the proposed vendor test system
- Define stakeholder group responsibilities
- Work closely with the stakeholders and vendors to define use cases that are SMART (Specific, Measurable, Achievable, Realistic, Timely)
- Create workflow diagrams for each use case that define visualization and situational awareness using the proposed test system and document the requirements for data usage and ingestion including existing workflows and file types
- Compile the findings from stakeholder meetings, determine conflicts, technology limitations and data overlap between stakeholders. Identify current data management systems and requirements for data ingestion, security and size limitations and end user needs; working interactively with the SDG&E EPIC project team, IT management, GIS, Aviation Services, and other participating stakeholders
- Develop a requirement traceability matrix including functional, technical, applicable standards, information systems/technology and security related requirements
- Provide a Task 2 report including use case summaries, existing stakeholder workflows, requirement traceability matrix, use cases, test plan and test cases
- Assist SDG&E's project team to select and prepare the baseline dataset or test circuit, and participate in collection of sample data to be given to the vendor, if a test circuit is chosen

Deliverables:

1. Summary of stakeholder group responsibilities
2. Summary of use cases
3. Use case workflow diagrams
4. Summary of requirements (functional, technical, information technology and security) and traceability matrix
5. Summary of test cases
6. Test case workflow diagrams

Task 3 - Test System Design, Development and Setup

- Describe the selected baseline dataset or test circuit data. Vendors provided high level system requirements for each of the vendor tools taking into consideration the test cases developed in Task 2, for comment and review
- Vendors provided a high-level system architecture diagram that illustrates basic building blocks, for comment and review
- Summarize and compare vendor tool design, basic architecture and system setup
- Develop high-level system design requirements for a prospective SDG&E system, agnostic of vendor, generated from the list of use cases identified in Task 2

Deliverables:

1. Baseline dataset outline
2. Evaluation of high-level vendor tool system requirements specification provided by vendor
3. Evaluation of vendor tool architecture diagrams provided by vendor
4. Summary and comparison of overall vendor tool design, architecture and setup
5. Draft high-level system design requirements for a prospective SDG&E system agnostic of vendor, based on the use cases identified in Task 2
6. Proposed system design recommendations for SDG&E

Task 4 - Evaluate Test System Demonstrations

- Perform system demonstrations, assist in testing (if applicable) and provide feedback on vendor tools and end user ingestion of data sets
- Collate demonstration feedback from stakeholders
- Review and analyze vendor ability to demonstrate selected test cases
- Report on vendor test case results and evaluate accuracy and confidence of findings
- Compare and summarize overall vendor tool abilities and user experience
- Expand high-level system design requirements based on what was demonstrated by the vendors

Deliverables:

1. Summary and comparison of stakeholder feedback
2. Summary and comparison of vendor test case results
3. Summary and comparison of overall vendor tool abilities and user experience
4. Proposed system design recommendations for SDG&E
5. Final high-level system design requirements prospective SDG&E system

Task 5 - Comprehensive Final Report

- Prepare a comprehensive final report that states the project objective (from the CPUC approved SDG&E application for EPIC-1), explains the relationship to state policies and industry needs, estimates the project success using predetermined metrics, describes the work performed, provides key test results and data analysis of test results, and provides the key findings, conclusions, and recommendations regarding possible commercial adoption of the methods and tools that were demonstrated. A standalone executive summary shall also be prepared. The executive summary shall not exceed two pages and shall be placed in the front of the final report. Work with SDG&E to develop an outline agreed upon in Task 1
- The report shall be of high professional and editorial quality including internal and external review and editing cycles, and shall follow the required outline developed in the project plan, and it shall adhere to EPIC guidelines. The graphics used in the report shall be high quality and high legibility
- Input shall be obtained from the SDG&E project team in preparing the report in draft form for review by the SDG&E stakeholder review panel
- The report must be revised into final form based on comments from the stakeholder review panel
- The Contractor shall submit the final report to SDG&E for review. SDG&E will file the final report with the CPUC and make available to the public
- Prepare a final PowerPoint presentation on the work

Deliverables:

1. Comprehensive final report, both hard and electronic copies

2. Final PowerPoint presentation on the work to be presented to all stakeholders at the end of the project

2.0 Stakeholder Analysis

SDG&E stakeholders were identified by EPIC project leadership for participation based on their interest in the project and the benefits that could flow from the implementation of advanced data analytics on LiDAR and imagery collected via Unmanned Aircraft Systems (UAS).

Representatives from the following stakeholder teams were selected for input in the kick-off meetings to discuss potential use cases: Aviation Services, Infrastructure, GIS, Reliability, Architecture, FiRM Program, Vegetation Management, Environmental Services and Land Management. The vendors also attended these meetings, which allowed them to gain an initial understanding of the issues faced by each stakeholder and what obstacles they were looking to overcome.

To make efficient use of the stakeholders' time and availability, the stakeholder representatives were split into the following 'buckets': Infrastructure, Vegetation Management and Environmental Services. Meetings were arranged between the stakeholder groups and vendors to further develop the use cases and narrow down the test case selection, that met the requirements in terms of the data set provided, cost and time.

This section describes the overall stakeholder group responsibilities and the inefficiencies they face when conducting their day to day business.

2.1 Infrastructure Stakeholder Group

2.1.1 Responsibilities

The 'Infrastructure' stakeholder group is made up of the Information Technology, Aviation Services and Enterprise Architecture Departments. Each team has its own set of roles and responsibilities which are outlined below.

Information Technology (IT)

The Information Technology Department (IT) is accountable for the architecture, hardware, software and networking of computers across SDG&E. Key responsibilities include programming, technical support, system administration, data management and security.

Aviation Services Department (ASD)

The Aviation Services Department (ASD) utilize UAS and helicopters to capture data at the request of other stakeholders. Currently, they can deliver Red, Green, Blue (RGB) imagery and video, LiDAR and Infrared (IR) data sets at relatively short timescales, usually within 24 to 48 hours after the request.

When a stakeholder request is beyond the technical capabilities or available resources of the ASD, the group uses a contractor to provide the required services. Once the data is collected and ready for delivery, ASD delivers information directly to the requesting group. ASD are responsible for managing, vetting and coordinating contractors that provide RGB imagery and video, LiDAR, Ultraviolet (UV), IR and other types of sensor data collected by UAS contractors.

Enterprise Architecture (EA)

The Enterprise Architecture Department hold an enterprise view of the architecture of the information technology systems at the Sempra level meaning they are responsible for both SoCalGas and SDG&E architecture. They are responsible for defining the strategic direction of technologies with focus on information management.

2.1.2 Problem Statement

All design and construction tasks undertaken across SDG&E departments involve data collection. Currently, data is collected and stored by each individual department on their individual systems and as a result data sharing is limited. There is no central repository to store collected data and users can lose perspective of where data is held and may be unable to determine what area or location the data represents.

Implementation of a central repository will prevent duplication of effort, for example by preventing teams from inspecting or surveying areas that have already been recently inspected thus increasing operation and maintenance costs, improve decision making and result in overall cost savings for SDG&E. Data inconsistency is caused by maintaining information in parallel databases, transferring data from department to department, and not having a single point of responsibility for keeping it clean and up to date. Bringing all SDG&E data into a centralized system with a geospatial interface is essential to solving this problem.

Appendix A shows the current Infrastructure workflow and highlights the inefficient and ineffective steps in the process in red.

2.2 Vegetation Management Stakeholder Group

2.2.1 Responsibilities

A large part of Vegetation Management Team's duties concern powerline and pole safety. All state utilities are required by law to clear brush and debris from primary electrical power lines. There are around 460,000 trees spread over 8,700 miles across SDG&E's utility network.

Vegetation Management are responsible for adhering to these laws to:

- Prevent electrocution during a storm or accident
- Reduce the risk of fire
- Prevent unnecessary power outages

The pole brush program is a cyclical year-round effort to remove brush from the base of wood poles supporting power lines, that may cause fires. Poles with certain equipment such as fuses, switches, arrestors, and certain connectors are required to have a firebreak of ten feet or more in each direction. Pole brushing is the removal of all vegetation down to the bare mineral soil.

The program also includes clearing around transmission line structures. This fire prevention program is mandated by laws enforced by Cal Fire and California Public Resources Code Section 4292. SDG&E has a three-tiered program to assure that the poles remain in compliance.

There are three steps to clearing brush as part of routine maintenance:

Herbicides

From November through February vegetation around poles is cleared and treated with a herbicide to prevent re-growth.

Mechanical Brushing

From March through June, vegetation around subject poles that were not treated with herbicides are mechanically cleared.

Mechanical Re-Clearing

All poles that are not treated with herbicides are visited again during July through October for re-clearing.

The brush clearing program can be triggered for either of the following reasons:

- A routine maintenance cycle begins
- Off-cycle regulatory maintenance is required due to non-compliance

If a non-compliance is discovered, an assessment of the hazard it poses is made. If the risk can be mitigated safely in the next routine maintenance cycle, then it will be managed at that point. If it cannot, then an ad-hoc work order is created to conduct maintenance works immediately.

2.2.2 Problem Statement

Sending out staff to manually conduct inspections and auditing tasks is extremely time, labor and resource intensive and there are many associated safety and accessibility issues.

The current workflow undertaken involves a pre-inspection to identify overhead power lines and identify what work needs to be done, along with quality assurance auditing and inspection.

Vegetation Management would like to explore how the findings from the advanced data analytics can provide a snapshot of the current scenario and reduce the number of pre-inspections that need to be conducted. The findings would inform a maintenance schedule that is more focused and sends staff to conduct full inspections in areas of interest.

Another issue faced by Vegetation Management is the fact that they do not have access to any of the LiDAR and imagery collected by other departments because of the way in which this is currently collected and stored. A common theme among all stakeholders is the desire for a single centralized repository to promote data sharing between teams.

The system currently used by Vegetation Management to store their tree data is called Powerworks and is a standalone system, built on Inframap which is an iteration of the Environmental Systems Research Institute (ESRI) Geographic Information System (GIS) software. The tree geographic locations are not accurately represented in the system because of the way they are currently displayed; trees are "spread out" so the user can see them all instead of them being clumped together at their true locations. This can create confusion about where the trees are in reality. In an ideal world, this issue would be rectified, and all trees would have accurate GPS coordinates assigned to them, they would be stacked in clusters, but these clusters would transform into individual tree markers as the user zooms in.

Appendix B shows the current Vegetation Management workflow and highlights the inefficient and ineffective steps in the process in red.

2.3 Environmental Services Stakeholder Group

2.3.1 Responsibilities

The Environmental Services group are responsible for the permitting and licensing of new and replacement of gas and electric utility projects. Environmental Services is also responsible for ensuring that work on existing and proposed infrastructure occurs in compliance with all applicable permits and regulations. Part of that review entails avoiding and minimizing impacts to the environment. Environmental Services works with project initiators at the inception of a project to provide input and constraints data so that the proposed activity avoids or minimizes the impacts to the environment.

Environmental Services are consulted whenever a new construction project is initiated, this could be either a rebuild or modification to existing facilities or new construction of transmission or substation infrastructure capital projects. In the early stages of project development Environmental Services works with the project initiator to provide environmental constraints data to inform the design of the project and avoid or minimize impacts to the environment. Once the design is at 60% complete the Environmental team analyzes any potential environmental impact and provides input to determine the appropriate licensing and permitting requirements. The process involves various internal resources including Subject Matter Experts (SMEs) such as biologists, aquatic and cultural experts, as well as external environmental contractor resources.

Key Environmental Services responsibilities include:

- Conducting environmental inspections to review potential impact on aquatic resources, biological resources and cultural resources before permitting any construction work
- Maintenance, monitoring and restoration of environmental conditions post-construction

2.3.2 Problem Statement

Sending out personnel to carry out environmental inspections can be resource heavy and time consuming. Personnel may also face access issues such as the type of terrain, occurrence of hazardous plants and animals, and accessibility to pole and work locations. A recent environmental assessment took three members of environmental staff, four full eight-hour days to complete.

In an ideal scenario, Environmental Services would review existing data sets and fly an UAS or helicopter to collect data as a pre-condition to conducting an environmental inspection. The data would be analyzed as part of the initial desktop review and provide valuable information regarding vegetation species, land forms, existing disturbances, access routes, avoidance areas and surface information. This would allow the environmental inspection to be more focused and reduce the time spent walking from pole to pole to gather the types of information that could easily and quickly be collected by an UAS or helicopter.

The environmental inspection cannot be completely replaced by remote technology since an element of field work will always be required, for example field verification of aquatic resources requires field observations to make a determination. However, having up to date imagery can greatly improve inspection planning, reduce the number of hours the inspections take and free up resources to work on other tasks. The initial desktop review currently relies on Google Earth for imagery and this can sometimes be several years out of date which can result in an inaccurate perception of the environmental conditions.

In addition, the introduction of a mobile tool to collect and upload field notes and assessment details directly into the vendor system would greatly improve processes and efficiency. Duplication of effort would be eliminated since personnel would not need to type up their field notes on return to the office.

Currently, when data is collected by Environmental Services during a job walk, it is stored on an independent project drive and is not available for sharing and likewise Environmental Services does not have access to the data collected by any other group. Consequently, they have also expressed interest in the implementation of a single centralized repository to promote data sharing between teams.

Appendix C shows the current infrastructure workflow and highlights the inefficient and ineffective steps in the process in red.

3.0 Use Case Summary

Several stakeholder meetings and interviews took place and a variety of potential use cases were identified. A common theme discovered amongst all stakeholder groups was the lack of a centralized data repository to store and visualize the vast quantities of data collected by SDG&E. Currently all stakeholder groups collect, manage and maintain their own data, which is stored on a system unique to each department which makes data sharing amongst teams difficult.

Other use cases were selected that make use of advanced data analytics to improve and enhance stakeholder processes. A key focus was finding ways to reduce the number of laborious manual inspections that must be undertaken by the various stakeholder groups.

Throughout this report, the term 'use case' describes any case or scenario that was identified by the stakeholders to assist and provide efficiencies to their current workflow. A 'test case' is a use case that was selected, by the EPIC Team and stakeholders, for progression and demonstration by the vendors. This section describes all the use cases that were identified.

3.1 Infrastructure Use Cases

The Infrastructure stakeholder group focused on the idea of implementing a centralized repository for full data lifecycle management for design and construction projects. One of the largest construction programs that is currently active within SDG&E is the Fire Risk Mitigation (FiRM) Program and it provides a strong example of the data management obstacles SDG&E are faced with, due to the huge quantities of data that are collected each day.

The FiRM Program started in 2013 and includes replacing older overhead distribution line equipment with advanced technology and improving their system to adequately handle known weather conditions. As part of the utilities commitment to providing safe and reliable energy, they are proactively addressing fire risk by "hardening" the critical areas within their service area most at risk for wildfires. As part of this initiative, thousands of circuit miles of LiDAR, ortho imagery and oblique imagery data has been collected. Some of the data has been post processed and uploaded to the Procore file transfer site for distribution to involved parties or to the FiRM SDG&E File Transfer Protocol (FTP) site.

The centralized repository must have an appropriate role-based access control model in place. This should be used to restrict certain data access based on the user's role and privileges, for example, transmission data, particularly bulk power transmission 230kV and 500kV should only be accessible by the Transmission Construction & Maintenance (TCM) and Transmission Engineering and Design (TED) Teams for reasons of cyber security.

The Infrastructure use cases describe how the vendor system can manage and maintain data throughout the full data lifecycle. The data lifecycle is shown in Figure 1.

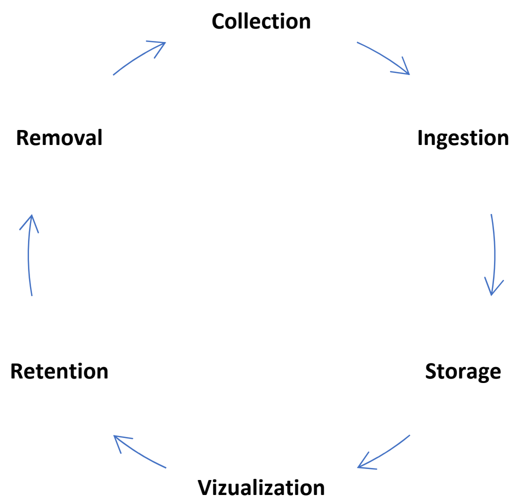

Figure 1: Data Lifecycle

3.1.1 Data Collection

Data can be collected for design and construction by UAS or helicopter or through traditional field data collection methods. Data collection is essential to all stakeholder groups and is the first step in the data lifecycle. For any of the documented use cases to commence, this use case must be executed.

UAS / Helicopter Data Collection

As part of the FiRM Program, an external vendor flies an UAS or helicopter to gather LiDAR and photogrammetry data from a given section of circuit. Photogrammetry data includes both orthorectified and oblique imagery.

This use case is triggered by the initiation of a project after the scoping of the project has been completed with internal stakeholders. The vast majority of the projects completed thus far includes the replacement of SDG&E's highest risk assets, small copper conductors and wood poles, in the highest risk fire locations.

Prior to flying the UAS or helicopter, appropriate permission must be sought from property owners in and around the flight path and other affected persons must be informed via the public outreach system.

Using a UAS or helicopter to collect LiDAR and photogrammetry data realizes the following benefits:

- Large quantities of data can be collected in a short timeframe
- Reduces the need for manual data collection inspections and patrols and consequently improves employee safety
- Ability to inspect difficult to reach and hazardous areas
- Resource, time and labor savings in comparison to field data collection methods

The overall flow of events for this use case includes the following steps:

1. Mission planning and risk assessment
2. Mobilization of UAS or helicopter
3. Collection of LiDAR and photogrammetry data

Throughout the FiRM Program, LiDAR and photogrammetry data will be collected throughout portions of the entire SDG&E service area.

Field Data Collection

Traditional field data collection, using 'feet on the ground', is an essential method for many SDG&E groups to take hand written field notes and photographs. The field data collection process could be significantly improved if a mobile device was used for collection.

Like most data collection requests within SDG&E, this use case is initiated by an engineering design contract which can either be a modification to an existing facility or new construction. The planning phase takes place where the data collection and resource requirements are identified before personnel go out and collect the data.

Within the FiRM Program, field data collection is known as a ‘job walk’ and includes representatives from the Design and Engineering Team, Land Services, Environmental Services, Construction, Surveying and Program Management. Before the job walk is undertaken, information about the circuit is gathered by the FiRM Program Team and includes data from the Engineering & Design Submittals, Corrective Maintenance Program (CMP) database, GIS, and photogrammetry. The Engineering & Design Consultant provides the following data in preparation for the job walk and are derivatives of the results of the PLS-CADD model that has imbedded in it the LiDAR and imagery data:

- Selected high risk poles in CSV format
- Map book including overview page, index page and pages for entire circuit
- ArcGIS shape file with pole locations and SanGIS parcel, owner, and assessor parcel number data included
- Google Earth KMZ file with pole locations and parcel data

Currently, field notes and photographs are taken as part of the job walk, and, in some cases, ecological field samples, such as soil and water samples, are also collected. Field notes are typed up and photographs are uploaded to each team’s individual systems, when the representative returns to the office. Once in electronic format, the data stays with the team who has collected it which reduces data sharing opportunities.

If a mobile device is used for data collection, inefficiencies caused through duplication of effort are eliminated as the user does not have to travel back to the office to write up and upload the data. Generally, users are familiar with the functionality of mobile devices so formal training is not usually necessary for personnel.

The overall flow of events for this use case includes the following steps:

1. FiRM Team collect information about facilities
2. Job package is created by the GIS and/or Engineering & Design consultant
3. Job package is shared with FiRM Program Management Team, Land and Environmental
4. Job walk is planned out and collection requirements are identified
5. Job walk is conducted using vendor mobile app

3.1.2 Data Ingestion

Data can be ingested into the vendor system through various means. Like data collection, data ingestion is another essential step in the data lifecycle and must be executed before any of the other documented use cases can commence.

Common data types that are used within SDG&E include LiDAR, RGB oblique imagery, RGB nadir imagery, RGB video, GIS shape files, Powerworks shape files, PLS-CADD models, ultraviolet data, infrared data, field notes and other supporting documents (PDF, XLS, KMZ, DWG).

UAS / Helicopter Data Ingestion

After the data is collected, the data is processed and subject to a quality control procedure to check coverage, point density and imagery quality.

When the data has passed all quality control checks, it can be ingested directly into the vendor system for visualization and analysis. An intermediate file transfer step may need to be incorporated if the UAS / Helicopter contractor does not have direct access the vendor system.

The overall flow of events for this use case includes the following steps:

1. Data is processed and LiDAR rasters are produced
2. Quality control checks are undertaken
3. Data is uploaded into the vendor system

For further information about how LiDAR point clouds are converted into a raster, readers are directed to the University of Colorado, Earth Lab website.[2]

[2] University of Colorado. Earth Lab found at www.earthdatascience.org/courses/earth-analytics/lidar-raster-data-r/lidar-raster-data/

Field Data Ingestion

Data is collected in the field using a mobile device equipped with the vendor app. Once the data has been collected on the mobile device, it can be synced directly with the vendor system without the need to go back to the office to upload or type up information.

The vendor mobile data tool must have an offline capability that allows data collection when there is no internet connection. This allows collected data to automatically sync with the vendor system when connection is resumed.

Using a mobile device equipped with the vendor app for data ingestion realizes the following benefits:

- Loss of information risks are reduced since the information is uploaded directly into the vendor system, through the mobile device, in real-time
- Near instantaneous data transmission allows other users to make use of the data immediately
- Data is ingested directly into a single, centralized repository which promotes data sharing

The overall flow of events for this use case includes the following steps:

1. Collected data is subject to in field QC to check required data and imagery has been acquired
2. Data is uploaded directly into the vendor system from the mobile app

Batch Data Upload

There are some instances where batch data must be uploaded into the vendor system. Some examples include exploratory boring data or seismic refraction surveys. The data may be collected by an independent consultant or expert and provided to SDG&E in spreadsheet or PDF format. It is essential there is a function to ingest large quantities of data into the vendor system in one action.

Data that is uploaded must be shown at the correct location on the map and any associated metadata must also be ingested and displayed accordingly. The file in which the data is documented, for example the Exploratory Boring Report, should be associated to the specific coordinates of each boring location.

The overall flow of events for this use case includes the following steps:

1. Request for batch upload is received
2. Data is converted into a CSV file
3. Data is ingested into the vendor system in one action
4. Associated files are attached to the data points

There is potential to automate the batch upload process, if a need arose, for repetitive data ingestion on a weekly or monthly basis.

3.1.3 Data Storage

At this point, data has been collected and ingested into the vendor system. The data is stored in the vendor system which acts as a centralized repository for all data types. The vendor system must be scalable and able to handle a growing data set which could reach considerable quantities of data. In addition, a robust data backup and recovery protocol must be established to prevent data loss.

Information is one of SDG&E's most valuable assets so having a dependable system for the storage and management of the plethora of data is critical. Implementing a centralized repository will greatly improve access and retrieval of data for all users, it becomes easier for users to navigate and search for required information and improves data sharing between teams. Increased data sharing amongst teams results in resource, time and cost savings as data from areas that has been recently assessed can be used by other teams. This reduces the need for further field work. One of the key issues faced by SDG&E, is the fact that data is held on a variety of different systems that are not accessible to all.

The overall flow of events for this use case includes the following steps:

1. Data is ingested into the vendor system
2. Data is stored in a centralized repository

3. Users search against and retrieve data of interest via a text search or sort tool, or through a geospatial interface

3.1.4 Data Visualization

Once the data is retrieved from the centralized repository, it must be presented in a logical format to provide the best value to the user. This use case will explore how the vendor system can retrieve, display and present various data types. For the purposes of the demonstration, the provided data types include LiDAR, RGB oblique imagery, GIS shape files, Powerworks shape files, PLS-CADD models and other supporting documents (PDF, XLS, KMZ, DWG).

Data must be retrievable through a search function or by drawing a bounding box on the map. All data must be geospatially referenced and shown at the correct location on the map. Associated metadata, files and attributes must be displayed a when user drills down into each data point.

The overall flow of events for this use case includes the following steps:

1. Data is retrieved using a search function or bounding box
2. Data is displayed accordingly
3. Users drill down into a data point to view associated metadata, files and attributes

3.1.5 Data Retention

Data must be retained in the vendor system as specified in SDG&E's data retention policies. The data retention policy can vary between data type and data owner. Data relevant to the construction and maintenance of an asset must be retained for the life of the asset plus five years. SDG&E's entire overhead system (transmission and distribution) is comprised of approximately 263,000 overhead facilities, with over 73,000 poles for example that are 50 years old or older and have a long history of engineering & design and inspection data. This means there must be a mechanism that can feed in construction decommissioning dates and handle the volume of data efficiently. Consideration must be given to data that has multiple associations, the data must be retained for the life of its final association plus five years, even if the retention period for its historical associations has elapsed.

There may be a case to automatically assign a retention period to data on ingestion, this could be based on the role or department of the user ingesting the data, or on the type of data that is being ingested. It is important that this workflow can be manually overridden in the event the data type requires a different retention period than expected. To implement a mechanism such as this, SDG&E must develop a thorough retention policy for all their data types.

The overall flow of events for this use case includes the following steps:

1. Data retention period elapses
2. Data is flagged for removal

3.1.6 Data Removal

Once the data retention period elapses and the data has been automatically flagged for removal, data must be purged from the vendor system. Data removal can either be done automatically or the workflow can allow for human intervention to make the final purging decision. Depending on the quantities of data flagged for removal in a given period, human intervention may not be practical.

Data removal is important for the health of any centralized repository system. Holding data for longer than required slows down overall system performance, response time and users can be overwhelmed with the sheer quantity of out dated information. Having an effective purging mechanism opens memory or storage space for other uses.

It is important that data is disposed of effectively and securely according to industry standards. This prevents data or security breaches.

The overall flow of events for this use case includes the following steps:

1. Flagged data is permanently removed from the system
2. Data is disposed of according to industry standards

Appendix D shows the future Infrastructure workflow and highlights the process improvements and efficiency savings (in green) that could be made by introducing a centralized data repository.

3.2 Vegetation Management Use Cases

The Vegetation Management stakeholder group would like to explore how advanced analytical methods can supplement their inspection and auditing procedures. Sending out personnel to manually conduct inspections and auditing tasks is time and resource intensive and there is associated safety and accessibility issues as well as liability and insurance costs.

Their ideal future state is to regularly fly an Unmanned Aircraft System (UAS) or manned helicopter to collect up to date photogrammetry and LiDAR data, ingest this data into the vendor system, then use advanced data analytics to complement inspection and audit procedures. The findings would allow more focused maintenance schedules to be created resulting in a safer, more efficient process. Once the contractors are sent to conduct the maintenance works, details regarding the work carried out should be directly uploaded back into the vendor system using a mobile device whilst out in the field.

The use cases below describe the types of advanced analytics that could be conducted and how the results will benefit the Vegetation Management team. An assumption is made that the data has already been collected and ingested into the vendor system prior to the use cases beginning.

3.2.1 Identifying Hardware and Firebreaks

Some poles are fitted with hardware and due to the potential fire risk they can pose, poles must be cleared of brush for the safe delivery of energy. Pole brushing is the removal of all vegetation down to the bare mineral soil to act as a firebreak. The firebreak must have at least a 10-foot radius from the outer circumference of the pole or tower.

Typical non-exempt hardware found on poles includes universal fuses, open link fuses, enclosed cutouts with universal fuses, solid blade disconnects, in-line disconnects, lightning arresters, non-porcelain lightning arresters, hot tap clamps, split bolt connectors, fargo connectors, LM connectors, grasshopper air switches and transmission air switches.

Rules and regulations regarding equipment on poles and the need for firebreaks is outlined in Section 4292 of the California Public Resources Code:

“Any person that owns, controls, operates, or maintains any electrical transmission or distribution line upon any mountainous land, or forest-covered land, brush-covered land, or grass-covered land shall, during such times and in such areas as are determined to be necessary by the director or the agency which has primary responsibility for fire protection of such areas, maintain around and adjacent to any pole or tower which supports a switch, fuse, transformer, lightning arrester, line junction, or dead end or corner pole, a firebreak which consists of a clearing of not less than 10 feet in each direction from the outer circumference of such pole or tower.”

This use case explores how the vendor system can analyze LiDAR and photogrammetry data to:

- Identify specific hardware on poles
- Identify the presence of a firebreak
- Calculate the radius of the firebreak

The results from the analysis will allow Vegetation Management to quickly and effectively locate poles that are non-compliant and take appropriate remedial action. The findings can be used to inform the maintenace schedule which is more focused and reduces the need for pole to pole inspections. Maintenance personnel can be sent directly to non-compliant areas to take remedial action.

The following scenarios are classifed as being non-compliant:

- Any pole with equipment but no firebreak
- Any firebreak with a radius of less than 10 foot

Figure 2 shows various firebreak examples from a plan view at ground level as stipulated by the California Department of Forestry and Fire Protection.

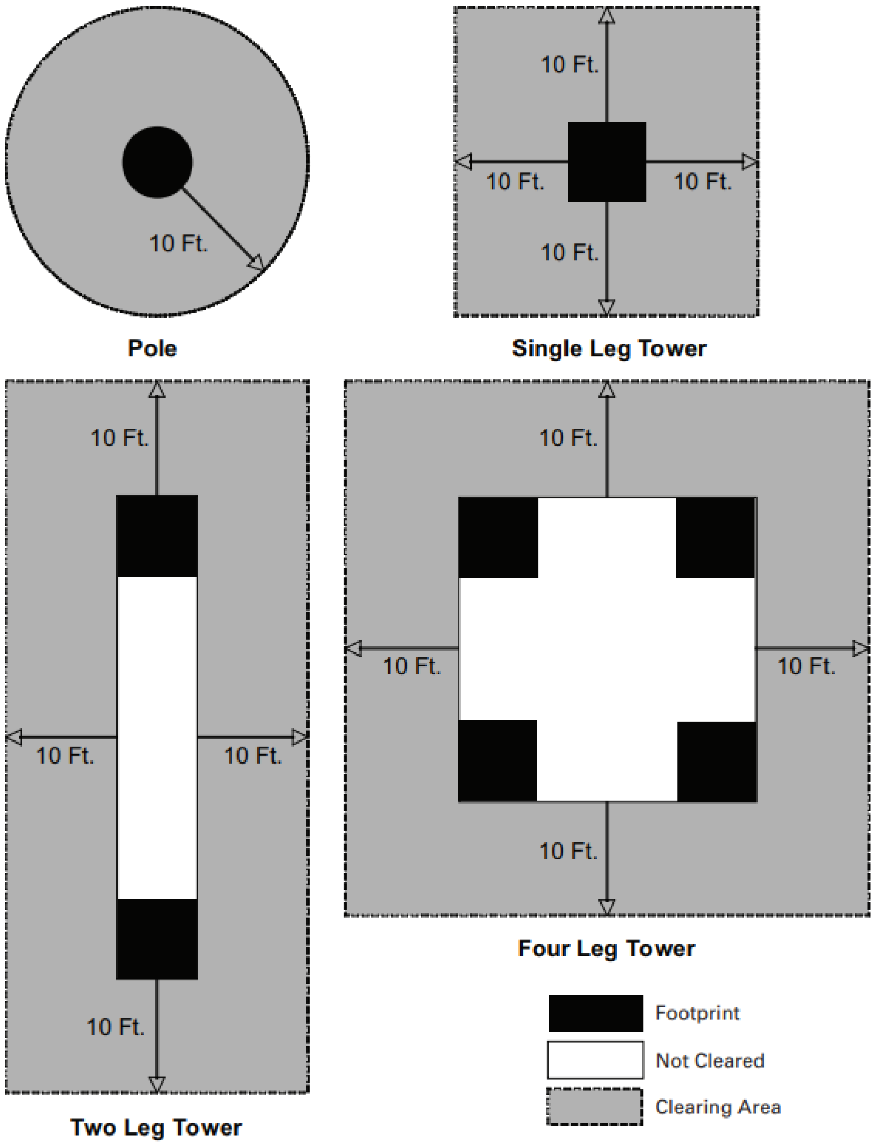

Figure 2: Firebreak Examples (Plan View at Ground Level)[3]

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and the following is established:
    a) Identification of hardware on poles

[3] California Department of Forestry and Fire Protection (2008). Power Line Fire Prevention Field Guide. Retrieved from: http://cdfdata.fire.ca.gov/pub/fireplan/fpupload/fppguidepdf126.pdf

b) Identification of poles without hardware
c) Identification of poles with firebreaks
d) Identification of poles without firebreaks
e) Calculate the radius of the firebreak

3. Informed maintenance schedule is created
4. Maintenance works take place
5. Field notes and maintenance details are uploaded directly into the vendor system through use of a mobile device

3.2.2 Identifying Tree Growth Patterns

Trees and vegetation grow at different rates depending on the surrounding environmental conditions. If the Vegetation Management Team had an idea of vegetation growth rates, maintenance works could be planned accordingly to prevent any non-compliances.

The vendor system must be capable of conducting advanced analytics on LiDAR and photogrammetry data to calculate the growth rates of specific vegetation types. Through comparison of historic versus current data, the growth or decline can be established. These rates will help prevent vegetation encroachment since maintenance works can be planned and conducted before it becomes non-compliant. If an area is found to be non-compliant, then contractors can be sent directly to the area to conduct corrective maintenance without the need to carry out pole to pole inspections.

Section 4293 of the California Public Resources Code outlines power line clearance requirements:

"Any person that owns, controls, operates, or maintains any electrical transmission or distribution line upon any mountainous land, or in forest-covered land, brush-covered land, or grass-covered land shall, during such times and in such areas as are determined to be necessary by the director or the agency which has primary responsibility for the fire protection of such areas, maintain a clearance of the respective distances which are specified in this section in all directions between all vegetation and all conductors which are carrying electric current:

a) For any line which is operating at 2,400 or more volts, but less than 72,000 volts, four feet.
b) For any line which is operating at 72,000 or more volts, but less than 110,000 volts, six feet.
c) For any line which is operating at 110,000 or more volts, 10 feet.

In every case, such distance shall be sufficiently great to furnish the required clearance at any position of the wire, or conductor when the adjacent air temperature is 120 degrees Fahrenheit, or less. Dead trees, old decadent or rotten trees, trees weakened by decay or disease and trees or portions thereof that are leaning toward the line which may contact the line from the side or may fall on the line shall be felled, cut, or trimmed so as to remove such hazard. The director of the agency which has primary responsibility for the fire protection of such areas may permit exceptions from the requirements of this section which are based upon the specific circumstances involved."

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and growth rates are calculated
3. Informed maintenance schedule is created
4. Maintenance works take place
5. Field notes and maintenance details are uploaded directly into the vendor system through use of a mobile device

3.2.3 Identifying Areas of Tree Health

Dead or dying trees can cause extreme fire danger in the SDG&E region as they allow wildfires to spread more rapidly in the already dry, hot, and drought-stricken environment. Consequently, Vegetation Management has an obligation to remove these trees and vegetation from around their assets as a preventative measure.

The vendor system must be capable of using advanced data analytics to identify areas of dead and dying vegetation. This can be done by inspecting changes in tree color, through analysis of infrared data or by other methods developed by the vendor.

Once the vendor system has identified these areas, maintenance contractors can be sent directly to the areas that require dead tree removal, eliminating the need for pole to pole inspections to check for dead vegetation. The overall fire risk is reduced because dead and dying trees can be identified and removed more quickly. Information about tree health can be shared with Environmental Planning for investigation.

Section 4292 and 4293 of the California Public Resources Code mentioned above, outlines power line hazard reduction and required clearances. In addition, Figure 3 provides a graphical representation of required vegetation removal around a pole. From the ground to 8 feet, all vegetation must be removed. From 8 feet to the conductors, all dead and dying vegetation must be removed.

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, dead and dying trees are identified and flagged for removal
3. Informed maintenance schedule is created
4. Maintenance works take place
5. Field notes and maintenance details are uploaded directly into the vendor system through use of a mobile device

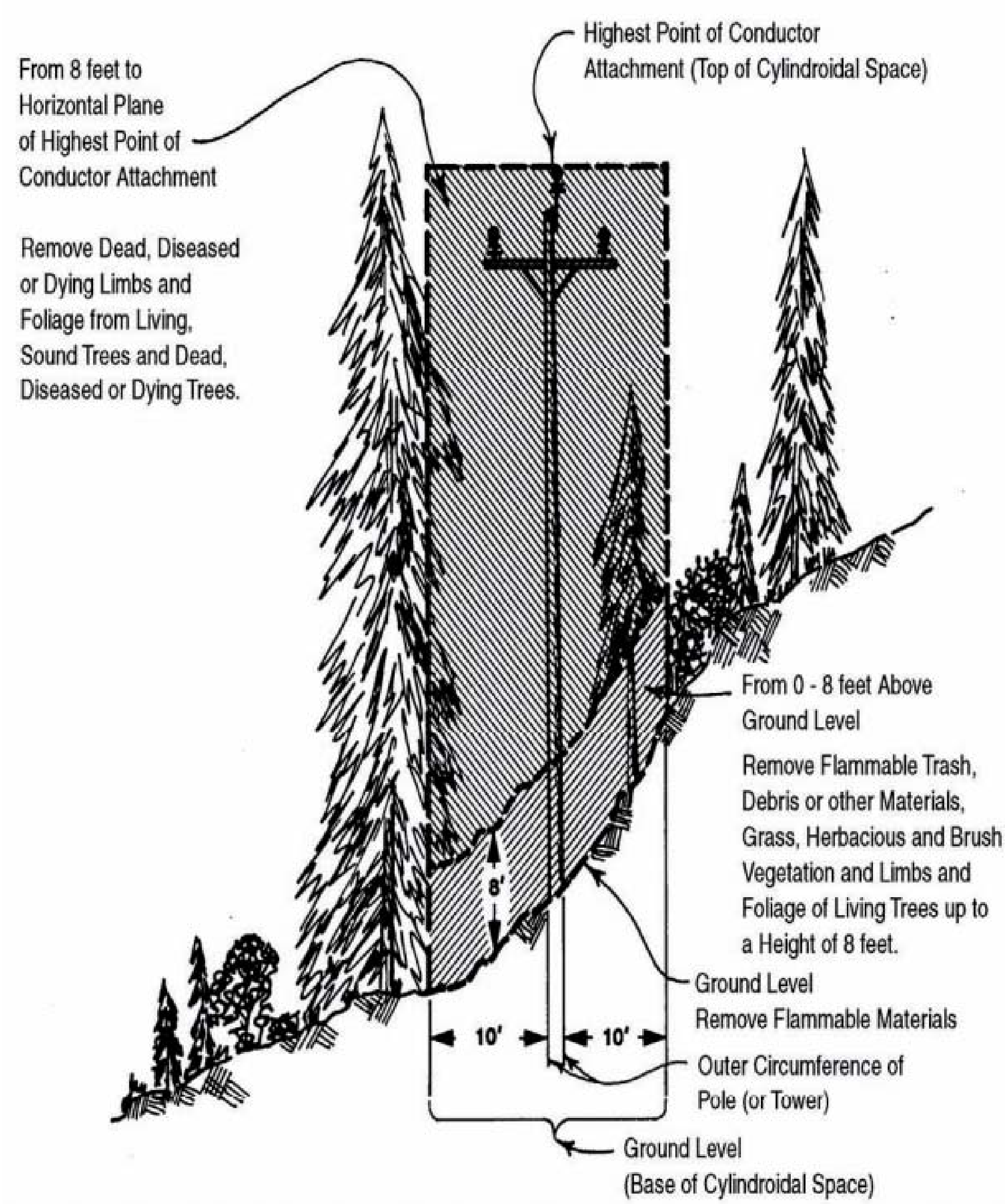

Figure 3: Firebreak Clearance Requirements Around Poles and Towers[4]

3.2.4 Identifying Changes in Pole Lean

Poles can begin to lean for various reasons such as pole damage and erosion issues at the pole base. Regulations state that poles must not lean more than 10 degrees from vertical. Any poles

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[4] California Department of Forestry and Fire Protection (2008). Power Line Fire Prevention Field Guide. Retrieved from: http://cdfdata.fire.ca.gov/pub/fireplan/fpupload/fppguidepdf126.pdf

that lean by more than 10 degrees must be flagged so corrective action can be taken. Vegetation Management would like to explore how the vendor system can identify the degree of pole lean so preventative or corrective action can be taken without needing to conduct pole to pole inspections. They are also interested in how pole lean has changed over time and the underlying reasons for the pole lean.

This use case explores how the vendor system can analyze LiDAR and photogrammetry data to identify the current degree of pole lean, compare a historical and recent dataset to identify the degree of pole lean after a set time and identify the source of pole lean, for example, erosion at the base of the pole.

Vegetation Management would like the vendor system to adhere to the following criteria when displaying the pole lean findings:

- Pole lean of less than 7 degrees is acceptable and shown in green
- Pole lean of 7 to 9.9 degrees triggers a warning and is shown in yellow
- Pole lean of 10 or more degrees triggers an alert and is shown in red
- If a pole leans by more than 5 degrees in a year then this should trigger an alert:
    - If the pole lean has changed over time, the percentage lean should be shown in red
    - If the pole lean has not changed over time, 0% change should be shown in green

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and the following is established:
    a. Identification of the current degree of pole lean
    b. Identification of the degree of historical pole lean over a set time
    c. Identification of the source of the pole lean
3. Informed maintenance schedule is created
4. Maintenance works take place
5. Field notes and maintenance details are uploaded directly into the vendor system through use of a mobile device

3.2.5 Maintenance Audit

Vegetation Management conducts regular audits to check that maintenance works have been completed where and when they should have. This use case explores the idea of running advanced analytics on a random sample of data to check for both compliances and non-compliances. The findings would then be checked against any maintenance that has been completed in the field, by checking vendor system records and through means of a manual inspection. Details surrounding the audit could then be uploaded directly into the vendor system via a mobile device while out in the field.

The overall flow of events for this use case includes the following steps:

1. Dataset is subject to advanced analytics
2. Results are analyzed
3. Areas of auditing interest are identified
4. Check historical vendor system records for the random sample
5. Manual inspections are conducted to compare findings
6. If a non-compliance is located, corrective action is taken
7. Audit results are uploaded

Appendix E shows the future Vegetation Management workflow and highlights the process improvements and efficiency savings (in green) that could be made through advanced data analytics.

3.3 Environmental Services Use Cases

The Environmental Services stakeholder group, who primarily focus on the licensing and permitting of capital projects, would like to explore how implementing advanced data analytics can streamline their current processes and realize time and efficiency savings. One of the key issues faced by Environmental Services is the lack of updated aerial imagery necessary to conduct preliminary desktop environmental assessments and plan and organize in-field assessments for electric transmission and substation capital projects. Consequently, the desktop exercise may lead to inaccurate assumptions and the follow up in-field review can be extremely time and resource heavy.

The use cases below describe overall process improvements, the types of advanced analytics that could be conducted and how the results will benefit the Environmental Services team. An assumption is made that the data has already been collected and ingested into the vendor system prior to the use cases beginning.

3.3.1 Identification of Potential Pole Sites

The Environmental Services team plays an important role in licensing and permitting construction works, be it a new construction of electric transmission or substation infrastructure or modifications to existing facilities. If the vendor system could identify pole sites (existing and/or proposed) that lack access and are in or near sensitive environmental resources, this would help identify which pole sites require in-field review, allow fast identification of the appropriate Subject Matter Experts (SMEs) needed to attend the in-field review and reduce the overall amount of time taken to conduct the review. Members of the Environmental Project Permitting (EPP) Team and SMEs could be sent directly to the potential pole sites to conduct their environmental assessments and access could be arranged ahead of time for hard to reach areas that may not be accessible. A similar concept could be used to identify workspaces required to perform construction, such as stringing sites.

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, potential pole and work sites are identified
3. A map book and list of potential pole or work sites is created
4. Personnel are sent directly to accessible areas of interest to conduct environmental assessment
5. Assessment details are uploaded into the vendor system through use of a mobile device
6. EPP with SME input make recommendations to minimize environmental impact
7. Design and construction begins

3.3.2 Identification of Water Bodies

The environmental conditions surrounding the existing and/or proposed pole is also important when considering a potential pole site and consequently it was decided that this use case should consider the distance of existing and/or proposed poles from water bodies. The vendor system should be able to calculate distances from certain environmental features and output the distances using red-yellow-green statuses depending on the criticality. The following criteria was defined by Environmental Services when considering the distance of a pole to a body of water:

- Green – water body is 100 feet or more away from the pole (acceptable)
- Yellow – water body is between 51 and 99 feet of the pole (warning)
- Red – water body is within 50 feet of the pole (critical)

The criteria above would help identify the existing and/or proposed poles near water bodies that need further review by an SME in the field. This information combined with the results for identifying potential pole or work sites will allow for a more efficient assessment process and better decision making when considering potential pole sites and their proximity to water.

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, potential water bodies are identified
3. A map book and list of potential water bodies is created
4. Personnel are sent directly to accessible areas of interest to conduct environmental assessment
5. Assessment details are uploaded into the vendor system through use of a mobile device
6. EPP with SME input make recommendations to minimize environmental impact
7. Design and construction begins

3.3.3 Identification of Vegetation Community

Identifying the type of vegetation found where proposed construction work will take place is key to developing the environmental approach. Some vegetation communities are protected, they provide homes to other wildlife and are important for the overall diversity and preservation of the habitat.

Currently, identifying vegetation types is done manually by field crews on the ground and is a timely and arduous process. If general vegetation communities could be identified by conducting advanced analytics it would realize cost and time benefits and potentially locate and identify vegetation types that a desktop assessment may miss. Reducing or eliminating the need for manual in-field assessments, frees up resources to work on other assignments and prevents exposure to associated safety hazards.

This use case explores how the vendor system could identify or help confirm the vegetation community in an area of interest, which in turn will inform the construction approach that can be taken.

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and vegetation types are identified
3. A desktop analysis is performed with SMEs recommendations to minimize environmental impact and conduct an environmental field visit to specified pole locations if required
4. Assessment details are uploaded into the vendor system through use of a mobile device
5. Construction approach is developed considering vegetation types
6. Design begins

3.3.4 Identification of Birds' Nests in Vegetation

SDG&E is mandated by state and federal regulations to preserve and protect California's flora and fauna. Careful consideration must be given to assure the avoidance and minimization of impacts to nesting birds during construction projects. San Diego is home to several endangered and threatened bird species including the Coastal California Gnatcatcher and the Least Bell's Vireo[5]. It is extremely important these birds are protected to ensure their future survival.

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[5] U.S. Fish and Wildlife Service. Species by County Report. Retrieved from: https://ecos.fws.gov/ecp0/reports/species-by-current-range-county?fips=06073

Currently, Environmental Services work in collaboration with an independent SME to identify birds' nests during in-field environmental assessments. This is a difficult task, the nests can be buried deep within the vegetation, and there is a risk that birds' nests can go unidentified. Many nests are positioned on steep slopes, on top of the poles or other locations that may pose a safety risk to surveyors (when walking/hiking for surveys). The overall identification process is very inefficient and resource and time heavy.

If the vendor system could automatically identify birds' nests, then SMEs could conduct more focused assessments in these areas. The need for time consuming job walks to locate birds' nests may be reduced but on-the-ground survey would still often be required since drones cannot fly below the canopy to survey. In some cases, the vendor system may reduce safety risk by allowing surveyors to view nests in hazardous areas via drone, instead of walking/hiking on dangerous terrain.

This use case explores how the vendor system can use machine learning or advanced data analytics to identify birds' nests from within vegetation.

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and birds' nests are identified
3. Personnel are sent directly to areas of interest to conduct environmental assessment
4. Assessment details are uploaded into the vendor system through use of a mobile device
5. SMEs make recommendations to minimize environmental impact
6. Construction begins

3.3.5 Identification of Noxious Weeds and Invasive Species

Environmental Services would like to explore how the vendor system could identify specific noxious weeds and invasive species through machine learning or advanced data analytics. If automatic identification of these species was possible, with reduced need for laborious inspections to locate them, it would allow SDG&E to identify potential mitigation sites and manage and control required restoration areas more effectively and quickly, reduce the potential for harmful plant exposure to employees, and free up resources for other tasks.

Concerns over whether the technology, at this point, could identify all these species, were raised by Environmental Services and it was suggested that this technology would likely only be useful in identifying larger perennial species or some of the most common annual species. Most of the weeds treated by Environmental Services are annuals and need to be microscopically identified. However, moving forward this technology could be used to assign ranks for the likelihood of certain species to occur, likely preventative measures to prevent the spread of certain weeds or even the absence of weeds allowing Environmental Services to tailor weed introduction preventative measures.

The overall flow of events for this potential use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and plant species are identified
3. Personnel are sent directly to areas of interest to conduct environmental assessment
4. Assessment details are uploaded into the vendor system through use of a mobile device
5. SMEs make recommendations to comply with mitigation restoration requirements or identify potential mitigation/restoration (i.e. tamarisk removal) sites.
6. Mitigation planning or site restoration monitoring and reporting begins

3.3.6 Identification of Staging Yards

Staging yards are large, empty pieces of land that SDG&E use to house construction equipment and material when they are carrying out reconductoring or pole replacement works. This kind of work can happen anywhere along the line but ideally the poles must be within a 2-mile drivable distance from the staging yard. The staging yard should also be flat with no more than 5% slope, paved or bare ground and be at least 2 acres in size.

Currently, staging yards are identified as part of a pole to pole inspection. As already discussed, manual inspections are time consuming, resource heavy and have associated safety concerns. Environmental Services would like to explore how the vendor system can automatically identify potential staging yards according to the criteria outlined above. If there was a way to interface with land owner information this would produce huge efficiency benefits. The land owner could be approached by Land Services on identification of a potential staging yard to request permission and begin contractual procedures.

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and potential staging yards are identified
3. List of potential staging yards is created
4. Staging yard land owner is contacted to request permission to assess
5. Personnel are sent directly to potential staging yard to conduct environmental assessment
6. If suitable, land owner is contacted to request permission to set up staging yard
7. Contract between SDG&E and land owner is signed
8. Environmental Release is issued
9. Staging yard construction begins

3.3.7 Comparison of Pre- and Post-Construction Work Areas

The Environmental Post Construction team is responsible for the restoration of sensitive vegetation communities affected by construction activities once construction activities on a given project are completed. Vegetation within construction work areas are assessed prior to the initiation of construction activities and provide the basis for the required condition of the site at the completion of habitat restoration activities. The vegetation assessment consists of determining total native and non-native cover as well as identification of all plant species within the construction work area. Final success within the habitat restoration area is based on a percentage of the preconstruction native and non-native cover.

Using advanced data analytics, Environmental Services would like the vendor system to:

- Identify the vegetation types in the pre-construction and surrounding areas
- Calculate the percent cover of native and non-native species in the pre-construction and surrounding areas
- Identify the vegetation types in the post-construction and surrounding areas

- Calculate the percent cover of native and non-native species in the post-construction and surrounding areas
- Generate a pre- and post-construction comparison report

If successful, this could allow the Environmental Services team to compare vegetation types and native species before and after construction, and quickly and easily determine whether the preservation and restoration process was successful for that particular project. This kind of data is crucial for post-implementation reviews and lessons learned.

Again, concerns were raised regarding the practically of doing this and whether current technology has the capability to identify all species. Theoretically, you could fly a drone over the area at high resolution and identify some species, but plant identification requires microscopic inspection of flower parts and other anatomical features that can only be done by hand. Environmental Services also deal with multiple strata of vegetation which means this technology would need to record data through multiple layers of vegetation with significant detail to identify individual species and their total cover.

The overall flow of events for this potential use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and the following is established:
    a. Identification of vegetation type pre- vs post-construction
    b. Calculation of percent cover of native and non-native species pre- vs post-construction
3. Pre- and post-construction comparison report is automatically generated
4. Restoration and preservation success is determined
5. Data is used for post-implementation review and lessons learned

3.3.8 Pole Accessibility from Road

The current method of determining pole accessibility is by manually walking from pole to pole and taking hand written notes. On return to the office, these notes are transferred into electronic format and stored in the specific project drive. Table 2 is an example of the field notes that are taken when determining pole accessibility.

Location #	Environmental Field Comments
1	Existing road access to pole. On dirt pad.
2	No road access. Hike to top of ridge in Coastal Sage Scrub.
3	No road access. Suggest moving south towards dirt pad on bluff surrounded by Coastal Sage Scrub. May need to hike to install helo set.
4	Existing road access to pole. On dirt pad. In open grassy area. Surrounded by wetland in ravines below.
5	Existing road access to pole. On dirt pad. Existing erosion issues.
6	Existing road access to pole. On dirt pad. In open grassy area. Access via higher Orchard road to dirt two track. Avoid access coming from poles Z567890 and/or Z456789 since trucks would drive through a wetland. Frogs seen and heard in wetland.

Table 1: Example of Pole Accessibility Field Notes

The pole to pole field walks can encompass between 20 and 100 poles and take several days to complete. It would be very useful if the vendor system could use LiDAR and imagery data analysis to calculate the distance and elevation to the pole from the roadway. This would reduce the need for pole to pole walks and allow for better planning in terms of the duration of field visits, the equipment, vehicles and safety precautions required to access each pole. One idea for displaying the findings is to use digital terrain modelling to show the distance, profile and grade from the roadway to the pole. Figure 4, taken from Google Earth, gives an idea of how the findings could be presented in the vendor system.

Figure 4: Option for Displaying Pole Accessibility Information

The findings from this analysis will inform Environmental Services of the distance and elevation of a pole from a roadway. This information will assist in the planning of job walks and constructability to access a pole; access may require construction of a new road, foot travel or overland travel and act as a screening tool to determine which poles are of interest to SMEs and require further inspection, making the overall process more effective and efficient.

The overall flow of events for this use case includes the following steps:

1. Collected data set is subject to advanced analytics
2. Results are analyzed, and the following is established:
    a. Distance from roadway to pole
    b. Elevation from roadway to pole
3. Findings inform planning of pole to pole inspection walk
4. Personnel are sent directly to areas of interest to conduct field assessment
5. SME recommendations are provided to project manager/engineer

3.3.9 Capture of Pole Accessibility Field Notes

As mentioned above, the current method of capturing pole accessibility notes is through means of a physical pole to pole inspection and taking handwritten notes and photographs. These notes are then typed up when the employee returns to the office.

Environmental Services would like to explore the idea of using a mobile tool, such as a tablet or other smart device to capture field notes and photographs while in the field. The mobile tool must be intuitive and easy to use and have the capability to automatically upload the field notes into the vendor system in real-time. Additionally, if the mobile tool had the capability to allow dictation using voice recognition software, statistics show that productivity may be increased by up to three times in comparison to typing. All collected data must be time and date stamped and the tool must be GPS enabled to provide geolocational information about where the data was collected. In addition, it is essential the mobile tool has an offline capability that allows data collection when there is no internet connection. Collected data must automatically sync with the vendor system when the connection is resumed.

Introducing a mobile tool for in field data collection will realize the following benefits:

- On the whole, users are familiar with using mobile devices so there will not be a heavy training burden
- Duplication of effort is reduced since the staff member will no longer have to type up their notes on return to the office
- Data can be uploaded into the vendor system in real-time resulting in near instantaneous transmission and decreasing idle times for staff waiting for the information
- Reducing idle times increases productivity in other areas and results in cost and resource savings
- Less time, effort and money are spent transporting personnel to and from the office to conduct inspections and write up notes
- Loss of information and data transcription errors are reduced; mobile platforms allow forms to be completed in the field and uploaded immediately
- Dropdown lists and other constrained values can be incorporated into the mobile tool to ensure consistent data collection

The overall flow of events for this use case includes the following steps:

1. Personnel are sent directly to areas of interest to conduct inspection walk
2. Field notes and photographs are collected using a mobile device
3. Data is saved and uploaded directly into vendor system
4. Data is made available to those who need it

Appendix F shows the future Environmental Services workflow and highlights the process improvements and efficiency savings (in green) that could be made through advanced data analytics.

4.0 Test Case Summary

After the potential use cases had been identified and documented, a decision was made by the EPIC Project Team, SDG&E stakeholders and vendors as to which test cases would be progressed considering the dataset provided and time and budget constraints of the project.

Once the team had determined which were possible, meetings took place between the vendors and stakeholder groups to achieve their buy in and listen to the vendor proposals. The stakeholder groups were satisfied with what the vendors proposed and gave them to go ahead to begin their platform design and development. The key purpose of this effort was to provide a pre-commercial demonstration of the vendor tools capability to assist stakeholders in the decision-making process of adopting a commercial tool in the future.

A 'test case' is a use case that was selected, by the EPIC Team and stakeholders, for progression and demonstration by the vendors. This section outlines which test cases were chosen for development and demonstration and gives an overview of the dataset that each vendor was supplied with by SDG&E for the purposes of the project.

Appendix G, the Vendor / Stakeholder Use Case Matrix, shows the use cases that were selected for progression and highlights the use cases that are common between the stakeholder groups.

4.1 Test Cases - Vendor A

The following test cases were selected for progression by the EPIC Project Team, SDG&E stakeholders and Vendor A. A full description of each can be found in Section 3.0, the Use Case Summary section.

4.1.1 Infrastructure

- Data Ingestion

4.1.2 Vegetation Management

- Identifying Changes in Pole Lean
- Maintenance Audit

4.1.3 Environmental

- Identification of Water Bodies
- Pole Accessibility from Road

4.2 Test Cases - Vendor B

The following test cases were selected for progression by the EPIC Project Team, SDG&E stakeholders and Vendor B. A full description of each can be found in Section 3.0, the Use Case Summary section.

4.2.1 Infrastructure

- Data Ingestion
- Data Storage
- Data Visualization
- Data Retention
- Data Removal

4.2.2 Vegetation Management

- Identifying Tree Growth Patterns

- Identifying Areas of Tree Health
- Identifying Changes in Pole Lean

4.2.3 Environmental

- Pole Accessibility from Road
- Capture of Pole Accessibility Field Notes

4.3 Baseline Data Set

The vendors were supplied with a baseline data set that included all the necessary files to demonstrate the selected test cases. A section of circuit was selected for the demonstration, made up of a 1.25-mile segment of SDG&E distribution circuit including 30 poles.

This segment was selected because the program had already collected data on this area during previous rounds of EPIC. Furthermore, the EPIC team was able to exploit LiDAR and imagery data had been collected as part of the FiRM Program back in September 2017 and more recently in early 2018.

The baseline data set included the following files:

- PLS-CADD models of design and as-built conditions, including Drawing Exchange Format (DXF) exports of the line and pole facilities, LiDAR cloud and stringing charts
- GIS electric distribution poles and vegetation data in database and shape file formats
- Log ASCII Standard (LAS) file of LiDAR point cloud collected in September 2017 and again in early 2018
- Documentation including SDG&E standards, pole identification lists, construction plans, Keyhole Markup language Zipped files (KMZs) and various reports
- RGB imagery collected during flight mission for PLS-CADD design
- Additional RGB imagery from other circuits for advanced data analytics totaling approximately 3000 photos
- High resolution oblique and nadir imagery collected in September 2017
- UAS close range oblique imagery and UAS pole-centric imagery for select poles

- Classified LAS file for entire test segment
- Environmental geodatabase, shapefiles and layers

5.0 Vendor Tool Demonstration System Design, Development and Setup

5.1 Vendor A – Vendor A Tool

5.1.1 Vendor A Tool System Summary

Utilities need to manage assets while simultaneously optimizing costs, improving safety, and ensuring reliability and customer satisfaction. With a large portion of budgets tied up in fixed costs, remote sensing applications are being looked to as a way to loosen the margin squeeze. Imagery from satellites, fixed-wing aircrafts, and UAS can provide a tremendous amount of data. But having data is not enough, the data needs to be transformed into information to answer specific questions and provide actionable intelligence.

Vendor A has developed a utility asset management platform called Vendor A Tool to help automate, scale, and optimize asset management operations to meet business challenges. Vendor A Tool can manage, process, and analyze geospatial imagery, apply deep learning, and deliver actionable intelligence. Figure 5 gives a pictorial view of the Vendor A Tool overall workflow.

Figure 5: Vendor A Tool Workflow Overview

5.1.2 Vendor A Tool Feature Summary

Manage Big Data

As utility companies capture and consume more remotely sensed data, establishing a centralized data management system is core to the foundation of their business. Users throughout the organization need quick access to the right data to make informed decisions.

Vendor A Tool fully utilizes Vendor A's core competency in processing, storing, discovery, and exploitation of geospatial data at scale and is able to ingest imagery, video, LiDAR and other forms of remotely sensed data to analyze utility transmission and distribution infrastructure. With Vendor A Tool, users in the field or in an operations/data center can quickly locate critical intelligence with advanced discovery and filtering capabilities so they can make informed decisions with a high degree of confidence.

Process and Analyze Data

Vendor A Tool is architected to deploy any number of analytics, including image classification, multi and hyperspectral analysis, and LiDAR feature extraction. These capabilities are brought together in Vendor A Tool in the form of utility-specific workflows, allowing a utility of any size to take advantage of all of the power of Vendor A's remote sensing analytics.

Deep Learning Technology

Vendor A Tool exploits advanced deep learning technology focused on extracting insights from remotely sensed data. Beyond standard libraries designed to detect common anomalies on transmission and distribution infrastructure, new classifiers can be developed with specific data collected by the utility and deployed within Vendor A Tool to provide tailored inspection analytics. These analytics can be automated to run on data ingest in real-time or used interactively by analysts to review and improve the deep learning models.

5.1.3 Platform Compatibility

Vendor A Tool has been tested using Windows 8.1 or higher. Supported browsers currently include:

- Chrome 67 or higher
- Firefox 60.0 or higher

The LiDAR Viewer requires a modern graphics card such as NVivida or AMD, which are manufactured from 2012 or later.

5.1.4 Deployment Options

Vendor A Tool can be implemented in a secure hosted environment or on premise, with deployment options dependent on preferred utility metrics such as circuit-miles covered, number of assets analyzed and imagery data size managed.

For on premise deployment, One Server class machine or EC2 instance with the following system requirements is recommended:

1 Server with GPU:

- 4 core 2.4 GHz Intel Xeon® CPUs
- 64 GB RAM
- NVidia GPU with 8GB or more of video memory

However, given the stage in early development, it is recommended SDG&E consider a cloud-based solution. This will provide the most flexibility and allow the system to scale up or down based on the amount of data collected, processed, and ingested. There are no known size limitations on file types at this time.

5.2 Vendor B – Vendor B Tool

5.2.1 Vendor B Tool System Summary

Vendor B's platform is called Vendor B Tool and it is used to provide solutions for both Transmission and Distribution utility networks. These solutions provide users with a view of the data that supports their day-to-day tasks and strategic objectives. Vendor B Tool has been designed to enable faster decision making by providing a central location to view critical asset and infrastructure details. Users can navigate the 'virtual grid', explore 3D models, perform virtual inspections, and initiate action.

Vendor B Tool delivers high-resolution imagery and LiDAR-derived business intelligence and data is immediately accessible and actionable for ongoing daily utility operations. Vendor B Tool is a secure, cloud-based, geospatial solution requiring minimal IT configuration and provides access to high-resolution ortho and oblique imagery, video of SDG&E assets and vegetation encroachment calculation and visualization. In addition to imagery, Vendor B Tool provides visualization for any feature-coded LiDAR data. Tools to virtually inspect assets using high definition imagery are supplied and this data is stored to create a digital library of the health of assets, which can be tracked over time.

The following points outline the key data hosting and visualization benefits supplied by Vendor B Tool:

- Secure, hosted web-delivery with ‘Google Earth’ like navigation
- High resolution orthophoto and oblique imagery
- Ability to ingest data from various sources
- 3-D classified and colorized LiDAR fused with ortho imagery
- Raster and vector data such as centerlines, canopy segments, and right-of-way boundaries

5.2.2 Vendor B Tool Interface Overview

This section describes the basic functionality of the Vendor B Tool interface and the overall look and feel of the platform.

The Explorer tab, found on the ribbon shown in Figure 6, contains buttons that are most commonly used.

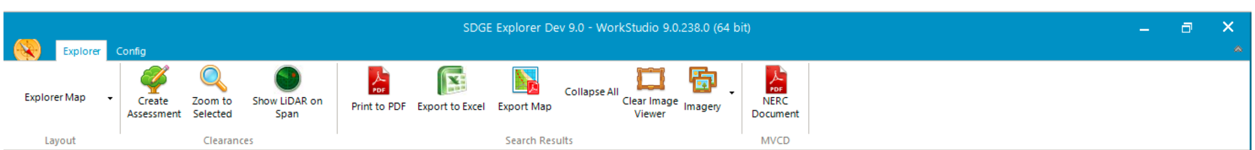


Figure 6: Vendor B Tool ‘Explorer’ Tab

A brief description of their functionality can be found below:

- **Layout** – changes layout view
- **Create Assesment** – creates a job in the client software
- **Zoom to Selected** – zooms to item selected on map
- **Show LiDAR on Span** – downloads LiDAR file for the span selected on the map
- **Print to PDF** – Prints selected items
- **Export to Excel** – export tabular data for items selected or queried

- **Clear Image Viewer** – clears out all images that have been added to the viewer
- **Imagery** – shows available imagery for selected items
- **NERC Document** – PDF of the North American Electric Reliability Corporation (NERC) standards for reference

The Config tab gives users options to change their layout preferences and download the LiDAR viewer, as shown in Figure 7:

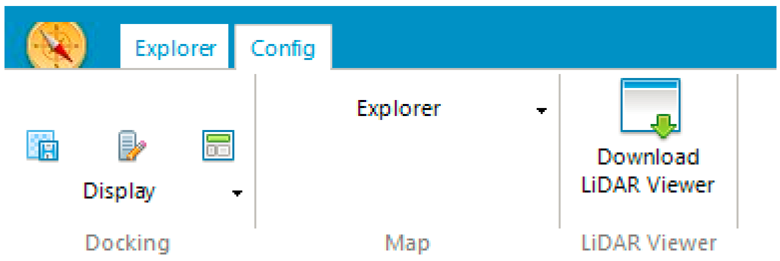


Figure 7: Vendor B Tool 'Config' Tab

The map controls are shown in Figure 8 with a brief explanation of their functionality.

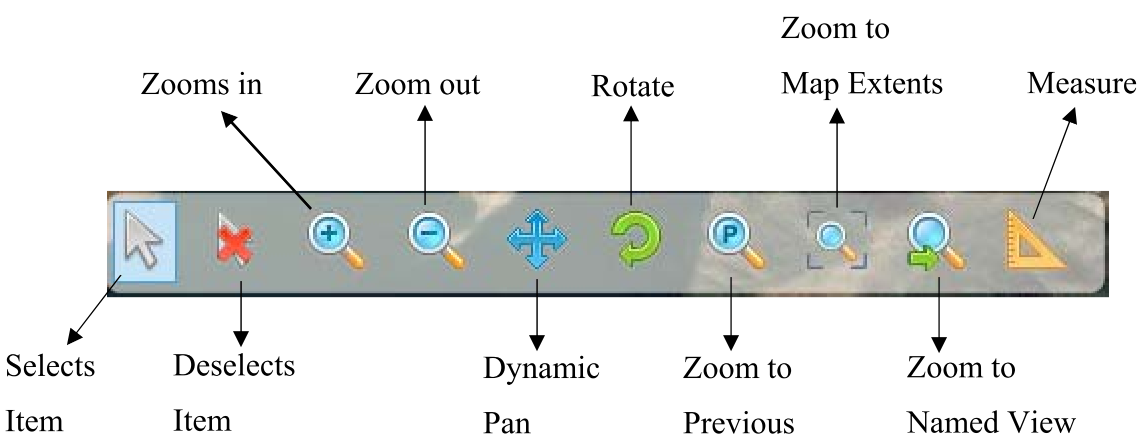


Figure 8: Vendor B Tool Map Controls

The sidebar, shown in Figure 9, shows the various map layer options that were ingested into the demo system. Note that; when the light bulb icon is yellow, the layer is switched on.
The blue light bulb means the layer will be active at a select map zoom.
When the blue light bulb is struck out with a red line, the layer is switched off.

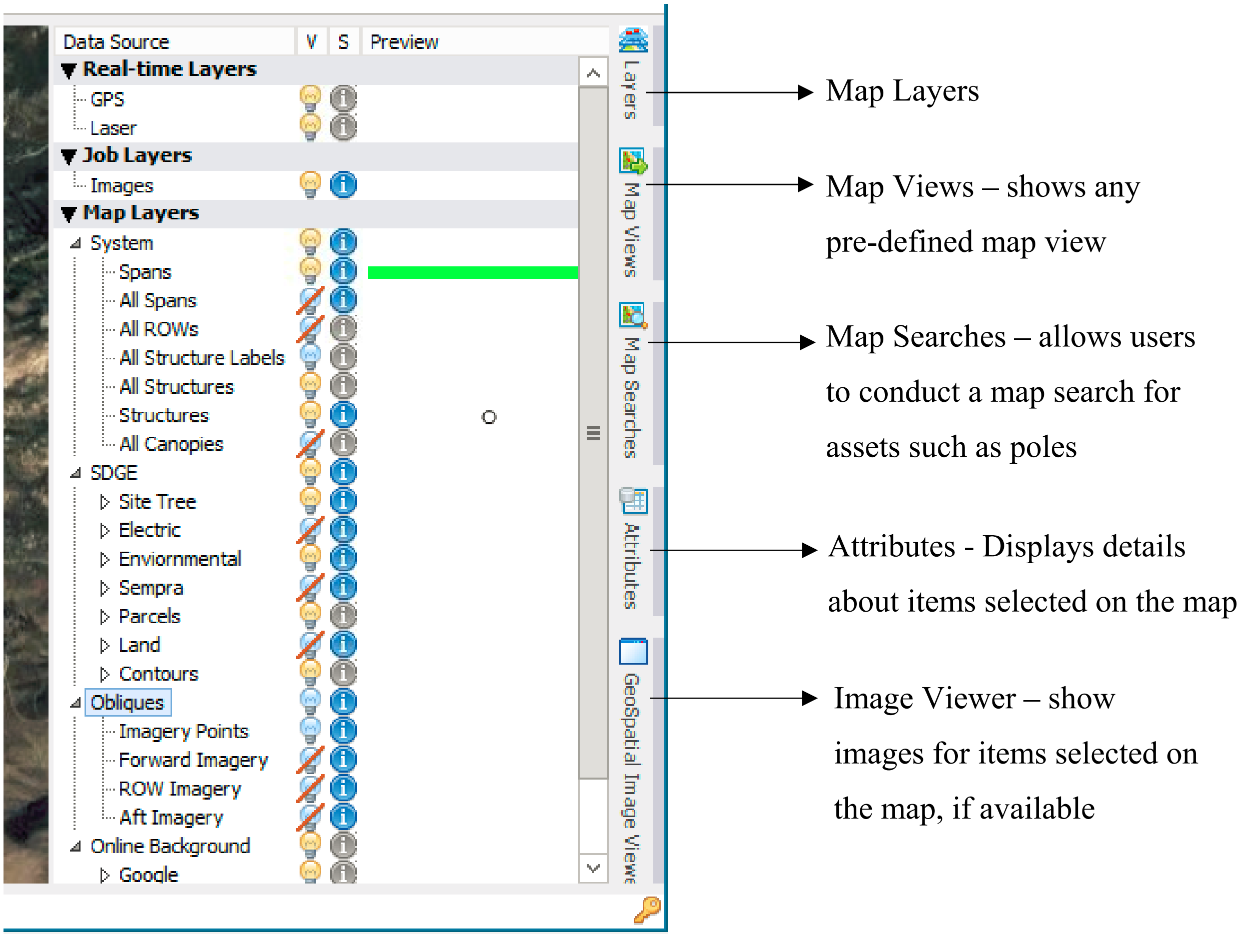


Figure 9: Vendor B Tool Map Layers Sidebar

Work searches are pre-configured queries against the Vendor B Tool database. A built-in tool, known as the Data Source Modeler, is used to join separate tables in the database together to get the results the user is looking for. Pole lean for example, the standard structure table is taken, which contains the name, location etc., and joined to the detailed table for structures where the pole lean information is located. The information is presented to the users and the degree of pole lean is established.

When fresh data comes in for ingestion, Vendor B has a data loading process that takes the data from the Production team and loads it into the database. If there are multiple surveys (i.e. different flights), the user can set the filter to only show the results for that survey.

Figure 10 shows how the work searches sidebar is configured to allow the user to search and filter against the data analytics results.

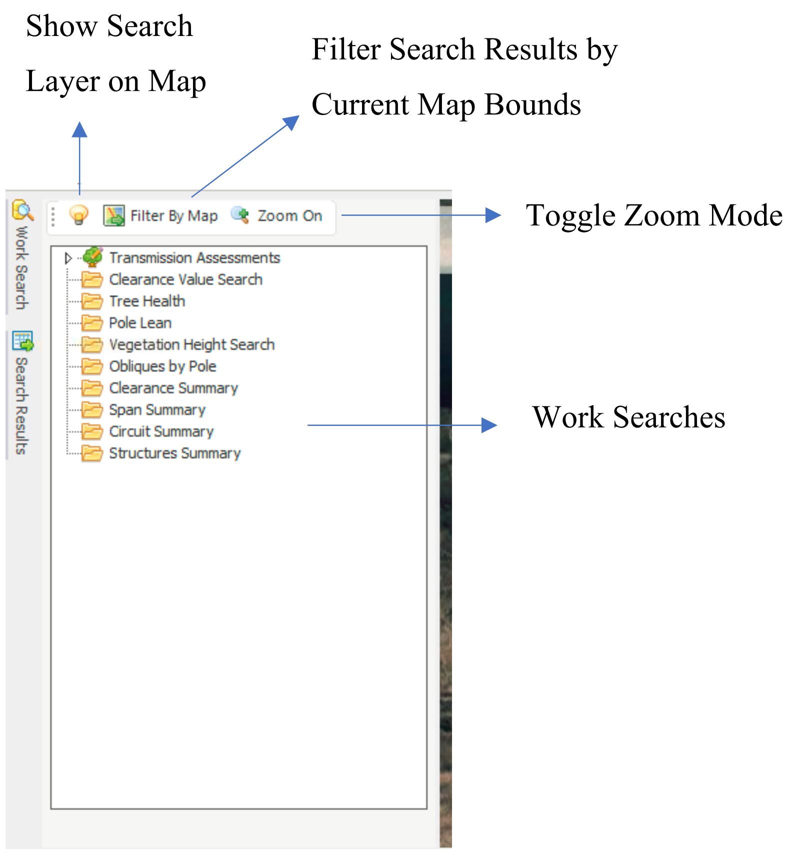


Figure 10: Vendor B Tool Work Searches Sidebar

5.2.3 Vendor B Tool System Requirements

Table 2 below highlights key system requirements. Each requirement is either already included as part of base functionality or is planned to be added in future iterations. Requirements that have been designated ‘customer enhancement’ require full development and build out on a per customer basis and will vary dependent on needs.

System Requirement	**Base Functionality**	**Planned Functionality**	**Customer Enhancement**
Data Storage Type: Digital pictures (varying resolution)	X		

System Requirement	Base Functionality	Planned Functionality	Customer Enhancement
Data Storage Type: Video (varying resolution)		X	
Data Storage Type: Infrared images	X		
Data Storage Type: LIDAR data	X		
Data Storage Type: Partial discharge		X	
Data Storage Type: Audio			X
Data Storage Type: Temperature	X		
Data Storage Type: Magnetic			X
Data Storage Type: Humidity	X		
Data Consumption: UAS	X		
Data Consumption: ROV	X		
Data Consumption: Cellular/smart phone	X		
Data Consumption: Internet/Cloud	X		
Data Consumption: Other			
Data Correlation/Association and Search	X		
Data Display/Map Interface	X		
Image Cropping		X	
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset based on the pictures/video	X		
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset base on the infrared data	X		

System Requirement	Base Functionality	Planned Functionality	Customer Enhancement
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset based on the Lidar data	X		
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset based on the partial discharge data			X
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset based on the audio data			X
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset based on the temperature data			X
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset based on the magnetic data			X
Analytics Capabilities: Ability to recognize and detect physical change in the characteristics of the asset based on the humidity data			X
Analytics Capabilities: Ability to recognize and detect any other physical change in the characteristics of any other data			X

System Requirement	Base Functionality	Planned Functionality	Customer Enhancement
Analytics Capabilities: Library of existing electric utility assets you have already trained	X		
Analytics Capabilities: Ability to trigger events, via integration or otherwise based on detected change	X		

Table 2: Vendor B Tool System Requirements

5.2.4 Vendor B Tool System Architecture

5.2.4.1 Hardware

Application Server. The application server is a physical box that the WorkStudio Server and Vendor B Tool application is installed on.

Database Server. The database can reside on the same physical box as the application server or it can be held on a separate physical box.

Storage Platform. The storage platform set up can vary depending on the amount of data that will be stored. In some cases, an object storage server may be required in addition to store video, imagery, LiDAR data, magnetic information, thermo imagery and audio.

5.2.4.2 Software

5.2.4.2.1 Operating System

The Operating System specification is outlined in Table 3:

	Work Studio Server	Work Studio Client	Work Studio Client	Work Studio InfoCenter
Device	Server (virtual or physical)	Tablet PC	Desktop PC	Server (virtual or physical)
CPU	Intel® Xeon®	Intel® i3/i5/i7®	Intel® i3/i5/i7®	Intel® Xeon®
Processor Speed	2 GHz or higher	2 GHz or higher	2 GHz or higher	2 GHz or higher
Minimum Memory	8 GB	4 GB	4 GB	4 GB
Free HDD Space	200 GB	80 GB	80 GB	80 GB
Operating System	Microsoft® Windows® - Server 2008 R2 - Server 2012	Microsoft® - Windows® 7 - Windows® 8 - Windows® 10	Microsoft® - Windows® 7 - Windows® 8 - Windows® 10	Microsoft® Windows® - Server 2008 R2 - Server 2012
Network	1,000 MB/sec	100 MB/sec WLAN	100 MB/sec	1,000 MB/sec
Suggested Hardware Options		GPS Camera 4G/LTE AirCard		
Other Software	SQL 2012/ 2012R2/2014/2016 Oracle database 11g/12c Oracle Client	Firefox IE8 or higher Chrome		SAP Crystal Reports Microsoft® IIS 7.5+ .NET 4.0 Oracle Client

Table 3: Vendor B Tool Operating System Specification

5.2.4.2.2 Communications

Vendor B uses a proprietary binary TCP/IP format known as Data Objects to communicate between the client application and the server application. The payload is encrypted via SSL using standard TLS based encryption.

5.2.4.2.3 Integration Protocols and Data Formats

Regarding integrations, Vendor B have a JSON API that can be utilized via http. They also have an internal binary proprietary TCP/IP API that has a .NET toolkit developed to interact with. Vendor B have a tool built into our product known as the DSM (Data Source Modeler) which is used to extract and transform data into a view that can be presented to the end user.

5.2.4.2.4 Availability and Reliability

Vendor B's secure Data Center is operational 24x7x365. Vendor B hosts many utility systems and ensures this data is reliable and accessible at all times. Customers covered under an annual maintenance agreement also have access to the Vendor B Support center, which is open Monday through Friday 7am – 6pm Central Time.

5.2.4.2.5 Performance

Database. Depending on the data that is housed in the database, the database can range from a few kilobytes in size up to 100 GB.

Performance. Can vary based on what action is currently being taken. Most operations will take less than a second to respond. The usual benchmark that is followed by Vendor B is that a user should never have to wait more than 5 seconds for an operation to take place.

Concurrency. Vendor B has carried out testing with up to 100 concurrent users within the system. It can vary greatly as to what kind of concurrency would be expected for most actions.

5.2.4.2.6 Security

Vendor B adheres to the NIST 800-53 Standard for Storage & Handling of Information and Data. This standard exceeds the requirements of NERC CIP. Vendor B also provides a written Information Security Plan based on client requirements and industry best practices.

6.0 Vendor Test System Demonstration Approach, Results and Recommendations

6.1 Vendor A Test Case Results

6.1.1 Infrastructure

As part of the Infrastructure test case, Vendor A demonstrated how the Vendor A Tool could ingest various data types, which are outlined below:

- **File Formats**
  - JPEG
  - LAS/LAZ
  - Vector/shape files
- **Deep Learning** - while these are the formats required for the Vendor A Tool deep learning engine, almost any data type can be converted to one of the supported deep learning formats before processing occurs.
  - TIFF
  - JPEG
  - ENVI
  - LAS/LAZ
- **Vegetation Encroachment**
  - LAS
  - PLS-CADD exported DXF files

6.1.1.1 Data Ingestion – Uploading and Ingesting Pole Data

6.1.1.1.1 Approach

As part of the baseline dataset, SDG&E provided an as-built pole list which provided the exact locations of the poles contained in the circuit, as well as their ID, location, and elevation. The Vendor A Team created a CSV file for demonstration purposes to be used as the vessel for ingestion.

In addition to pole information, two items were added to the CSV file: the map coordinate system (EPSG) and a "Pole Must be Brushed" column. The EPSG value is required to determine the exact map coordinates based on the X, Y, and Z values. The "Pole Must Be Brushed" column contains a zero or one, depending on whether the pole is expected to be brushed. The EPSG Geodetic Parameter Dataset is a collection of definitions of coordinate reference systems and coordinate transformations which may be global, regional, national or local in application.[6] Table 4 shows an example CSV file containing the aforementioned pole data:

Type	**Structure No.**	**Station (ft)**	**X Easting (ft)**	**Y Northing (ft)**	**Centerline Z Elevation (ft)**	**TIN Z Elevation (ft)**	**Ahead Span (ft)**	**Line Angle (deg)**	**Pole Must be Brushed**
ESPG	2230								
Pole	P370070	647.106	6365541	1907218	1105.83	1105.83	172.42	6.1283	0
Pole	P139204	819.526	6365616	1907373	1108.30	1108.30	62.886	5.1828	0

Table 4: Pole Data CSV Example

Once the CSV file was created, the pole data was successfully ingested into the Vendor A Tool. The following analytics were automatically performed when the pole information was uploaded:

- Determination of the pole accessibility from the closest road
- Identification of the proximity of water to a pole
- The database is updated and an association between images and poles is created
- The database is updated and an association between LiDAR data and poles is created

6.1.1.2 Data Ingestion – Uploading and Ingesting LiDAR Data

6.1.1.2.1 Approach

LiDAR data can be uploaded to the system as LAS or LAZ files. If the file header contains an EPSG map coordinate code, the upload process automatically detects the coordinate system. If the file header does not contain the EPSG code, users must specify the EPSG coordinate system

[6] International Association of Oil and Gas Producers. About the EPSG Dataset. Retrieved from: http://www.epsg.org/

during the upload process. As with any map-based system, if no code or the wrong EPSG code is provided, the data and results will not use the correct coordinate system.

When a LiDAR dataset contains multiple tiles (LAS/LAZ files) all the LAS/LAZ files should be uploaded in one step.

If multiple LiDAR collects exist for a specific area; for example, the same area collected months apart, the datasets must be uploaded in two different steps.

The following actions were automatically performed once the LiDAR dataset is uploaded:

- Metadata is extracted, including collection date and EPSG code (if available)
- The database is updated and an association to poles that fall within the extents of the LiDAR dataset is created
- The pole lean is computed and a calculation of the change in lean is made if previous measurements are available
- Poles requiring a firebreak maintenance audit are identified and vegetation encroachments within the 10-foot protected area around each pole are detected

6.1.1.3 Data Ingestion – Upload and Ingest UAV Images

6.1.1.3.1 Approach

UAV JPEG images were uploaded to the system along with the pole data, either as one step or separately. One or more JPEG files could be uploaded at a time.

The following actions are automatically performed once the pole information was uploaded:

- exif metadata is extracted, including the GPS location and date of collection
- The database is updated, and an association is created between images and poles. When users click on a pole, the map view for the primary (closest) image is displayed

6.1.1.4 Data Ingestion – Optional Upload Settings

6.1.1.4.1 Approach

During the upload process, the collection date is determined by the exif metadata tag for imagery and the LAS header for LiDAR data. If the exif or header details are not available, the collection date defaults to the date of the upload. Users can override this value by specifying a collection date.

During the upload process, users can specify a retention period that dictates when the system automatically purges the data from the system. If no value is provided, the image will be retained indefinitely.

6.1.1.5 Data Ingestion – Add /Edit /Remove Attachments to or from a Pole

6.1.1.5.1 Approach

In addition to associating imagery and LiDAR data with poles, users could attach other file types to assets within the Vendor A Tool. To attach a file to a specific pole, the user should click on a pin in the map, or select an image from the catalog view, to access the Image Viewer. Within the Asset Details section, a document could be attached by clicking the upload icon. A file browser window appeared which was used to navigate to the desired file.

Once a document had been associated with the pole, the attachment could be accessed by clicking on the filename and downloading the file to a local desktop. Users are able to make edits on their local system and reattach the updated document to the system by clicking the upload icon next to the filename. Multiple files could be associated to an individual pole. Attachments could also be removed by clicking the remove button. Figure 11 shows the attachments menu.

Figure 11: Attachments

6.1.1.6 Data Ingestion - Use Batch Processing to Add Reports to Specific Georeferenced Locations

6.1.1.6.1 Approach

SDG&E stakeholders, particularly the Infrastructure group, require the ability to create a batch process to upload Seismic Refraction Surveys and Exploratory Boring reports to an area, to share across the organization. Since each report contains a different format and metadata, Vendor A defined a CSV format for each report type according to the format specified in the sample report as shown in Table 5 below:

Exploratory Boring Locations

Type	**ID**	**Lat**	**Lon**	**Ground Elevation**	**Exploration Date**	**Depth**	**Units**
Boring	B-1	33.29963	-116.943	1529	3/7/2018	19.5	Qc
Boring	B-2	33.316	-116.939	2321	3/7/2018	19.5	RS/grwx

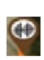
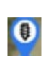
Seismic Refraction Surveys

Type	**ID**	**Lat1**	**Lon1**	**Lat2**	**Lon2**
seismicrefractionsurvey	SL-1	33.3195	-116.937	33.31979	-116.936
seismicrefractionsurvey	SL-2	33.3157	-116.939	33.31603	-116.939

Table 5: Boring and Seismic CSV Format Examples

During the upload process, users can choose settings such as the collection date, owner, and retention policy. The collection date will default to the date on the file; however, users can specify a collection date. If a retention policy is not specified, the file will remain in the system indefinitely.

Once the data was uploaded, the documents appeared as small markers in the map view:

- Seismic Survey: 
- Exploratory Boring Report: 

If the attachment is in a format that the browser can display, for example a PDF, users are able to click on the marker and view the file within the Vendor A Tool. If the web browser does not support the file format of the attachment, users were prompted to download the file. Once downloaded, the required software application could be launched to view the data.

6.1.1.7 Data Ingestion – Overall Results

The Vendor A Tool successfully demonstrated the ability to create a central repository for imagery, LiDAR, and georeferenced files. This coupled with on-ingest analytics provided all users with a single source of the most current data and actionable insights to make informed and timely decisions.

Furthermore, the system demonstrated the ability to use vector shapefiles and public domain digital elevation models (DEM) to generate actionable results.

Users of the system can quickly locate details about the overall health of assets or filter results and conditions based on specific needs such as vegetation, environment, or inspections.

Analytic results can be exported to a CSV file and used to update existing GIS asset information such as vegetation encroachment, missing avian covers and other analytic conditions.

6.1.1.8 Vendor A Recommendations

The following functional recommendations should be considered to maximize results in an operational environment:

- Formalize user and group requirements for access roles, security protocols, and common data retention policies among stakeholders.
- Create pre-built workflows to provide targeted results based on user-defined roles. For example, determine asset health according to a specific functional group's needs such as groups and organizational functions leaning poles, vegetation encroachment, etc.

- Develop dashboards to easily diagnose analytics results and filter relevant data by functional group. With increased data volume and archived information, it will be critical to provide streamlined access to insights generated by the system.

6.1.1.9 Conclusions

The Vendor A Tool is a viable and robust solution for the transmission and distribution asset management workflow. The underlying technology is designed to scale up and outward, which will allow the system to grow to meet storage and processing needs as usage expands.

Using data provided, the imagery and results of the analytics developed as a part of the proof of concept were successfully ingested and catalogued into Vendor A's data management system using an automated process. Results were automatically categorized, and visual indicators were provided to alert users to specific areas of concern. This test case successfully demonstrated that users across the organization can quickly and easily access data to make informed decisions regarding the state of the infrastructure, how to mitigate vegetation risks, or when to respond to environmental issues. Several implementation recommendations were provided to anticipate the use of the system in an operational environment.

While this test case demonstrated a lightweight client for viewing imagery, layers, and results, the scope did not target system integration. As next steps are explored for operationalizing the system, the Vendor A Tool has been architected so that it can be integrated solely as a backend solution.

6.1.1.10 Export Results for Downstream System Integration with GIS

Although not one of the official documented use cases, information technology (IT) stakeholders expressed interest in having access to the Vendor A Tool analytic results to include in their GIS system of record. The desired outcome was to link the two systems using Open Geospatial Consortium (OGC) data access standards. However, in the short term, the team requested the ability to export the results to a CSV file that can be easily scripted to update their GIS system. Additional stakeholder groups expressed an interest in using the results for planning purposes.

6.1.1.10.1 Approach

Working with stakeholders, conditions such as leaning poles and severity were defined, as outlined in the test cases above. Users could filter by specific conditions and any combination of severities, such as the severity (angle) of pole lean. The CSV format delivered as a part of the export was tailored according to each condition, for example:

- **All**: All details for each condition
- **Pole Lean** contains: Pole ID, Date, Pole Longitude, Pole Latitude, Pole Elevation, Severity, Information, Lean Change, Pole Angle Degrees 1, Measurement Date -1, Pole Angle Degrees 2, and Measurement Date 2
- **Pole Access** details: Pole ID, Date, Pole Longitude, Pole Latitude, Pole Elevation, Access Severity, Information, Nearest Road Point Longitude, Nearest Road Point Latitude, Elevation gain (m), Distance to Road (m), Terrain Max Slope (rise/run), Terrain Min Slope (rise/run), Elevation Climb (m), and Elevation Difference (m)
- **Avian Covers** details: Pole ID, Date, Pole Longitude, Pole Latitude, Pole Elevation, Avian Cover Severity, and Information
- **Encroachment** details: Date, Encroachment Severity, Information Encroachment Distance, Encroachment Longitude, and Encroachment Latitude
- **Water Proximity** details: Pole ID, Date, Pole Longitude, Pole Latitude, Pole Elevation, Water Proximity Severity, Information, Distance to Water (m), Nearest Water Point Longitude, and Nearest Water Point Latitude
- **Brushings** details: Pole ID, Date, Pole Longitude, Pole Latitude, Pole Elevation, Information, Brushing Severity, Brushing Date, Brushing Center Longitude, Brushing Center Latitude, Brushing Min Height (m), Brushing Max Height (m), Brushing Points 10 feet, Brushing Points 20 feet, Brushing Date 2, Brushing Center Longitude 2, Brushing Center Latitude 2, Brushing Min Height (m) 2, Brushing Max Height (m) 2, Brushing Points 10 feet 2, and Brushing Points 20 feet 2

The GIS team indicated that their short-term solution is to create script files to consume various portions of these outputs and to update their GIS records via a batch process. The output formats were created to provide stakeholder information derived from the analytics (such as terrain information) to aid in planning. Vendor A stated they can easily adjust the CSV output formats to meet stakeholder needs.

6.1.1.10.2 Results

Vendor A successfully proved a simple form of integration could be done from the Vendor A Tool. Further studies are recommended to understand operational requirements and expand output results to include bounding boxes boundaries, polyline coordinates, and volume metrics.

6.1.1.10.3 Vendor A Recommendations

The CSV outputs in this test case were simple examples to show the concept of moving data through the system. Recommendations include:

- Conduct study to understand operational requirements for downstream systems; e.g., GIS.
- Develop APIs to share asset records on demand or as scheduled processes.
- Integrate Map layers to share spatial information.

6.1.1.10.4 Conclusions

While a lightweight integration methodology was demonstrated, one or more common OGC data access standards, including Web Map Services (WMS) and Web Feature Services (WFS) can be used to share information between systems. Moreover, APIs must be created to populate and maintain links between the GIS records and the Vendor A Tool.

In the past, the Vendor A have demonstrated a simple case of using OGC layers to connect to ArcGIS which should be expanded to include sharing asset records and additional map layers. The Vendor A Tool and on-ingest analytics can be used in its current form or it could be deployed as a backend data store with the analytics exposed through the ArcGIS toolkit.

6.1.2 Vegetation Management

6.1.2.1 Identifying Changes in Pole Lean

6.1.2.1.1 Approach

The pole location was provided as part of the as-built pole information and when the LiDAR classified point cloud data was uploaded to the Vendor A Tool, the on-ingest analytics calculated the pole angle through a series of steps. To calculate the pole lean, all points associated with the pole were extracted, while other points were removed.

The height of the pole was identified by subtracting the vertical position of the top-most point from the bottom-most point. Once the height was calculated, points that lie between 1 meter from the bottom and 2 meters from the top were removed. This left only the middle segment of the pole which is a more reflective sampling of the pole angle. A Random Sample Consensus (RANSAC) algorithm was used to calculate the best fit line, which reflects the pole angle. The angle of the pole defines the severity and is outlined in Table 6:

Indicator	Condition	Tilt / Lean
Green	Normal	< 7 degrees
Yellow	Warning	7 – 9.9 degrees
Red	Alert	>= 10 degrees

Table 6: Pole Lean Conditions

If multiple point cloud datasets existed for a particular pole, the pole angle difference was calculated between the current dataset and the closest previous dataset in time. To account for normal variations between collections, the pole angle difference was highlighted in red when the change was greater than 2 degrees. If the difference was equal to or less than 2 degrees, the value was highlighted in green. In situations where the pole lean had been remedied, the pole angle difference reflected a negative value and is highlighted in green. Figure 12 shows a sample of the leaning pole details.

Asset Details	
Type	pole
ID	P370077
Filename	ops_lidar_coded_color_fixedz
Collection Date	2017-10-28
Owner	Joe Smith
Location	32.905737N 116.884595W
Pole Angle	1° (0° change)

Figure 12: Leaning Pole Details

6.1.2.1.2 Results

Vendor A found that the sample dataset used for this demonstration did not contain any poles meeting the criteria for warnings or alerts. To verify analytic results, a pole was created by duplicating an existing pole, placing it in a new location, and rotating the points to create a significant lean extending over two collection timelines.

The pole accessibility results were quickly located by conducting a search and filter query. Users can filter against the pole lean proximity condition and the desired severity. The pin colors in the map indicated the severity of the pole lean. Green specified that the angle is normal, yellow indicated warnings, and red alerted the user to when a pole is leaning more than 10 degrees. Figure 13 shows the search and filter functionality when considering pole lean.

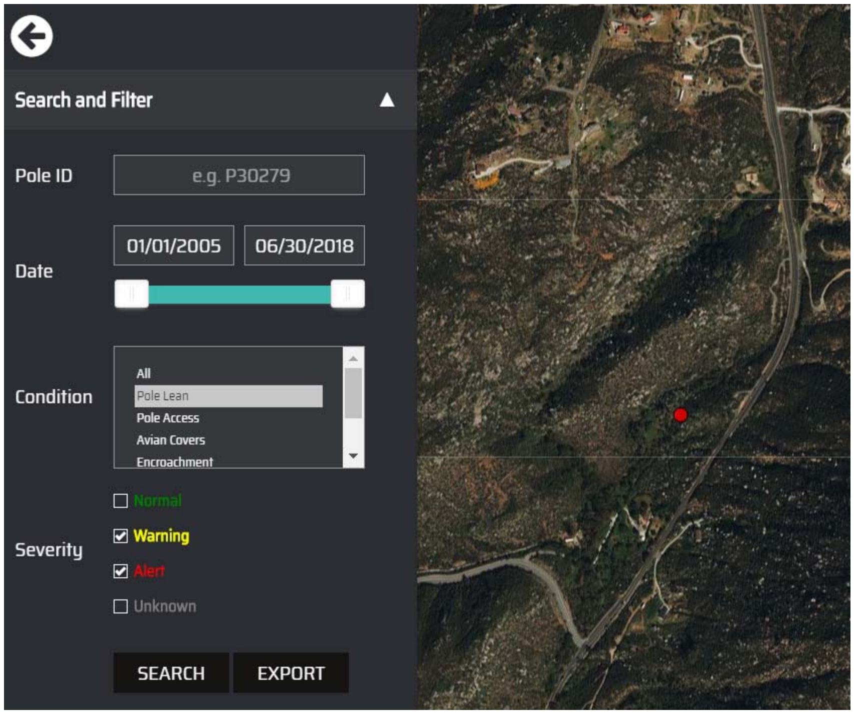


Figure 13: Search and Filter by Pole Lean

When point cloud results were viewed, the camera is pointed toward the selected pole. A grey vertical axis was displayed to help visualize the pole's current angle, as show in Figure 14.

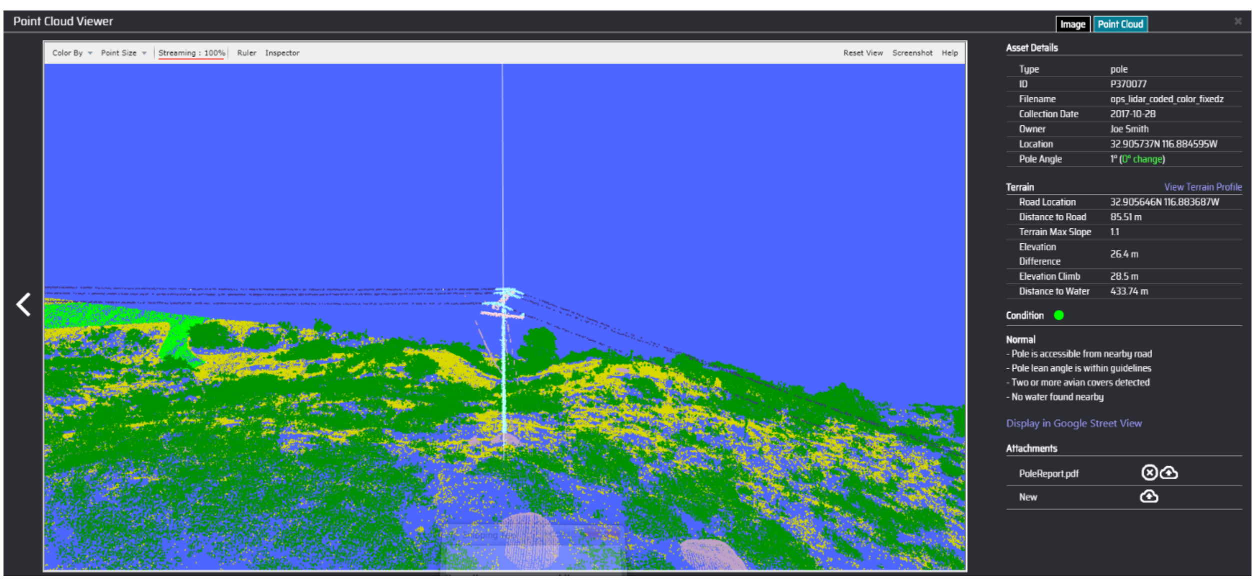


Figure 14: Point Cloud Viewer

Using the Point Cloud Viewer application, users were able take a simulated orbital flight around the pole. In addition, the results could be manually viewed using a mouse to navigate through the point cloud. Users could also choose to view the pole angle from the road by clicking the Display in Google Street View link.

Using as-built pole information and LiDAR point cloud data, algorithms were successfully developed by Vendor A to calculate pole angles. Results were confirmed by viewing the calculated RANSAC best fit values for each of the 37 poles included in the demonstration. Figure 15 illustrates two examples.

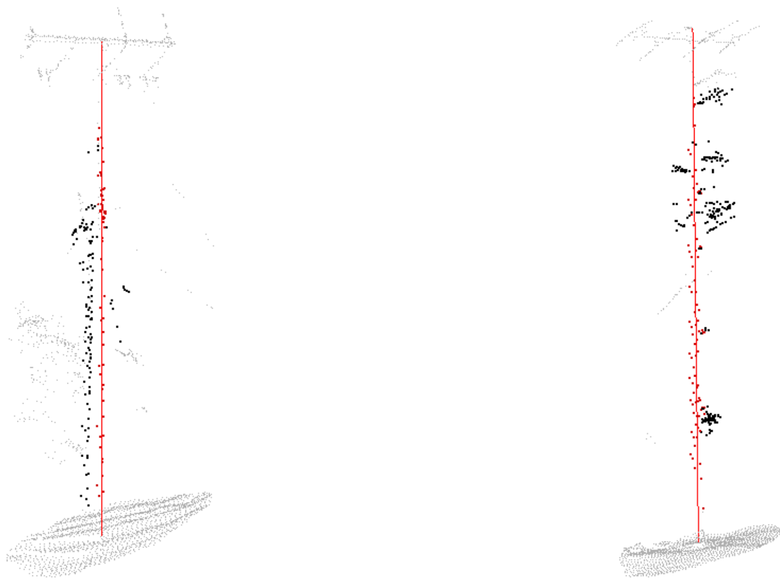


Figure 15: Calculated Best Fit Line

Grey dots represent the points excluded from the calculation. Red and black dots represent the points used by the algorithm to calculate the best fit. The red line represents the calculated best fit line. In both cases, Vendor A stated that the algorithm performed as expected.

While most results were successful, there were four cases where the calculated best fit line used the outside radius points on opposite sides of the pole instead of the center points. In the most extreme case, the pole lean was calculated at a higher value of 7.3 degrees versus the correct value of 3.1 degrees, as shown in Figure 16. Vendor A confirmed that this rare case could be addressed by applying additional filtration methods and by improving the best fit scoring mechanisms used by the algorithm.

Figure 16: Outside Radius Points Used to Calculate Best Fit

To evaluate the algorithm's accuracy, the calculated best fit line for each pole was visually compared to the expected center line. Vendor A found the algorithm demonstrated 93% of the poles were measured accurately. The accuracy results are displayed in Table 7:

	LiDAR Dataset 1 (34 poles)	**LiDAR Dataset 2 (38 poles)**
Best fit line correctly identified	31	36
Best fit line slightly misaligned	2	2
Best fit line outside of pole	1	0
Accuracy	91.2%	94.7%

Table 7: Accuracy Results

6.1.2.1.3 Vendor A Recommendations

Recommendations for further development concerning the pole lean test case include:

- Use deep learning to identify pole locations in an unclassified LiDAR dataset. While SDG&E provided a classified point cloud and subsequent as-built location details, removing the need to classify point clouds could reduce costs and improve turnaround times.
- Apply additional filtering options to calculate best fit and refine best fit scoring options in pole lean algorithms, which will improve results.
- Expand the difference calculation by comparing the latest angle to the previous one to calculate the rate of change for the pole over time.
- Add a visual indicator to reflect where 90° is expected, relative to the calculated pole angle.
- Integrate the Vendor A Tool with existing work order systems, to verify work has been performed to remediate a leaning pole and to identify poles to include in a maintenance audit.
- Explore with stakeholders if the pole lean algorithm should be modified from reporting degrees of lean to percent change relative to the pole's height.
- Use an RGB per-point LAS file to help users and provide more meaningful visualization to users.
- Integrate the pole lean results. An RGB LAS file can be generated by collecting LiDAR and imagery simultaneously with the organization's work management systems to verify work has been performed to remediate a leaning pole. An RGB LAS file can be generated by collecting LiDAR and imagery simultaneously.

6.1.2.1.4 Conclusions

This test case proved that the pole angle can be automatically calculated using LiDAR data and the pole location. The overall accuracy indicates the analytics can provide actionable insights for poles at risk. In addition to calculating the current pole angle, the test case was expanded to show the difference from one collect to the next. As this workflow is operationalized, the analytics should be extended to incorporate all available time series values to create a predictive rate of change.

6.1.2.2 Maintenance Audit

6.1.2.2.1 Approach

To determine if firebreak maintenance is required, pole locations and brush status were provided to Vendor A in the as-built pole information. When the LiDAR classified point clouds were uploaded to the Vendor A Tool, the on-ingest analytics evaluated if a firebreak existed on the required poles.

Using the classified point cloud, the algorithm defined a 10-foot cylinder around the base of the pole. Using standard American Society for Photogrammetry and Remote Sensing (ASPRS) feature codes for high, medium, and low vegetation, the algorithm queried the LiDAR holdings for points in that area that were feature-coded as vegetation. Vegetation points found within the cylinder were colored red to indicate encroachment as shown in Figure 17.

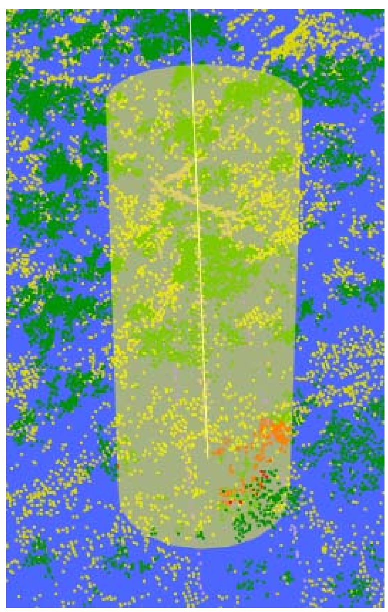


Figure 17: Vegetation Points Detected within a Firebreak

If vegetation is found within the defined firebreak, the severity is set accordingly. Table 8 shows the severity conditions:

Indicator	Condition	Firebreak
Green	Normal	Required / No Vegetation Detected
Red	Alert	Required / Vegetation Detected

Table 8: Firebreak Severity Matrix

6.1.2.2.2 Results

The pole brushing results were quickly located by conducting a search and filter query. Users can filter against the pole brushing condition and the desired severity as shown in Figure 19. The pin color on the map indicated the severity. Green indicated that the pole had been brushed and is normal. Red alerted the user to when vegetation exists within a pole firebreak that should have been brushed.

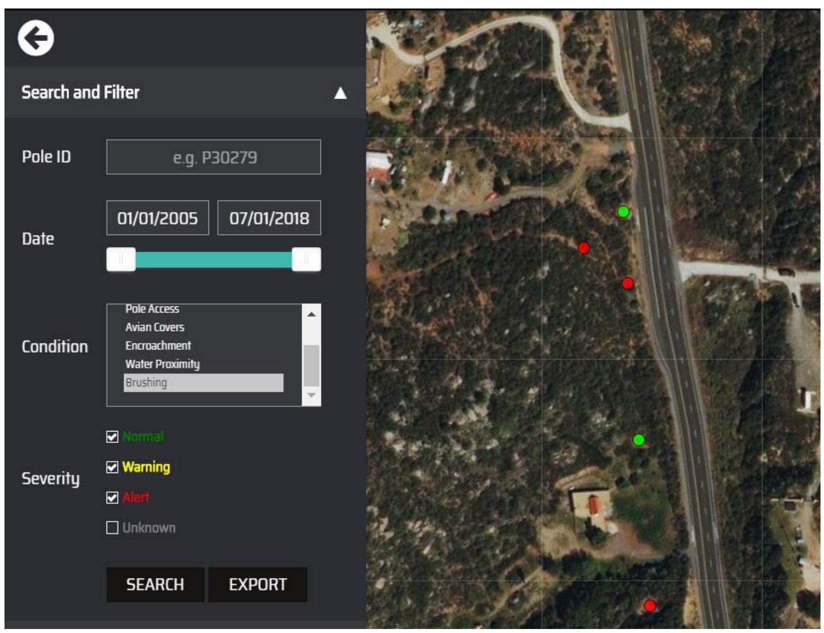


Figure 18: Search and Filter for Firebreak Maintenance Audits

When viewing point cloud results, the camera is pointed toward the selected pole. A yellow cylinder was placed around the pole to help visualize the vegetation within the firebreak as displayed in Figure 20.

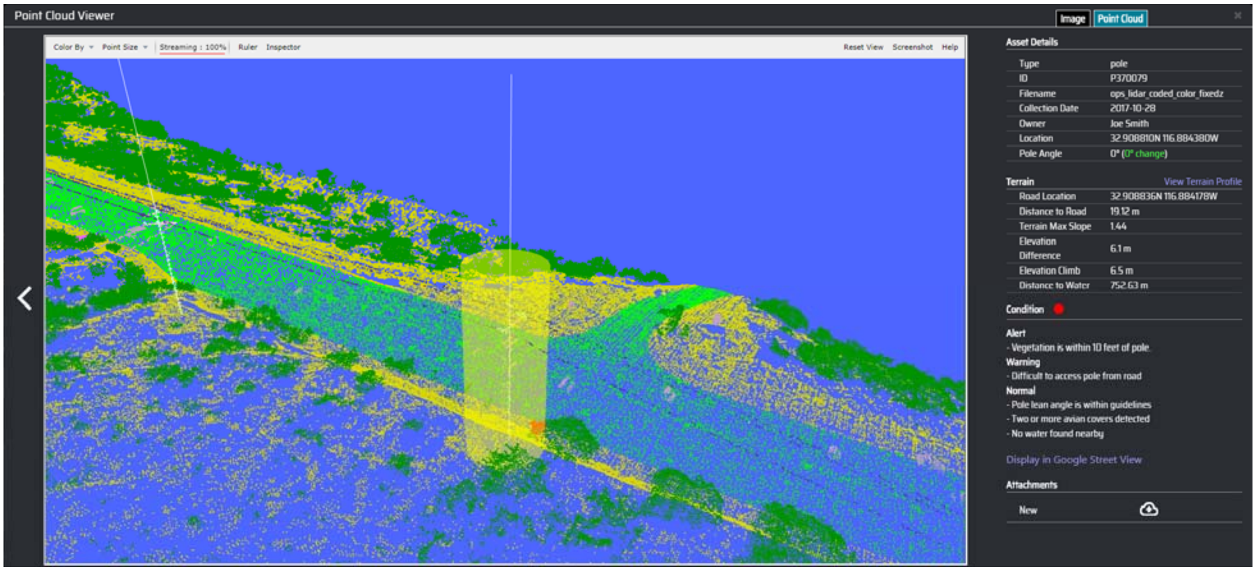


Figure 19: Vegetation within Firebreak

Using the Point Cloud Viewer application, users were able take a simulated orbital flight around the pole. In addition, the results could be manually viewed using a mouse to navigate through the point cloud. Users could also choose to view available imagery in addition to point cloud data, as well as clicking the link to view the pole from the road using Google Street View.

Using classified LiDAR point cloud data, Vendor A successfully developed algorithms to locate and categorize vegetation encroachments within a defined area around a pole. They found the LiDAR data was of good quality and density to support vegetation detection as well as other potential asset related measurements.

To confirm the accuracy of the analytic results, Vendor A used UAS imagery to perform a visual inspection of the five poles selected for this demonstration. The visual inspections confirmed that the analytic results were 100% accurate for detecting vegetation within the defined cylinder area.

6.1.2.2.3 Vendor A Recommendations

This test case was successful and proved the technical risk to a LiDAR-based vegetation encroachment solution is small. Further studies are recommended to determine how this technical capability can be deployed into an existing vegetation management workflow. Recommendations include:

- Quantify the severity of vegetation encroachment by volume or height. This can help estimate the scope of remediation and identify required equipment.
- Use raw LiDAR data that has not been feature-coded. By calculating pole locations from raw data, a significant processing step can be alleviated.
- Use multiple historical LiDAR datasets to identify vegetation growth trends and to recommend brushing frequency or techniques such as mechanical vs. herbicide.
- Use fused RGB/infrared imagery and LiDAR data to identify the health and distance of the encroachment to establishing work order priorities such as dead tree branches within eight feet of cross arms.
- Add the ability to exclude exempt areas such as those with fixed irrigation.

6.1.2.2.4 Conclusions

This test case used LiDAR data to successfully demonstrate how the maintenance audit process can effectively verify poles have been brushed. The technical risk is low. To fully operationalize this workflow, integrating with SDG&E's existing work order management tool will reduce the need for the Vegetation Management team to perform field inspections and enable them to verify work has been performed as expected by outside contractors.

Furthermore, this technology, in conjunction with the automatic detection of at risk poles (using deep learning) can ensure SDG&E complies with California code 4292. This code requires a cylindroid space of 10-feet surrounding each pole that contains a switch, fuse, transformer, or lightning arrestor.

6.1.3 Environmental

6.1.3.1 Identification of Water Bodies

6.1.3.1.1 Approach

Vendor A used the as-built pole information and a vector water layer to identify the distance to the nearest water feature. During the demonstration, Vendor A stated that this capability can be easily expanded to include other layers of interest such as archeological avoids. For this demonstration, a water feature did not exist in the sample area, so one was created.

The distance to water was calculated when the pole information was uploaded to the system. The distance was shown in the terrain section of the Asset Details view (see Figure 21).

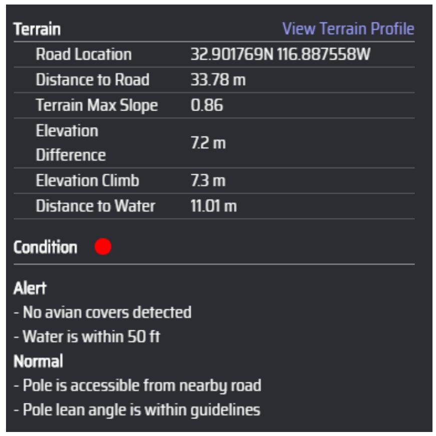


Figure 20: Asset Details View – Distance to Water

The condition was determined by the distance between the pole and the nearest water body as reflected in Table 9:

Indicator	Condition	Distance
Green	Normal	>100 feet
Yellow	Warning	50 – 100 feet
Red	Alert	<=50 feet

Table 9: Water Body Conditions

Like the other layers, the water body layer could be switched on and off accordingly.

6.1.3.1.2 Results

The pole accessibility results were quickly located by conducting a search and filter query. Users can filter against the water proximity condition and the desired severity. The pin color on the map indicated the proximity of a pole to a water feature. Green indicated there is no water nearby, yellow indicated warnings, and red alerted users to when water was less than 50 feet away. Figure 22 shows the search and filter interface when consider proximity to water.

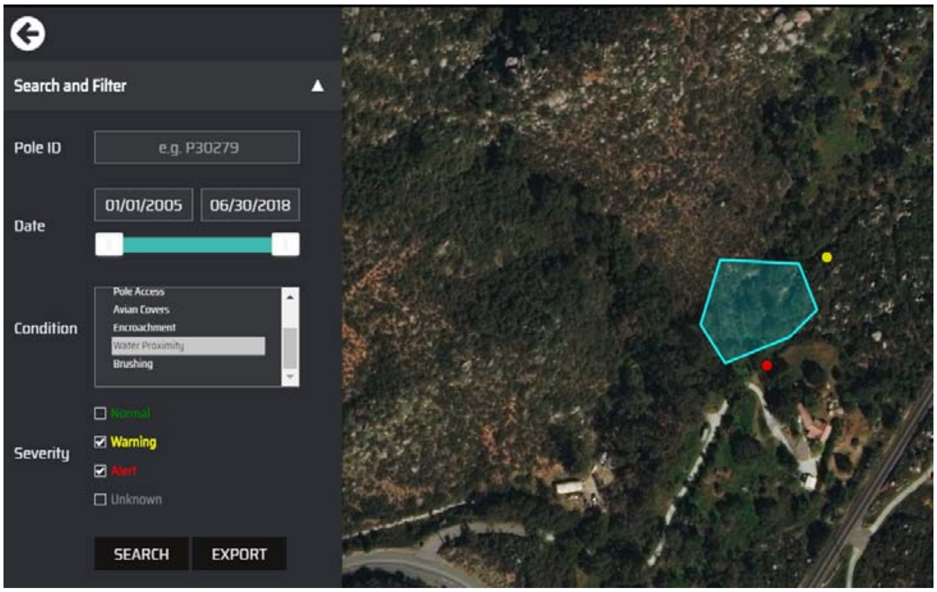


Figure 21: Search and Filter by Water Proximity

Using the pole location provided and a vector layer, analytics were successfully developed to measure the distance from the pole to water feature. The layers provided as a part of the baseline dataset did not contain a water feature in the selected area, so a water layer was manually created by the Vendor A team to be used for demonstration purposes.

6.1.3.1.3 Vendor A Recommendations

Recommendations for further development concerning the identification of water bodies test case include:

- Work with the Environmental Services team to understand additional workflows, user access controls, and security needs.
- Using Open Geospatial Consortium (OCG) standards, provide integration between the Vendor A Tool and GIS systems, for example, layers and results.
- Expand analytics to include additional GIS layers such as archeological avoids.

- Use additional analytics to automatically identify and detect features such as water, marsh areas and other areas of interest.

6.1.3.1.4 Conclusions

Analytics that measure the distance between two objects are easy to implement and operationalize. Integrating the Vendor A Tool with SDG&E's existing GIS systems will provide tremendous value with low risk. The analytics can be easily updated to provide distance information for other environmental layers such as archeological avoids and protective habits. Access to sensitive information can be controlled through user-defined roles. These results will provide the Environmental Services team a more robust view of the areas surrounding a pole and will allow them to engage specialists early in the project planning phase.

6.1.3.2 Pole Accessibility from Road

6.1.3.2.1 Approach

Vendor A used the as-built pole information and vector street layer to identify the distance and path to the nearest road. Since the LiDAR data collected for this area only represented a narrow swath, a United States Geological Survey (USGS) model, a type of Digital Elevation Model (DEM), was added to the system to calculate terrain information including maximum slope, elevation difference, and the overall elevation between the pole and road (see Figure 23).

Terrain	View Terrain Profile
Road Location	32.906926N 116.883829W
Distance to Road	37.57 m
Terrain Max Slope	2.33
Elevation Difference	15.5 m
Elevation Climb	17.6 m
Distance to Water	560.23 m

Figure 22: Terrain Details

Figure 24 shows an example terrain profile. The terrain profile was created to allow users to visualize the topography between the pole and the road.

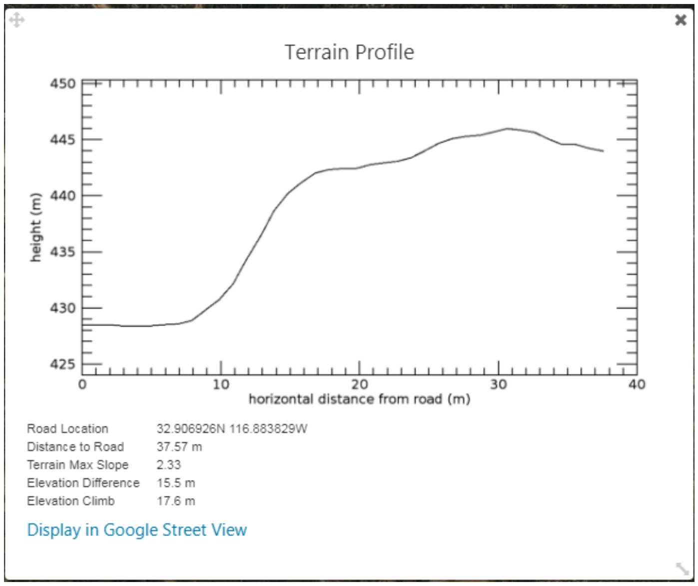


Figure 23: Terrain Profile

The pole accessibility was determined by evaluating the steepness or grade of each point along the path. The grade measures the vertical rise per unit of horizontal run forward. For example, perfectly flat terrain has a grade of "0", and terrain with a 45-degree angle has a grade of "1". With sudden drops and rises in elevation being significant obstacles for access, the largest grade along the path was used to determine the pole access condition. The parameters can be easily amended depending on customer requirements, current parameters are outlined in Table 10:

Indicator	Condition	Grade
Green	Normal	<= 1.2
Yellow	Warning	1.21 – 2.0
Red	Alert	>= 2

Table 10: Pole Accessibility Criteria

6.1.3.2.2 Results

The pole accessibility results were quickly located by conducting a search and filter query. Users can filter against the pole accessibility condition and the desired severity as shown in Figure 25. The pin color on the map indicated if the pole could be accessed from the road. Green specified access was normal, yellow indicated warnings, and red alerted users to when the grade is greater than 2. The blue line shows the path between the pole and the nearest road. Clicking on the blue line displayed the terrain profile.

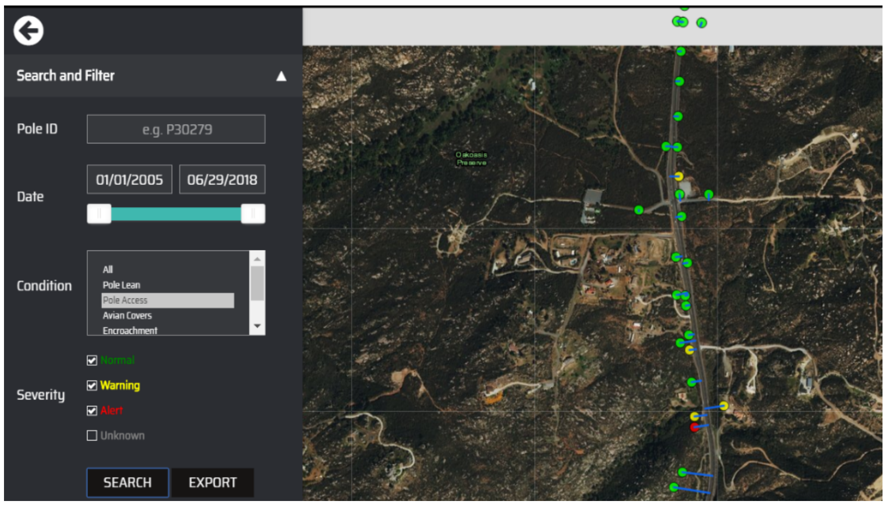


Figure 24: Search and Filter by Pole Accessibility

In addition to the terrain profile and available pole imagery, users could choose to view the pole from the road by clicking the <u>Display in Google Street View</u> link (see Figure 26). A new tab opens in the browser with a view from the road pointing toward the pole (see Figure 27).

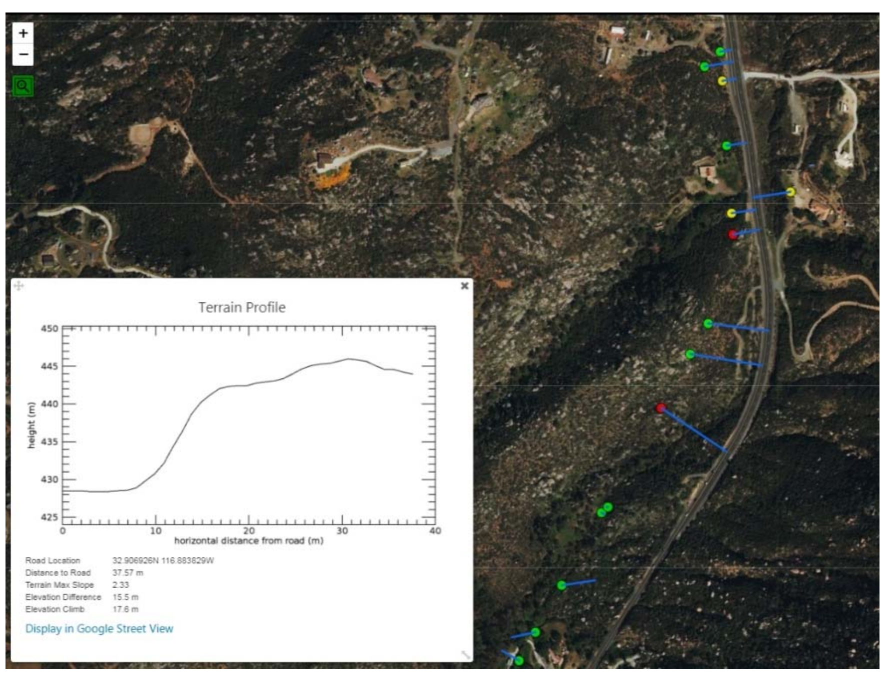


Figure 25: Terrain Profile Map View

The terrain information provided in the asset detail view, combined with the terrain profile and imagery (pole images and Google Steet View), provide valuable insights into the area surrounding the pole.

Figure 26: Google Street View

In addition to exporting road access details, imagery contained within the Vendor A Tool can be saved locally by right-clicking on the image within the Image Viewer as shown in Figure 28.

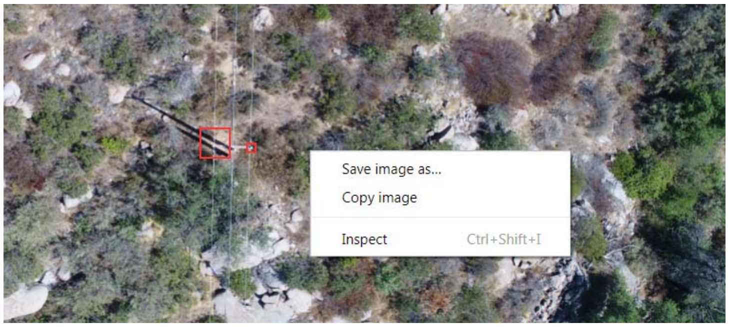
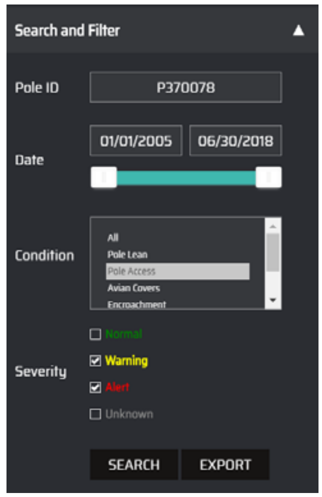
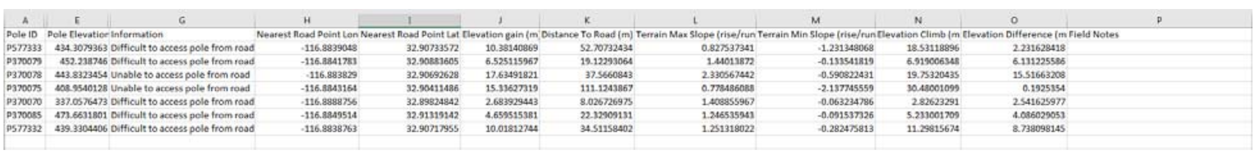


Figure 27: Save Imagery for Inclusion in Project Documentation

Users can also generate a template for capturing field inspection notes. Using the filter and export features, a CSV file containing terrain details for a specific pole or a set of conditions can be created by exporting the pole access results as seen in Figure 29.





A	E	G	H	I	J	K	L	M	N	O	P
Pole ID	Pole Elevation	Information	Nearest Road Point Lon	Nearest Road Point Lat	Elevation gain (m	Distance To Road (m)	Terrain Max Slope (rise/run	Terrain Min Slope (rise/run	Elevation Climb (m	Elevation Difference (m	Field Notes
P577333	434.3079363	Difficult to access pole from road	-116.8839048	32.90733572	10.38140869	52.70732434	0.827537341	-1.231348068	18.53118896	2.231628418	
P370079	452.238746	Difficult to access pole from road	-116.8841783	32.90883605	6.525115967	19.12293064	1.44013872	-0.133541819	6.919006348	6.131225586	
P370078	443.8323454	Unable to access pole from road	-116.883829	32.90692628	17.63491821	37.5660843	2.330567442	-0.590822431	19.75320435	15.51663208	
P370075	408.9540128	Unable to access pole from road	-116.8843164	32.90411486	15.33627319	111.1243867	0.778486088	-2.137745559	30.48001099	0.1925354	
P370070	337.0576473	Difficult to access pole from road	-116.8888756	32.89824842	2.683929443	8.026726975	1.408855967	-0.063234786	2.82623291	2.541625977	
P370085	473.6631801	Difficult to access pole from road	-116.8849514	32.91319142	4.659515381	22.32909131	1.246535943	-0.091537326	5.233001709	4.086029053	
P577332	439.3304406	Difficult to access pole from road	-116.8838763	32.90717955	10.01812744	34.51158402	1.251318022	-0.282475813	11.29815674	8.738098145	

Figure 28: Pole Access Export for Field Notes

The CSV file is editable and can be tailored to meet the needs of the user to capture notes in the field.

Using LiDAR and DEM, analytics were successfully developed to calculate the distance from the pole to nearest road; however, environmental factors that do not appear in these formats, such as chain-link fences, were not detected for this demonstration.

To confirm the accuracy of the analytic results, Vendor A used Google Street View and UAS imagery to perform a visual inspection of the 49 poles provided in the sample dataset. Visual inspections confirmed the analytic results were accurate for detecting access to the nearest road based on the established criteria. To provide a more comprehensive perspective into all potential access points to a pole, Vendor A stated the analytics can easily be extended to include other layers such as known parking lots, dirt roads, pathways and barriers such as fences.

While the sample LiDAR datasets provided were an excellent source for creating DEMs, the coverage was too narrow and did not include nearby roads. To overcome this limitation, Vendor A added a USGS DEM of the circuit to the Vendor A Tool. The DEM was then expanded to include the entire service area.

The DEM enabled the test case to be expanded to include a terrain profile that provides additional insights about the topography and accessibility of the pole from the nearest road. The ability to use DEMs and vector layers to provide these insights highlights the extensibility of the system.

6.1.3.2.3 Vendor A Recommendations

Recommendations for further development concerning the pole accessibility use case include:

- Work with the Environmental Service team to adjust thresholds and rules to meet specific operational requirements.
- Use additional data sources (such as high-quality LiDAR or UAS-derived point clouds) in conjunction with DEMs to identify hard-to-detect obstacles such as chain-link or barbed-wire fences.
- Allow users the ability to update/override pole access conditions.
- Expand export capabilities to allow users to filter results to a specific area or the map extents currently displayed.
- Expand analytics to include additional GIS layers such for consideration such as roads, paths, and parking lots.
- Identify and classify access restrictions such as foot access only, small trucks, or larger vehicles.
- Locate alternative paths to a pole when straight-line road access is difficult (see Figure 30).

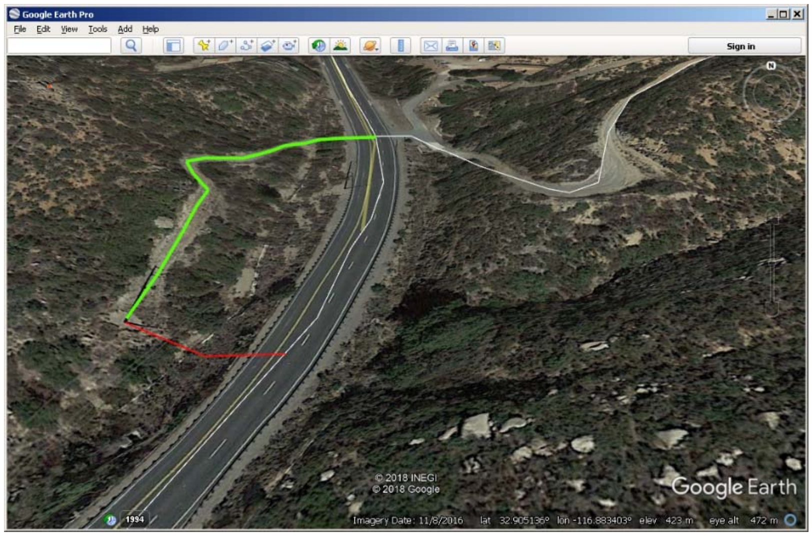


Figure 29: Alternative Path Analysis

6.1.3.2.4 Conclusions

This test case proved layers and elevation data can be successfully used to calculate distances and evaluate access to poles; however, to make this more compelling, the Vendor A Tool should be integrated with the SDG&E GIS system of record. This integration will allow for additional layers to be used by the analytics to provide a more robust view into the areas surrounding a pole. These layers, along with the ability to download images to local desktops and terrain insights, will reduce time spent gathering data for creating map books and performing visual inspections in the field.

6.1.4 Documented Use Case Recommendations

The use cases described in this section were not included in the demonstration due to limitations in the baseline dataset as well as time and budgeting shortfalls. Vendor A have outlined their recommended approach for each below.

6.1.4.1 Vegetation Management - Identifying Hardware and Firebreaks

To conduct a useful proof of concept in the future, the following approach is recommended:

- Use deep learning to locate non-exempt equipment on the pole using still imagery. Non-exempt equipment includes universal fuses, open link fuses, enclosed cutouts with universal fuses, solid blade disconnects, in-line disconnects, lightning arresters, non-porcelain lightning arresters, hot tap clamps, split bolt connectors, fargo connectors, LM connectors, grasshopper air switches and transmission air switches.

- Identify a circuit that contains similar types of components, specific types of lightning arrestors, hot clamps and other equipment.
- Engage subject matter experts to correctly identify and label an initial set of selected components.
- Use the properties of the selected components to define collection requirements such as the number of images, distance from pole, resolution and collection geometry (orbiting or nadir).
- Collect imagery according to the defined specification.
- Label training data for each object of interest.
- Develop and test deep learning algorithms and classifiers against a reserved dataset.

6.1.4.1.1 Conclusions

Once the deep learning models have been developed and tested, the algorithms can be set up as on-ingest processes in the Vendor A Tool. In addition to using imagery for identifying the components, the brushing analytics (firebreak maintenance audit test case) would require LiDAR data for the same poles used for the deep learning portion. The logic for determining condition and severity can be easily updated to support this new workflow.

The technique for locating objects on a pole and identifying vegetation points within a firebreak are analytics Vendor A has successfully proven. To successfully complete this proof of concept, advanced planning and collaboration will be required between SDG&E and Vendor A.

6.1.4.2 Environmental Services – Identification of Staging Yards

To conduct a useful proof of concept going forward, the following approach is recommended:

- Ingest a LiDAR dataset for the entire area around assets. This data must extend beyond the corridor of interest.
- Process the LiDAR point cloud as follows:
    - Classify points to identify terrain, vegetation, buildings, and power lines.
    - Create a DEM by extracting bare earth points from the point cloud.

- Calculate a surface normal for each bare earth point (see Figure 31).

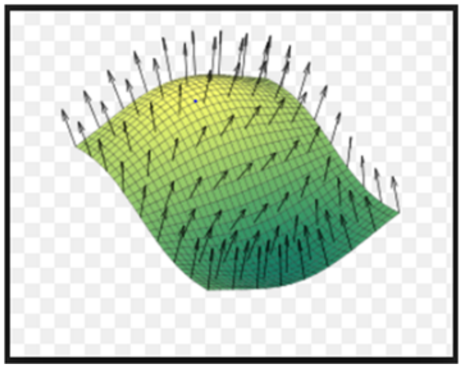


Figure 30: Surface Normal Model

- Search for areas of terrain that meet the following criteria:
  - The area is relatively flat as measured by the uniformity of the surface normals of the ground and slope.
  - The site is a minimum of two acres.
  - The site is clear and free of non-terrain points above ground such as buildings, tall vegetation, and trees.
  - The area is within two miles of the construction site.
  - There are no buildings nearby.
  - The site must be easily accessed from a nearby road.
- Create a polyline for suitable areas. A polyline is a continuous line composed of one or more line segments.
- Display potential sites on a map in the system and make them available as a downloadable shapefile (see Figure 32).

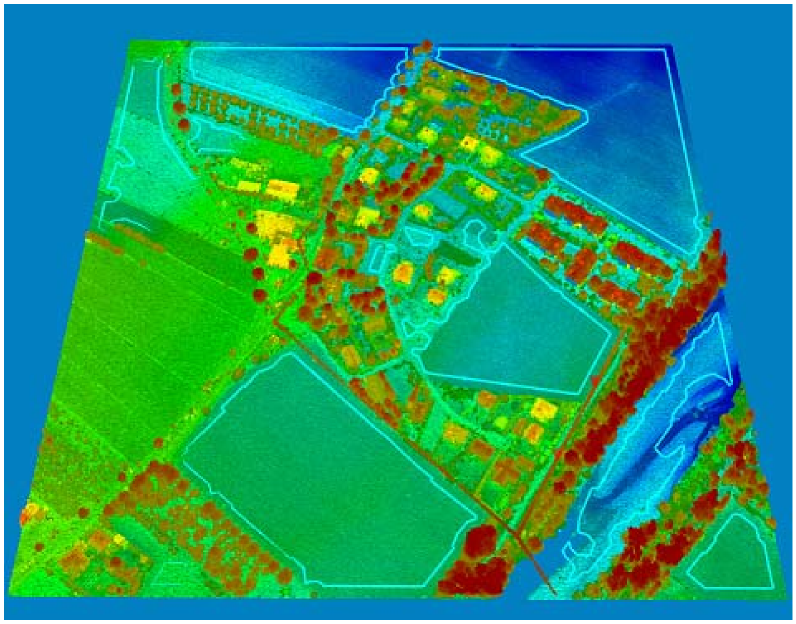


Figure 31: Potential Staging Yards

- Metrics are computed and stored as metadata and displayed. They include:
    - Acreage
    - Maximum slope in area
    - Distance to construction site
    - Distance to nearest power line

6.1.4.2.1 Conclusions

The technique for identifying potential staging yards is similar to existing analytics Vendor A has already successfully developed for locating potential helicopter landing zones for the military. The technical risks are low to make this workflow operational. Once requirements are understood for identifying potential pole sites, this capability could be expanded to automatically identify potential sites as well.

6.1.5 Vendor A System Recommendations

The recommendations outlined below were discussed and presented by the stakeholders during the Vendor A demonstration and apply to the Vendor A Tool.

Camera Direction

To allow the users to have a better idea of the conditions in an area of interest, the vendor system should show what direction the camera was facing when an image was taken.

Pole Lean Visual Indicator

Add a visual indicator to the map to show the angle of pole lean away from 90 degrees.

6.1.6 Vendor A Project Summary

With consumer reliability expectations high, tolerance for power outages low, and operational expenses under scrutiny, utilities are under pressure to leverage newer forms of technology to manage their asset infrastructure more effectively. This series of EPIC projects has allowed Vendor A to demonstrate how a remote sensing data management system coupled with sophisticated geospatial analytics technology can be an effective solution for gaining intelligence on network infrastructure.

In this proof of concept, the executed test cases expanded the use of the Vendor A Tool to include UAS imagery, LiDAR, publicly available elevation data, and supporting data related to assets. The on-ingest analytics successfully delivered actionable insights to several functional groups, incorporating a web-based client application with advanced viewing and reporting capability that emphasized the versatility of the overall system. An initial integration use case was developed, and other opportunities were highlighted that described how data residing in disparate SDG&E systems could be leveraged in this environment.

6.2 Vendor B Test Case Results

6.2.1 Infrastructure

Vendor B chose to tackle the overall Infrastructure use case from data ingestion through to data removal. Their demonstration showed how the Vendor B Tool can be used as a single, central repository to manage data throughout the full data lifecycle.

The Vendor B data model is an incremental loading and delivery data model. The data is loaded or unloaded by generating ADD, MODIFY, or DELETE records. During loading, objects are created in the database by auctioning ADD records. Updates to an object (pole, wire, vegetation canopy, etc.) are achieved with MODIFY records. Finally, the life cycle of an object can be ended by publishing and loading into the system DELETE records. This allows for the near-real-time realization of data as it becomes available and allows for refinement of data once it is loaded into the system.

The data model was designed to support multiple surveys of data in the system simultaneously. This means that objects, such as structures, can exist multiple times with different attributes based on their state during a particular survey.

The standard data model utilizes unique identifiers for every data feature (structure, wire, circuit, vegetation canopy segment, etc.). These unique identifiers allow the history of a feature to be tracked from survey to survey (or year to year). This provides a tool to perform longitudinal analysis of infrastructure health. For instance, a pole's lean can be recorded independently over several years with each observation linked to the same physical asset.

6.2.1.1 Data Ingestion

Once Vendor B received the baseline dataset, it was reviewed, processed, and ingested into the Vendor B Tool. The following data was successfully ingested into the vendor tool:

- **PLS-CADD Models** - Using the standardized database structure, assets in the PLS-CADD models were imported into the database. This import included structures, spans, and catenary geometry in one or more weather condition (at survey, maximum operating temperature, and/or maximum sway).
- **LiDAR** – LiDAR data was indexed using a well-known quad-tree spatial indexing algorithm and placed onto Vendor B's LiDAR server's storage space. The indexing allows for the quick selection and extraction of LiDAR data over a given area.
- **Oblique Imagery** – Using the metadata contained in the acquired images (position, attitude, and gimbal orientation) the view of the camera was projected onto a ground model. This projection provides a representation of the coverage of the image. It is then possible to intersect the camera footprints with other features to determine which images

provide a view of the area in question. The images were georeferenced and shown on the map using a camera icon.

- **GIS Layers** – The Environmental GIS layers were sorted and those that had features in the chosen test segment, were successfully ingested into the system.

6.2.1.2 Data Storage

Vendor B's standardized data model supports multiple surveys to allow more than one year's worth of data, or flights, to be stored in the system. All data that is ingested into the system can be stored and retrieved for examination at the request of the end user.

6.2.1.3 Data Visualization

The data that is stored within the Vendor B Tool can be visualized in a variety of ways. During the demonstration, the data was visualized using the methods outlined below:

- Map view – data is georeferenced and shown at the correct location on the map
- Map icons
    - Camera Icon – shown on the map at the place in which the photograph was taken, with an arrow to show camera direction
    - Pole Icons – shown at the correct location on the map and rotated to the angle of pole lean
    - Vegetation Encroachment Polygons – color coded to reflect severity of the encroachment, shown as polygons on the map
    - Tree Health Polygons – color coded to reflect tree health, shown as polygons on the map
- Contour lines – contour lines were produced from the LiDAR included in the baseline data set. Contour lines are shown on the map at 10-foot intervals
- Grid view – the results of any work search or query are shown in a grid view to the left of the map
- LiDAR viewer – the LiDAR viewer is used to view 3D point clouds from within the platform
- GIS layers – the Environmental GIS layers were ingested into the platform and could be turned on or off as required

6.2.1.4 Data Retention and Removal

Data deletions are handled through the same data loading mechanism for adding data. To unpublish (delete) data a copy of the publication that loaded the data is made, and all of the ACTION verbs in each record are changed from ADD or MODIFY to read DELETE. A software tool exists to select a dataset and generate the removal records. This tool can also be scripted in WorkStudio so that a given dataset can be automatically unloaded after a certain period. Similarly, the tool can be scripted from in WorkStudio to allow users to select a dataset and generate the deletion within the application.

6.2.1.5 Conclusions

Vendor B demonstrated how their platform, Vendor B Tool, could be used to manage data throughout the full data lifecycle from data ingestion to data removal.

They successfully showed how the system could ingest all the data provided in the baseline dataset which included PLS-CADD models, LiDAR, oblique imagery and GIS layers and how this data could be stored within their system, which would act like a central repository.

The interface is intuitive and visually pleasing with good use of icons and various means to retrieve data analytics results through means of a work search. Results can be viewed in both a grid view and map view depending on what is most useful for the user’s task in hand.
Vendor B Tool is a secure, cloud-based, geospatial solution that also delivers high-resolution imagery and visualization of feature coded LiDAR. Tools are provided to virtually assess imagery and LiDAR and findings can be stored to create a historical log of asset health to assist with comparison works over time.

The Vendor B Tool can be stood up with little IT configuration and is flexible enough to expand to meet storage and usage needs as the SDG&E dataset increases over time.

Nevertheless, there is currently no method for automated data removal in accordance with a data retention policy, however data can be filtered and manually removed from the system by running a script. With some additional development, Vendor B could potentially introduce automated data retention and removal functionality.

With the addition of an automated data retention and removal mechanism, the Vendor B Tool is a strong candidate for the SDG&E central data repository requirement and could be used to manage data through the full data lifecycle.

6.2.2 Vegetation Management

6.2.2.1 Identifying Tree Growth Patterns

6.2.2.1.1 Approach

Vendor B explored the theme of vegetation encroachment to demonstrate this use case. Further work and development is required to identify tree growth patterns.

Using the feature coded LiDAR data and the PLS-CADD models, canopy segments (polygons) were generated representing tree canopies. Measurement distances were then calculated between the polygon and nearest conductor under various conditions (max sag and grow-in, at survey and grow-in, blowout and grow-in, max sag and fall-in, at survey and fall-in, blowout and fall-in). Based on Minimum Vegetation Clearance Distance (MVCD) values, these results are filtered down to only display points of interest in which other actions can be performed using the software, such as viewing associated LiDAR, oblique imagery, and creating an assessment job to review in the field.

Figures 33 and 34 illustrate how the measurement distances are calculated. The grow-in and fall-in distances are calculated in return space. This means they have no context to determine which surface they were reflected from and how they might be related to any other returns.

Figure 33 shows how the grow-in measurement is the distance from each return to the MVCD buffer.

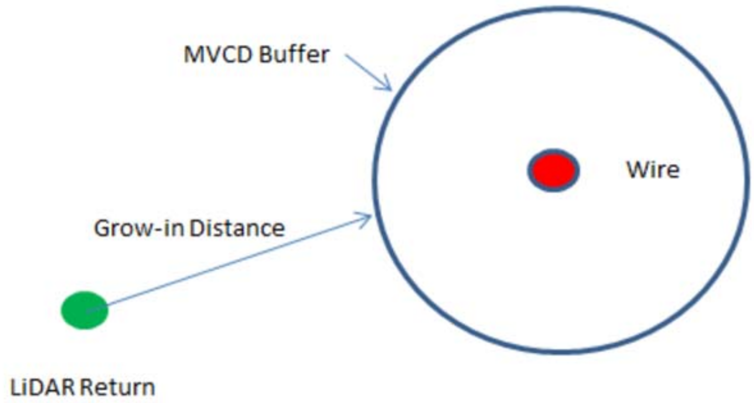


Figure 32: Grow-in Measurement Diagram

Figure 34 below depicts the fall-in measurement. The fall-in measurement is the difference between the return height and the distance from the MVCD to the ground projection of the return. These values are negative for violations.

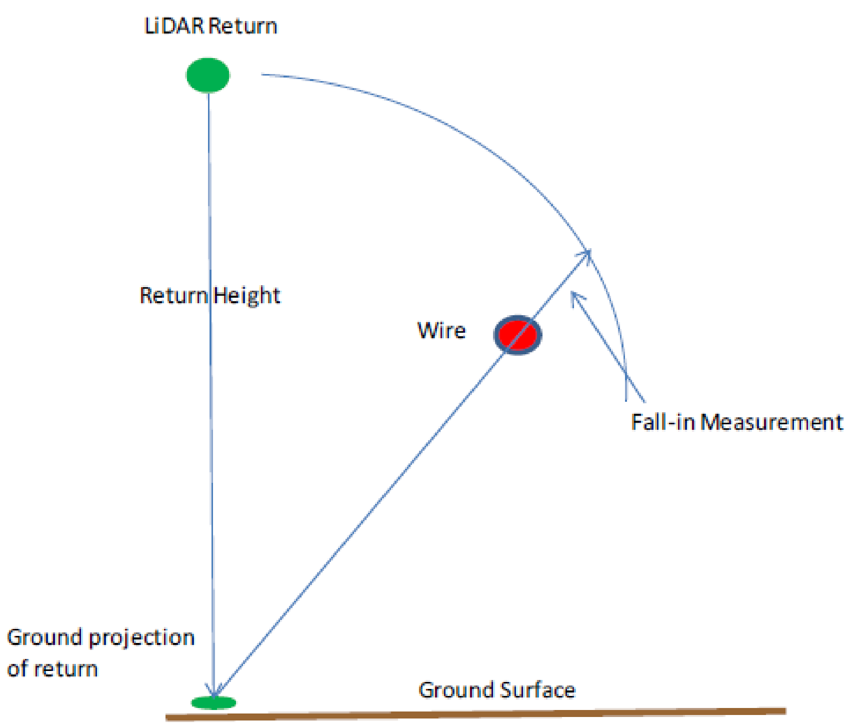


Figure 33: Fall-in Measurement Diagram

Unlike the grow-in/fall-in measurements, the violation height is calculated in canopy segment space. When a canopy segment is located in the same place as the stem and encompasses all of the tree's foliage, it represents the maximum height that tree can attain before it intrudes on the vegetation buffer. It is the best guess on an actual tree falling through the critical zone. Another measure of interest is the wire lift. That is the distance that the wire would have to be lifted to prevent a tree of canopy segment height from intruding into the vegetation buffer.

Figure 35 shows the violation height is the distance from the ground projection of the canopy segment centroid to the MVCD buffer. This is how tall a tree with a stem located at the canopy segment centroid would have to be to strike the MVCD buffer.

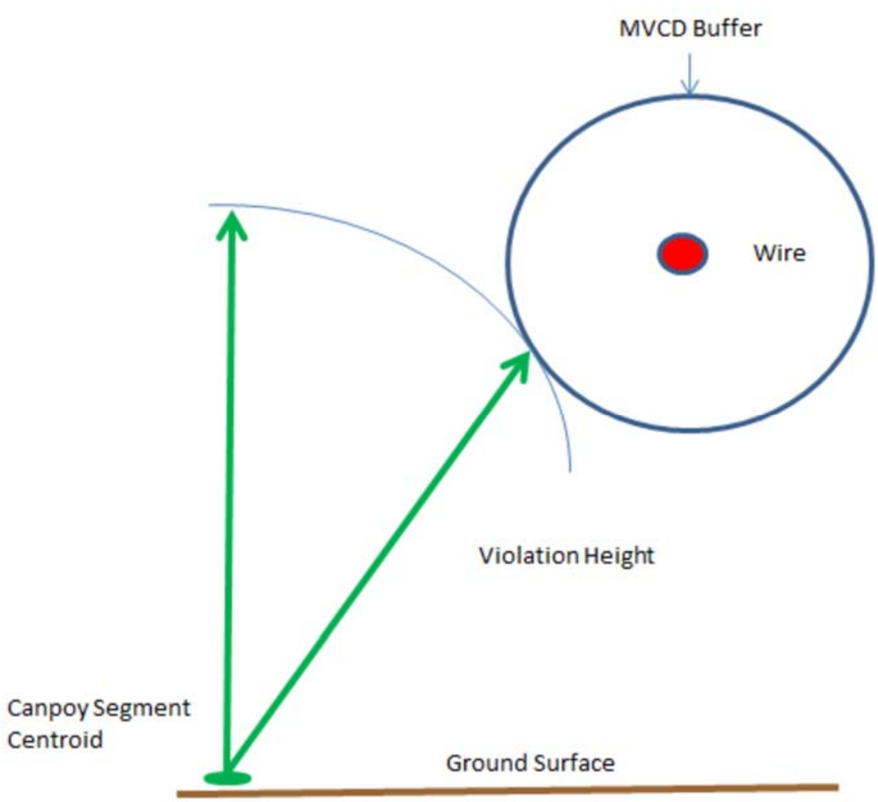


Figure 34: Violation Height

6.2.2.1.2 Results

The Vendor B Tool was successfully able to identify areas of vegetation encroachment, but further development of predictive analysis mechanisms is required to identify tree growth patterns.

The thresholds for encroaching trees can be customized according to customer specifications and encroachment can be conducted on any polygon. Work searches can be filtered based on the survey, voltage (kV), circuit, minimum clearance (ft), maximum clearance (ft), clearance type, right of way (not included in baseline dataset), within right of way (not included in baseline dataset), measurement case, wire safety and work order.

Once the search is conducted, color coded polygons appear on the map that show the different breakdowns for clearance values, the results are also shown in the grid view (see Figure 36). The criteria for encroachment values and color coding can be amended according to customer thresholds. The encroachment can also be observed within the LiDAR viewer (see Figure 37).

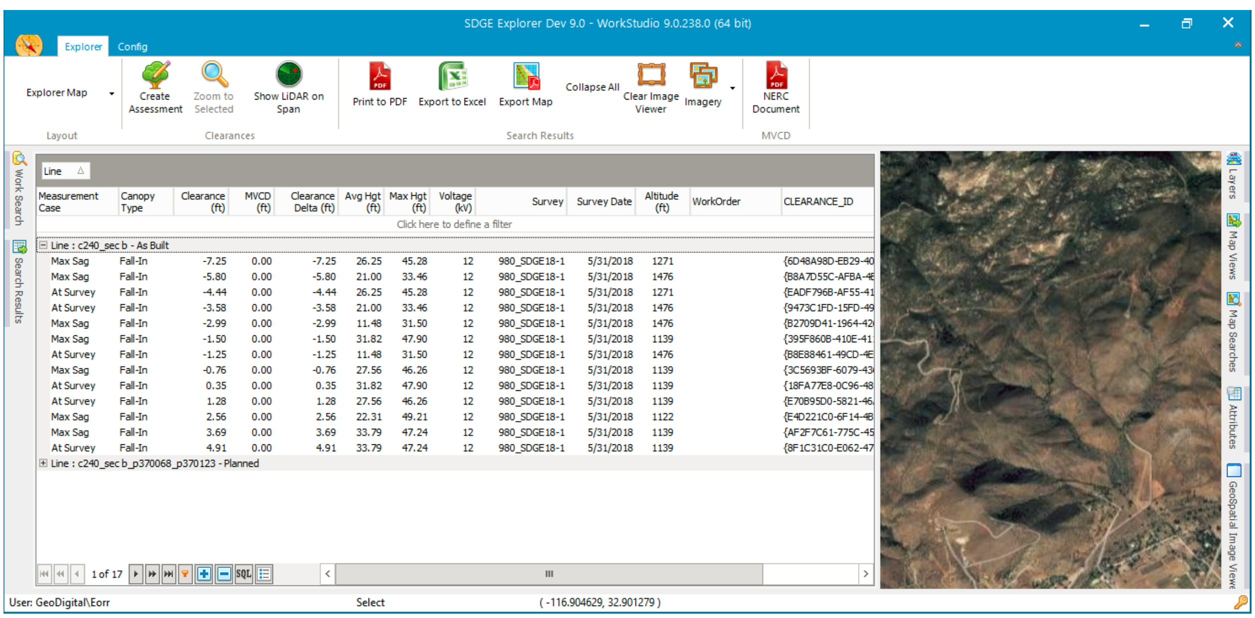


Figure 35: Vegetation Encroachment Results

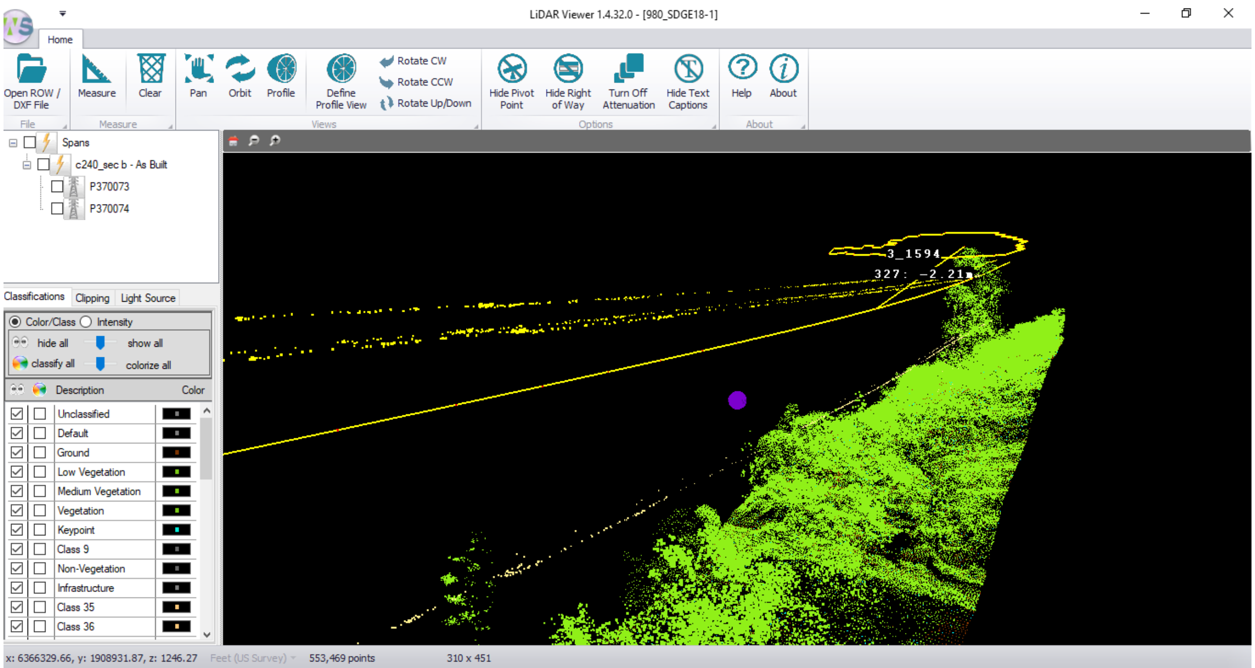


Figure 36: LiDAR View of the Encroachment

6.2.2.1.3 Conclusions

The Vendor B Tool was successfully able to identify areas of vegetation encroachment, but further development of predictive analysis methods is required to identify tree growth patterns.

Predictive analysis of tree growth patterns would assist Vegetation Management with planning their cutting and pruning maintenance schedule and allow for a more efficient process with reduced non-compliances.

6.2.2.2 Identifying Areas of Tree Health

6.2.2.2.1 Approach

LiDAR data and imagery were used to produce a classification of the canopy to show tree health. Typically, foliage is classified into three classes healthy (G), unhealthy (R), and dead (D). A manual classification based on true color imagery, orthographic and, as necessary, oblique imagery was conducted. It is important to note that unhealthy and dead foliage can occur on healthy trees in the autumn and winter when the leaves are senescing. Thus, images collected too early in the spring or too late in the fall will produce spurious results.

The data for this process, produced from the LiDAR survey, consists of canopy segment geometry and pixel color summaries for the canopy segments.

6.2.2.2.2 Results

Vendor B’s platform was able to identify and categorize areas of the canopy to show tree health. This use case was delivered in the form of a work search and Figure 38 shows how the results were both listed and displayed on the map as polygons with a corresponding color code to reflect the health of the trees in a particular area.

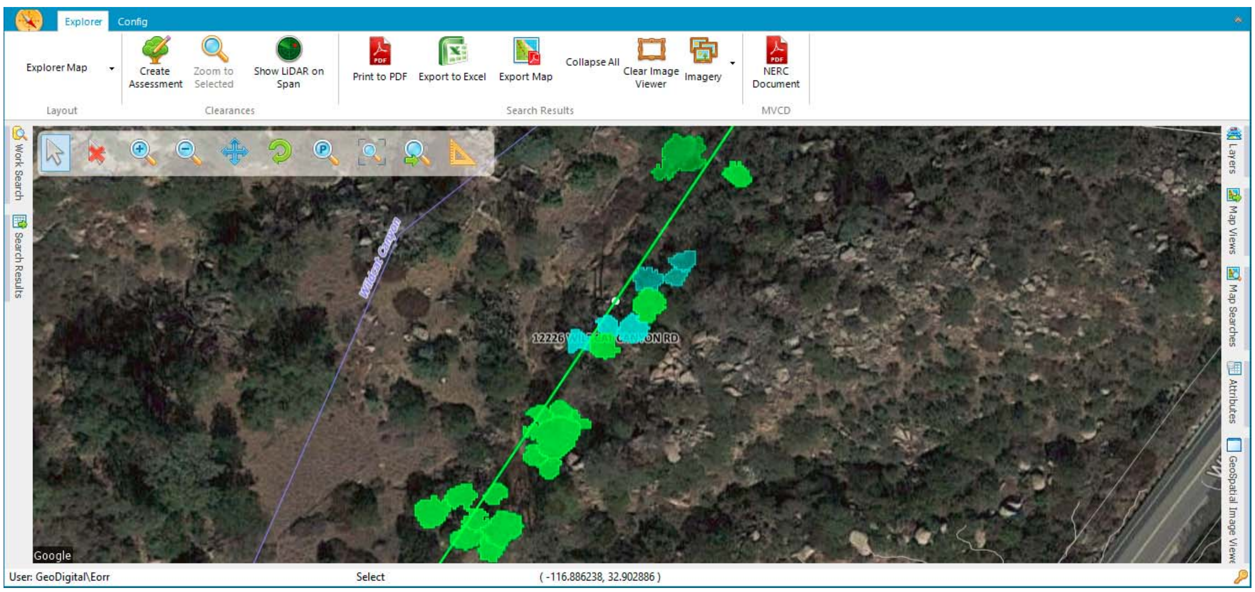


Figure 37: Tree Health Map

Infrared data was not supplied as part of the baseline dataset and the analysis was conducted using LiDAR and imagery data alone. Infrared data can be used as a means to measure tree health since healthy vegetation absorbs red and blue light for photosynthesis resulting in the reflection of more shortwave infrared light than visible green light. When a plant becomes unhealthy, it reflects more of the visible red light and less of the invisible infrared. Figure 39 depicts healthy vegetation infrared absorption and reflection.

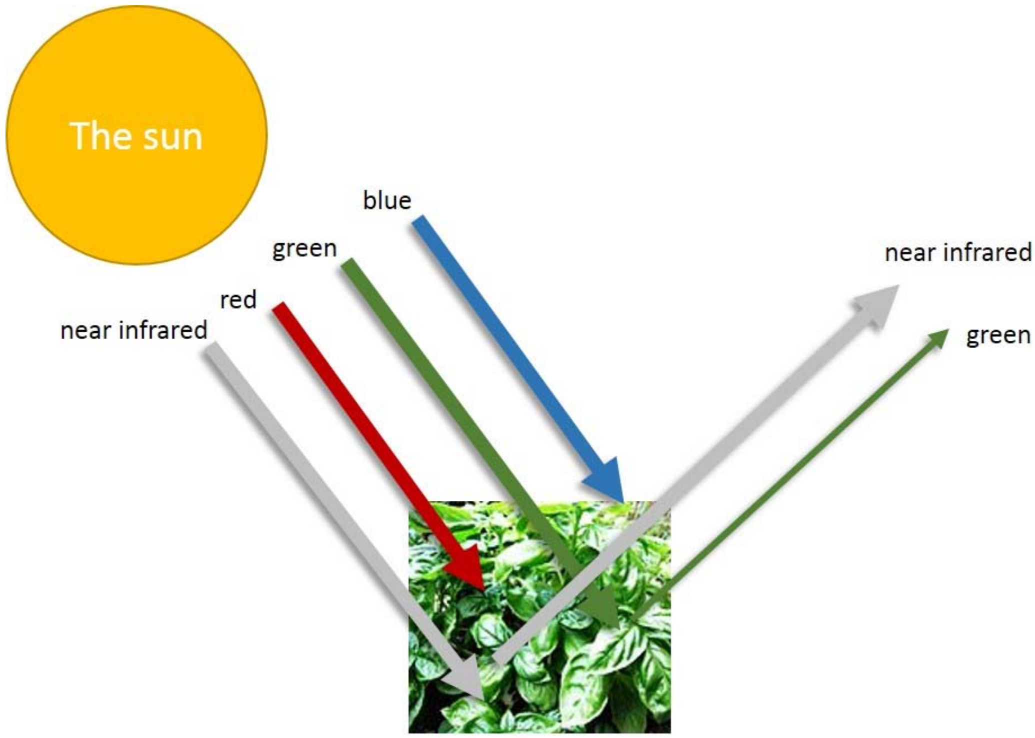


Figure 38: Healthy Vegetation Infrared Absorption and Reflection[7]

If infrared data were to be provided, the accuracy and reliability of the tree health results would be significantly improved.

6.2.2.2.3 Conclusions

Vendor B's platform was able to identify and categorize areas of the tree canopy to show tree health. The analysis was carried out manually based on true color imagery, using orthographic and oblique imagery. LiDAR data was also used to determine the canopy segment geometry and pixel color summaries for each segment. The results were shown as polygons on maps and a color coded depending on the perceived health.

Since this analysis was conducted through means of a manual classification, there is room for human error and inconsistency of results. Automated analytical methods should be developed to improve accuracy and reduce the time burden associated with manual analysis.

[7] DAI Remote Sensing Part 3: Identify Healthy Vegetation from Space. Retrieved from: https://dai-global-digital.com/lush-green-remote-sensing.html

In addition, the results would be greatly improved if infrared data was supplied by SDG&E as part of the baseline dataset.

6.2.2.3 Identifying Changes in Pole Lean

6.2.2.3.1 Approach

Each pole in the subject area was analyzed using the LiDAR point cloud. The analysis extracted the coordinates of two points along the middle of the pole. The height above ground for these two points (H_1 and H_2) were recorded as was the Euclidean distance between (L) the two points.

These three values were utilized to calculate the lean of the pole. The simple trigonometric relationship states that the lean of the pole is found to be arc cosine of the ratio of the differences in heights above ground (H_2-H_1) to the length (L) of the vector.

6.2.2.3.2 Results

The findings were made available in a work search where a user could filter poles to only show those greater than 7 degrees or filter against a particular survey or structure name. The results were viewed in the results tab which gave a grid view of all the poles that match filtered criteria. The pole icon displayed on the map was also rotated the value of the lean and one pole was found to have a lean of more than 7 degrees (see Figure 40).

The Vendor B team stated that the pole lean thresholds can be customized, and color coded depending on the severity of the lean and the customer requirement. A red, yellow and green 'traffic light' type system could be used to quickly determine the pole lean criticality.

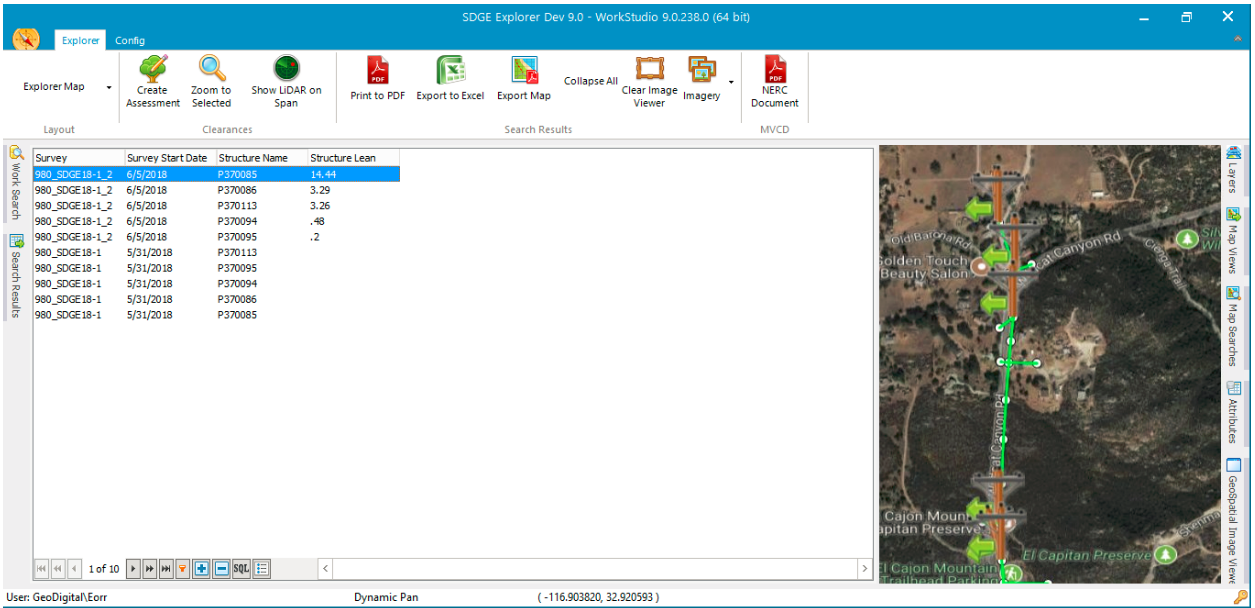


Figure 39: Pole Lean Results

6.2.2.3.3 Conclusions

The Vendor B Team successfully identified changes in pole lean using their developed methods to calculate the degree of lean from perfectly straight (90-degree angle).

This test case proved that the pole angle can be calculated using the LiDAR point cloud data and displayed in the map and grid view as meaningful results for users.

6.2.3 Environmental

6.2.3.1 Pole Accessibility from Road

6.2.3.1.1 Approach

Using the LiDAR provided by SDG&E, the Vendor B team produced contour lines at 10-foot intervals and applied smoothing and simplification. The results were then added to the map. Using the contours combined with ortho imagery, oblique imagery, and other GIS layers users are able to assess the pole accessibility remotely.

The system also has functionality to add field notes, for example to inform other personnel of the presence of a gate or other obstacle. Once this information is digitalized, it becomes available to all other users.

6.2.3.1.2 Results

The user is able to search against the pole of interest and zoom in to this area on the map. When zoomed in sufficiently, the contour lines become visible. The measuring tool can be used to measure the distance from the pole to the road and a determination of the terrain and elevation can made by manually studying the contours as shown in Figure 41. The system does not provide a terrain profile or automatic calculation of the distance of the pole from the roadway. However, the Environmental Team could see value in having access to the contour line information and measuring tool as part of their initial desktop assessment.

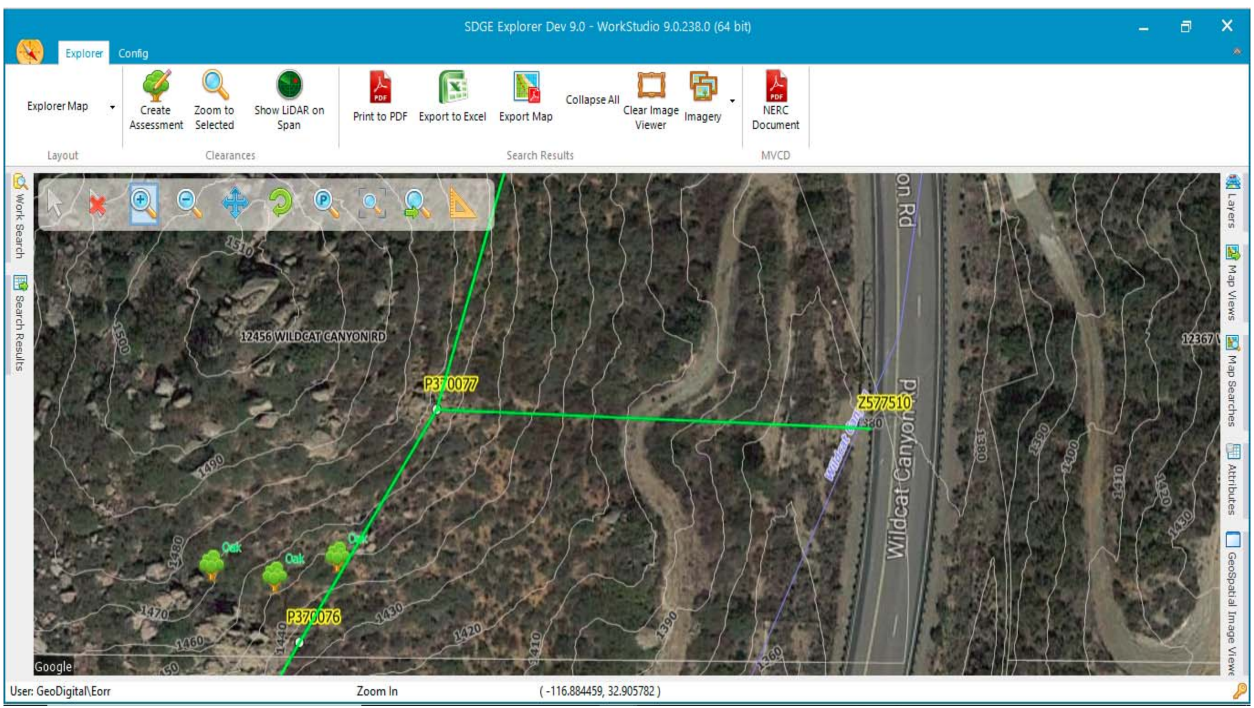


Figure 40: Pole Accessibility from Road

6.2.3.1.3 Conclusions

Vendor B successfully created contour lines from the LiDAR data provided by SDG&E and plotted these on the map at 10-foot intervals. Measurement tools were provided to measure the distance between the pole and the road and the contour lines could be studied to gain knowledge regarding the incline and decline along the route.

More value would be added to the user if a terrain profile was generated to give users a quick visual of the expected terrain and if distance from the roadway to the pole was automatically calculated without the need to use measuring tools on the map.

Vendor B could build upon this use case in the future to provide alternative paths to the poles, for example focusing on the easiest route on foot or the best route to take a vehicle, as opposed to a direct straight line.

6.2.3.2 Capture of Pole Accessibility Field Notes

6.2.3.2.1 Approach

Users are able to generate an 'assessment job' within Vendor B Tool that can be assigned to any user in the system. The assessment job is used to identify and describe the type of work that is due to be carried out in the field. Once the server has created the job, the assignee is able to sync the job to their mobile device to take into the field. Once in the field, assessment related notes, comments, observations, pictures and such like can be recorded and saved to the job.

When the user re-connects to a network (cellular or Wi-Fi), the job can be synced back to the server to make all information collected available to other users. A workflow can also be followed to transition the job from one group or user to another to enforce data integrity.

6.2.3.2.2 Results

The Vendor B Team successfully demonstrated the creation of an assessment job, showed how the job could be synced to a mobile device, executed and re-uploaded to the Vendor B Tool (see Figure 42). All teams could see value in this functionality, particularly the Environmental Team, due to the huge time and efficiency saving potential.

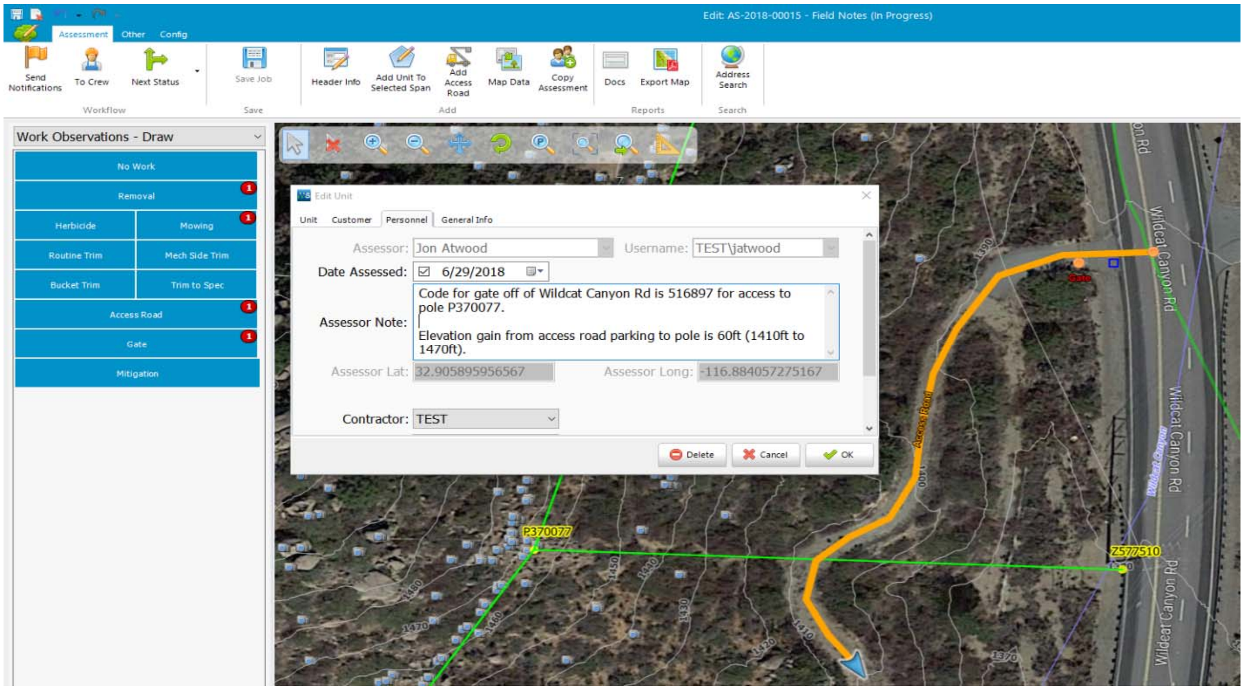


Figure 41: Field Notes Example

6.2.3.2.3 Conclusions

Vendor B showed how the Vendor B Tool could be extended to provide mobile functionality. The Vendor B Team successfully demonstrated how an assessment could be created and completed on a mobile device, such as a tablet. This provides tremendous benefits for in-field data collection. Where there is no network service, the assessment is synced back to the server when connection is re-commenced.

All stakeholders could see the benefits that in-field mobile data collection could bring, and this capability should be considered by SDG&E for implementation in the near future.

6.2.3.3 Vendor B Recommendations

Vendor B did not submit individual recommendations for each test case that was demonstrated, however they did submit an overall recommendation for the EPIC project which is outlined below.

Vendor B recommend that SDG&E define and develop a system security policy to allow users that are assigned specific roles and belong to certain groups privileges and access that match their needs. This is known as role-based access control (RBAC). In order to do this, roles must be defined for various job functions then the permissions to perform certain operations are assigned to specific roles. Since users are not assigned permissions directly but only acquire them through their role, management of user rights is simplified.

Since the Vendor B Tool can be configured to handle many other use cases or data analytics, Vendor B would like to hold more meetings with stakeholders to further define the additional use cases and associated workflows that were discussed during the various stakeholder meetings. This would allow stakeholders to make a determination of whether the platform could be a good fit in SDG&E's current environment.

6.2.4 Documented Use Case Recommendations

The use cases documented in this section were not included in the demonstration due to limitations in the baseline dataset as well as time and budgeting shortfalls. Vendor B have outlined their recommended approach for each below.

6.2.4.1 Vegetation Management - Identifying Hardware and Firebreaks

Vendor B propose to tackle this use case using LiDAR, obliques and GIS data. An analysis of the imagery would take place to identify hardware on the poles from a list of known assets. Firebreaks would be identified by analyzing both the LiDAR and imagery. A work search would be created to return the results from the analyses which would be shown on both the map and in the grid.

6.2.4.2 Environmental Services - Identification of Potential Pole Sites

In order to execute this use case successfully, more information is needed regarding the requirements for a potential pole site. At a minimum, Vendor B would need imagery and parcel information, as well as site specific criteria. It is likely that the analysis would be carried out manually and a work search would be created to return the results.

6.2.4.3 Environmental Services - Identification of Vegetation Community

Vendor B would use LiDAR and obliques to conduct a manual analysis of vegetation type by comparing with known sources. Where possible, obscure or unknown vegetation type found in imagery would be verified by a subject matter expert. A work search would be created to return the results.

6.2.4.4 Environmental Services - Identification of Birds' Nests on Poles

Initially, Vendor B proposed to use oblique imagery to view the poles and possible nests. An analyst would manually assess each image to check for the presence of a bird's nest and a GIS layer would be created to display the results. Once enough imagery was collected, the assessment process could be automated.

6.2.4.5 Environmental Services - Identification of Noxious Weeds and Invasive Species

LiDAR and oblique imagery would be used as part of the identification process. An analysis would be set up, with defined parameters that could be run. Results would show visually on the map and in the grid by means of a work search.

6.2.4.6 Environmental Services - Identification of Staging Yards

To begin with, Vendor B proposed to use oblique imagery to manually identify staging yards according to the criteria defined by SDG&E. An analyst would manually assess each image to check for suitable areas and a GIS layer would be created to display the results. Once enough imagery was collected, the assessment process could be automated.

6.2.4.7 Environmental Services - Comparison of Pre- and Post-Construction Work Areas

Vendor B would use LiDAR, obliques, GIS and PLS-CADD data to make the comparison between pre- and post-construction work areas. This would be handled by manually assessing the data and identifying differences in the areas over time. A work search would be created to allow the users to view and filter the results.

6.2.4.8 Documented Use Case Conclusions

Vendor B provided low-level approaches and recommendations for the documented use cases that were not included as part of the final demonstration. These included the following:

- Vegetation Management
    - Identifying Hardware and Firebreaks
- Environmental Services
    - Identification of Potential Pole Sites
    - Identification of Vegetation Community
    - Identification of Birds' Nests on Poles
    - Identification of Noxious Weeds and Invasive Species
    - Identification of Staging Yards
    - Comparison of Pre- and Post-Construction Work Areas

For all these use cases, the main approach involves the manual assessment of data to produce results. There is potential to automate some of the processes once enough data has been collected. Manual assessments of data, although useful, can introduce human error and inconsistency, which in turn reduces accuracy.

Automating the analytics and introducing machine learning to produce accurate results and analytics quickly and consistently, would be a useful capability addition to the Vendor B Tool.

6.2.5 Vendor B System Recommendations

The recommendations outlined below were discussed and presented by the stakeholders during the Vendor B demonstration and apply to their tool.

View Images from LiDAR Viewer

It would be useful if a user could view images directly from the LiDAR viewer for further clarification, for example, this may allow a user to determine what species a tree is or get a clearer idea of the terrain.

Terrain Profile

Although the vendor system contained contour lines that were derived from LiDAR, there was no mechanism to automatically determine the distance and gradient to a pole when considering its accessibility, this had to be done manually by the user. Ideally, the system would calculate this automatically and display it as a terrain profile as shown in Figure 43.

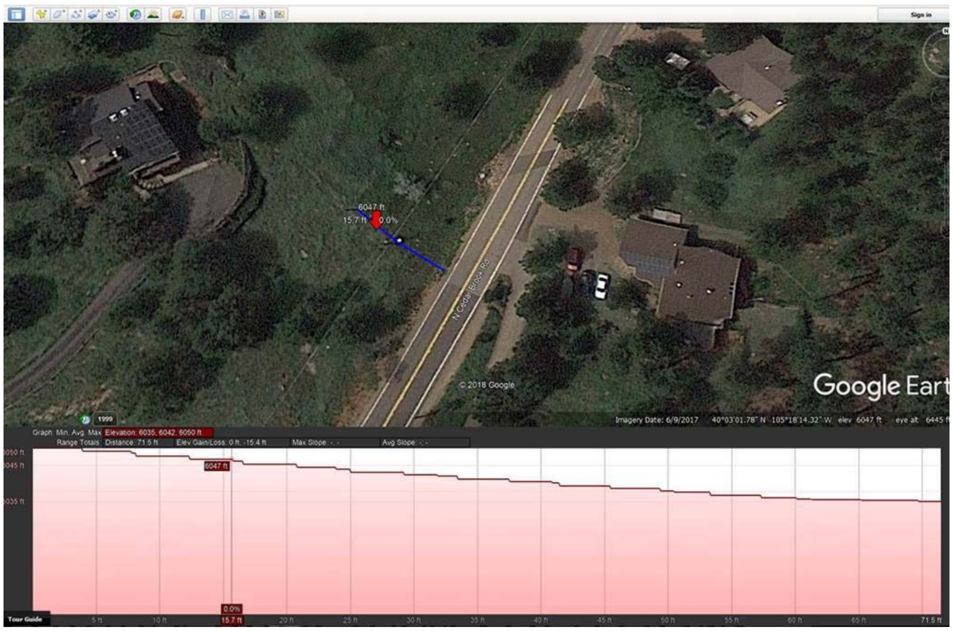


Figure 42: Terrain Profile and Grade from Pole to Nearest Roadway[8]

Tree Growth Patterns

Although Vendor B were successfully able to demonstrate vegetation encroachment during this round, they did not demonstrate or document how they would build upon this to identify tree growth patterns. Tree growth pattern analysis is an extremely important tool that can be used to assist the Vegetation Management Team with planning their maintenance works. Vendor B may consider further research and development of tree growth pattern analysis, if they are selected as a vendor in future EPIC projects.

Develop Machine Learning Tools

[8] Image taken from Google Earth. Retrieved from: https://earth.google.com/web/

Vendor B's recommended approach for future use cases are focused on manual analysis, where an analyst will pore through a dataset, for example oblique imagery, looking for a feature of interest. Vendor B should consider developing or outsourcing machine learning techniques to carry out this analysis to reduce the time burden and improve accuracy and confidence of results.

Automatic Retention and Removal Mechanism

Data that is ingested into the Vendor B Tool is stored indefinitely until an administrator goes in and manually deletes the information. A workflow should be implemented where retention periods could be set on ingestion, and the data be automatically removed once they elapse. Overall data management would be improved, removing redundant data improves system performance and makes it easier for the user to find what they are looking for.

6.2.6 Vendor B Project Summary

With SDG&E looking to introduce innovative technologies to improve business processes and increase efficiency, this EPIC project has allowed Vendor B to showcase the Vendor B Tool. Vendor B Tool could be used as a single, centralized repository for the vast plethora of SDG&E data and has functionality to manage the data throughout the full data lifecycle from collection to removal.

Vendor B showed how their system could be used to conduct the required analytics to accomplish meaningful results for the test cases. With further discussion with the stakeholders, additional analytics could be developed to incorporate different use cases, datasets and work searches to meet the needs of SDG&E end users.

7.0 Requirements for Prospective SDG&E System

This section outlines the vendor-neutral requirements for a prospective SDG&E system to act as a central repository, with advanced data analytics capabilities, to increase internal efficiency and productivity. The requirements specification is based on how the stakeholders foresee the prospective system working and were captured throughout the use case development process. This requirement specification is designed to be used as a basis for any full-scale commercial deployment of such system that may occur in the future.

7.1 Requirements Specification

The prospective system requirements have been categorized into functional (general, system services, mobile data capture, advanced analytics), non-functional and collection requirements and are outlined below.

7.1.1 Functional Requirements - General

ID: FR1

Title: Central Repository

Description: All data must be held in a central repository. The repository must be capable of ingesting the following data types: LiDAR, RGB oblique imagery, RGB nadir imagery, RGB video, GIS shape files, Powerworks shape files, PLS-CADD models, ultraviolet data, infrared data, field notes and other supporting documents (PDF, XLS, KMZ, DWG).

ID: FR2

Title: Geospatially Referenced Data

Description: All data must be shown at the correct location on the map. Pins must show where the data is on the map. When a user clicks on the pin, information about that asset or data point must be displayed.

ID: FR3

Title: Draw Bounding Box

Description: Users must be able to draw a search box on the map and all georeferenced data in that area must be displayed. Pins must show where the data is on the map.

ID: FR4

Title: Measurement Tools

Description: Measuring tools must be available to measure distance, area and volume on the map.

ID: FR5

Title: Attribute Fields

Description: Each asset much have associated fields to store attribute data.

ID: FR6

Title: Marker Clusters

Description: Marker clusters must be used to display larger numbers of markers on a map. As a user zooms into any of the cluster locations, the number on the cluster will decrease, and the user will begin to see the individual markers on the map. Zooming out of the map consolidates the markers into clusters again.

ID: FR7

Title: Zoom and Pan

Description: To move the map, users must be able to click and hold the left mouse button and drag the map to an area of interest. Alternatively, the map could be moved north, south, east or west using the pan arrows. The central pan button must re-center the map, returning to the last result.

ID: FR8

Title: File Viewer

Description: Users must be able to view Microsoft Word documents (DOC), Adobe PDF documents (PDF), Microsoft Excel spreadsheets (XLS), video files, picture files, text files and binary files in a file viewer.

ID: FR9

Title: Spatial Layers

Description: The system must have capability to ingest and display spatial layers on a map that can be switched on and off as required. Examples include road layers, aerial imagery and water bodies.

ID: FR10

Title: Pole Centric Data

Description: There must be an option to link data to a pole.

7.1.2 Functional Requirements – System Services

ID: FR11

Title: Data Categorization

Description: Data must be categorized by date/time, by type, by source (camera, UAV, helicopter etc.), by angle (for images) and by x, y, z coordinates (location).

ID: FR12

Title: Search Function

Description: Data must be searchable by a pre-defined keyword, by date, by type, by source and by location.

ID: FR13

Title: Reporting Function

Description: Users must be able to generate reports against selected criteria. Criteria must include pre-defined keywords, date ranges, data type(s), data source(s) and location(s). The full history of each asset should be displayed.

ID: FR14

Title: Download Function

Description: Users must be able to download data and reports from the system in PDF and XLS formats.

ID: FR15

Title: Print Service

Description: Downloaded data must be printable.

ID: FR16

Title: Batch Data Upload

Description: The system must have a bulk upload function to allow large quantities of data to be uploaded from an CSV file in one action.

7.1.3 Functional Requirements – Mobile Data Capture

ID: FR17

Title: Mobile Data Tool

Description: A mobile data tool and customized app must be available for the collection of field data.

ID: FR18

Title: Timestamped Data

Description: All collected data must be time and date stamped.

ID: FR19

Title: GPS Capability

Description: The mobile data tool must have GPS capability to provide geolocational and time information about where and when data was collected.

ID: FR20

Title: Voice Recognition Software

Description: The mobile data tool must have voice recognition capability to allow dictation of field notes.

ID: FR21

Title: Offline Capability

Description: The mobile data tool must have an offline capability that allows data collection when there is no internet connection. Collected data must automatically sync with integrated systems when connection is resumed.

7.1.4 Functional Requirements – Advanced Data Analytics

ID: FR22

Title: Identification of Equipment on Poles

Description: The system must be trained to automatically identify the following equipment on poles; universal fuses, open link fuses, enclosed cutouts with universal fuses, solid blade disconnects, in-line disconnects, lightning arresters, non-porcelain lightning arresters, hot tap clamps, split bolt connectors, fargo connectors, LM connectors, grasshopper air switches and transmission air switches.

ID: FR23

Title: Identification of Firebreaks

Description: The system must be trained to automatically identify firebreaks at pole feet.

ID: FR24

Title: Automatic Measurements

Description: The system must have the capability to automatically measure the radius of the firebreak and flag those that have a radius of less than 10 feet.

ID: FR25

Title: Comparative LiDAR Analysis

Description: The system must have the capability to compare historic LiDAR data with current LiDAR data to identify vegetation growth patterns and pole lean. Poles that lean by more than 10 degrees must be flagged.

ID: FR26

Title: Image Analysis

Description: The system must have the capability to analyze images to determine tree health through color change and calculate pole lean angles. Poles that lean by more than 10 degrees must be flagged.

ID: FR27

Title: Identification of Potential Pole Sites

Description: The system must be trained to identify potential pole sites.

ID: FR28

Title: Identification of Vegetation Type

Description: The system must be capable of identifying and distinguishing vegetation type.

ID: FR29

Title: Identification of Birds' Nests

Description: The system must be trained to identify birds' nests on poles and within vegetation.

ID: FR30

Title: Identification of Noxious Weeds and Invasive Species

Description: The system must be capable of identifying noxious weeds and invasive species and giving a determination of their variety.

ID: FR31

Title: Identification of Staging Yards

Description: The system must be trained to identify potential staging yards according to the following criteria:

- Staging yard should be flat with no more than 5% slope, paved or bare ground
- Staging yard must be within a two-mile drivable distance of the poles
- Staging yard must be at least 2 acres in size

ID: FR32

Title: Identification and Categorization of Pole Anchors

Description: The system must have the capability to identify pole anchors and make a determination of the area in which they fall, for example in a water body.

ID: FR33

Title: Comparison of Pre- and Post-Construction

Description: The system must be trained to identify changes in the environment after construction works have been completed by comparing LiDAR, imagery and other data types.

The system must have the capability to identify vegetation types in the pre- and post-construction surrounding areas and calculate the percentage of native species before and after construction.

ID: FR34

Title: Pole Accessibility from Road

Description: The system must be able to determine the accessibility of a pole from a roadway by considering distance, elevation and other environmental features such as the presence of water bodies.

ID: FR35

Title: Auditing

Description: The system must have functionality to select and analyze a random sample of data for audit.

7.1.5 Non-Functional Requirements

ID: NR1

Title: Simple User Interface

Description: The user interface for both the desktop and mobile app must be intuitive and easy to use.

ID: NR2

Title: Interface to GIS (ESRI)

Description: The system must be integrated with GIS.

ID: NR3

Title: Interface to GEARS

Description: The system must be integrated with GEARS.

ID: NR4

Title: Interface to Powerworks

Description: The system must be integrated with Powerworks.

ID: NR5

Title: Interface to Pole Information Data System (PIDS)

Description: The system must be integrated with PIDS.

ID: NR6

Title: Interface to PLS-CADD

Description: The system must be integrated with PLS-CADD.

ID: NR7

Title: Interface to External Aerial Imagery Source

Description: The system must be able to leverage up to date aerial imagery from an external source and present it in a useable format.

ID: NR8

Title: Bind to SDG&E Security Protocol

Description: The system must bind to the SDG&E access control model.

ID: NR9

Title: Role-Based Access Control

Description: Certain data access must be restricted based on the user's role and privileges.

ID: NR10

Title: Protection of Sensitive Data

Description: Access to cultural data must be restricted to authorized users only through use of a role-based access control model.

ID: NR11

Title: Data Retention

Description: Data must be retained according to SDG&E's data retention policy. For construction, the data must be retained for the life of the construction plus five years. Data should not be purged until it is all out of service. For example, linked assets my still be in service even if the primary asset is not. The primary asset cannot be purged until all its affiliated data is out of service.

ID: NR12

Title: Displaying Pole Accessibility Results

Description: Pole accessibility results must be calculated and displayed according to the following criteria:

Indicator	**Condition**	**Grade**
Green	Normal	<= 1.2
Yellow	Warning	1.3 – 2.0
Red	Alert	>= 2.0

ID: NR13

Title: Displaying Distance from Water Body

Description: The distance from a water body must be calculated and displayed according to the following criteria:

Indicator	**Condition**	**Distance**
Green	Normal	>= 100 ft
Yellow	Warning	51 – 99 ft
Red	Alert	<= 50 ft

ID: NR14

Title: Displaying Pole Lean Results

Description: Pole lean must be calculated and displayed according to the following criteria:

Indicator	**Condition**	**Degree**
Green	Normal	<= 6.9
Yellow	Warning	7 – 9.9
Red	Alert	>= 10

7.1.6 Collection Requirements

ID: CR1

Title: UAS or Helicopter LiDAR Collection

Description: LiDAR data must be collected according to SDG&E specifications (see SDG&E Document TE-0135; Specification for Surveying, Aerial Photography and Mapping of Overhead Transmission and Distribution Line Corridor).

ID: CR2

Title: UAS or Helicopter Imagery Collection

Description: LiDAR data must be collected according to SDG&E specifications (see SDG&E Document TE-0135; Specification for Surveying, Aerial Photography and Mapping of Overhead Transmission and Distribution Line Corridor).

8.0 Project Outcome

In this section, recommendations and prospective next steps resulting from this EPIC project module are presented for the industry to consider.

8.1 Recommendations

8.1.1 General Recommendations

The recommendations outlined below are general recommendations that were discussed and presented by the Project Team to the stakeholders throughout the various project meetings.

Implementation of Data Standards

To guarantee the consistency and quality of data, SDG&E should develop and put into effect data standards to cover the collection, format and maintenance of all data types. Standards provide data integrity, accuracy and consistency and minimize redundant data. Utilizing high quality data allows organizations to make better business decisions and produces cost savings through increased productivity since staff will spend less time reconciling inaccurate and missing data.

Data Retention Policy

A retention policy should be created that considers all data types and data owners to ensure clarity in how long data and information should be retained.

Mobile Data Collection Tool

Currently, much of the field data is collected manually by means of handwritten notes then converted to electronic format on return to the office. The introduction of a mobile tool would streamline the data collection process, decrease loss of information risks, reduce duplication of effort, improve data consistency and provide near instantaneous data transmission.

The mobile data collection tool must have offline capability to allow data collection when there is no internet connection.

Voice Recognition Software

By introducing the capability to allow dictation from within the mobile tool, using voice recognition software, can dramatically increase productivity. Statistics show that productivity may be increased by up to three times in comparison to typing. This capability could be particularly useful when collecting field notes.

Collection of Cultural Imagery

The Environmental Services Cultural Team expressed imagery collected by UAVs must have sub-meter accuracy to realize the most benefits for them.

Field Training Programs

To maximize the value of time spent by employees in the field, SDG&E should consider running comprehensive training programs that cover in field data collection techniques, in field data analysis, equipment use and health and safety considerations.

Batch Uploads

CSV file templates must be developed for all batch upload scenarios. Ideally, one template should be created that can be used for all eventualities. It is important that all reports for batch upload contain GPS coordinates, so they can be georeferenced within the system.

Infrared and Ultraviolet Data

To inform accurate tree health estimates using advanced data analytics, SDG&E should consider collecting infrared and ultraviolet data in areas where tree health assessments must be made. IR and UV data is also critical for detecting hot spots, corona and partial discharge.

Tree Health Data

To ensure consistency, data related to tree health must be collected in a consistent manner and consideration should be given to the season in which the data is collected. Unhealthy and dead foliage can occur on healthy trees in the autumn and winter when the leaves are senescing. Thus, images collected too early in the spring or too late in the fall will produce spurious results.

Locations of Individual Trees

Vegetation Management would like access to a handheld device that can be used in the field to determine and collect the GPS locations of individual trees. The tree location data held in Powerworks is not as accurate as it could be and often trees are not displayed correctly because of grouping and stacking. There is potential to supplement aerial data with terrestrial scans and photogrammetry taken from below the canopy to assist with this.

8.1.2 Recommendations for Vendor-Agnostic System

The recommendations outlined below were discussed and presented by the EPIC Project Team to the stakeholders during the vendor demonstrations and apply to both vendor tools. The project team recommends commercial adoption of this technology for SDG&E.

Link to Customer Information

The vendor system should be integrated with a source of customer information to allow specific users to resolve customer centric concerns.

Stakeholder Group Dashboard

A dashboard should be created for each stakeholder group that contains key information and provides a quick view to overall asset health and recent updates.

User Defined View

A user should be able to create their own default view that allows them to select the layers, labels, zoom levels and other constraints that are most useful for their day to day business. User preferences could be stored within login information.

Current Aerial Imagery

SDG&E personnel must have access to current aerial imagery to conduct their initial desktop analyses accurately. The vendor system must be able to leverage up to date aerial imagery from an external source and present it in a useable format.

Tree Canopies

Ideally, an algorithm would be in place that could calculate the numbers of trees in each canopy and display them on the screen logically using marker clusters. As a user zooms into any of the cluster locations, the number on the cluster will decrease, and the user will begin to see the individual markers on the map. Zooming out of the map consolidates the markers into clusters again.

Retention Policy

A workflow must be implemented within the vendor system that reflects the retention policy and allows data to be flagged with the appropriate retention period on ingestion.

Data relevant to the construction and maintenance of an asset must be retained for the life of the asset plus five years. To accommodate this, a mechanism must be put in place to feed in construction decommissioning dates.

8.2 Next Steps

The internal EPIC Project Team and vendors have worked closely with SDG&E stakeholders to gather and execute on a variety of functional and implementation requirements, and a series of next steps has been jointly compiled. Key areas for consideration include:

Identify IT security and user access controls to maintain data security requirements

This critical topic was briefly discussed during project meetings, but there is much more detail required to implement a system that will provide the right level of access to each user while complying with organizational security requirements.

Determine specific requirements for integration with other operational systems such as GIS and work order management

While there is clearly value in a user interface to the system for data managers, analysts, and occasional users who have access to specific dashboards and reports, there are also valuable uses of the system as an integration point for downstream operational systems. There is a significant opportunity to leverage information from the vendor platforms throughout the enterprise by integrating with these operational systems.

Implement deep learning and other geospatial analytics to automate maintenance inspections, construction planning, vegetation management and other operational workflows

Several examples of automating workflows through analytics were demonstrated, but there are significant opportunities to expand the use of both vendor systems. Both vendor systems can be configured to handle many other workflows and analytics can be developed to support them.

Determine stakeholder requirements for user interfaces and dashboards to ensure analytic results are timely and meaningful

For those users who will be interfacing directly with the system, it will be critical to design ergonomic interfaces to allow easy use of the system. Data administrator, data analyst, inspector, and engineer are a few of the user personas that should be formally implemented.

Ensure UAS imagery and LiDAR is collected to realize the most benefits to stakeholders by informing deep learning and other advanced data analytics

The UAS should be flown in close proximity to the poles to collect imagery and LiDAR data that will be suitable to identify hardware and the firebreaks. Enough data must be collected to allow for an additional training set to train any deep learning tool. Larger datasets available for training result in more accurate and reliable results.

Data collection should be expanded outside of pole corridors to cover surrounding areas. This would inform several key use cases for the Environmental Services team, including the identification of potential pole sites, the identification of staging yards and comparison of pre- and post-construction sites.

Collect more of the same data to allow comparative works to be undertaken to detect changes in the infrastructure and landscape over time.

Expand pole accessibility test case to determine the best route to the pole

Both vendors successfully quantified the straight-line distance and terrain type from the roadway to a pole. This test case be expanded to produce route options to reach the pole where the maximum gradient, proposed vehicle type or on foot, and obstructions, such as canyons, are considered.

9.0 Technology Transfer Plan

9.1 SDG&E Technology Transfer Plan for Project Results

A primary benefit of the EPIC program is the technology and knowledge sharing that occurs both internally within SDG&E and across the industry. To facilitate this knowledge sharing, SDG&E will share the results of this project by widely announcing to industry stakeholders that this report is available on the SDG&E EPIC website and by presentations in EPIC and other industry workshops and forums. SDG&E will also conduct formal presentations of the results to internal stakeholders to encourage adoption, as needed.

9.2 Applicability to Other Utilities and Industry

As technology evolves, utilities are poised to leverage UAS and other data collection technologies to capture high resolution imagery and increase visualization and situational awareness for operations. In some cases, these images have been stored and used by individual stakeholders in different business units within the organizations for their own purposes. This EPIC project module demonstrated the value of having a central repository (data management platform) to store, catalog, and sort data that could be visualized by multiple stakeholders concurrently. It allows the stakeholders to create custom views for their area of operations. It also allows the stakeholders to perform deep learning analytics on the vast amount of data to provide actionable results for applications ranging from automated identification of equipment on poles to tracking vegetation encroachment on power lines. These are just a few of the use cases that the data captured from UAS will enable stakeholders to leverage. All these cases will enable the utilities to perform virtual asset inspection that enhances safety and reliability of power system equipment.

10.0 Metrics and Value Proposition

10.1 Metrics

This project module used various demonstrations to evaluate and measure the value of UAS technology and advanced data analytics tools, provided by vendors. In addition to results from the test cases, the following metrics should be considered by users when assessing the project outcome and/or using the project results:

Maintain/reduce operations and maintenance costs

The project successfully demonstrated how implementing a single centralized repository, UAS for data collection and advanced data analytics can be used to reduce inefficiencies, increase productivity and reduce operations and maintenance costs.

Implementation of a central repository will prevent duplication of effort by preventing teams from inspecting or surveying areas that have already been recently inspected, improve decision making, and result in overall cost savings for SDG&E.

Sending out staff to manually conduct inspections and auditing tasks is extremely time, labor and resource intensive and there are many associated safety and accessibility issues. Collecting and assessing UAS data as a pre-condition to conducting a physical inspection allows the inspection to become much more focused. Having up-to-date UAS imagery can greatly improve inspection planning, reduce the number of hours needed for the inspections, and free up resources to work on other tasks, ultimately resulting in cost savings for SDG&E.

Finally, the implementation of advanced data analytics, to automatically identify areas of interest, for example poles that are leaning, significantly reduces the time, cost and effort required to go into the field and physically inspect each pole. Advanced data analytics can be used to improve day-to-day business processes and realize efficiency savings in a vast number of areas. Key areas where advanced data analytics can be utilized within the industry include planning and forecasting, change detection, feature identification and auditing.

Habitat area disturbance reductions

Not only is the use of UAS more cost effective than most other data collection methods, it is also much more beneficial for the environment. UAS can be sent out quickly and easily to conduct aerial inspections and surveys, while generating minimal disturbance and noise to the surrounding wildlife and habitat. By eliminating the need to have "feet on the ground", plants and wildlife are not affected by humans conducting physical inspections.

Utility worker safety improvement and hazard exposure reduction

Using UAS to collect data significantly improves the safety of utility personnel by reducing the need for manual data collection inspections. UAS has a unique ability to inspect difficult to reach and hazardous areas, meaning that personnel do not have to put themselves in danger by attempting to reach these places. Advanced data analytics is also used to provide data metrics about the health of the infrastructure and surrounding environment, which in turn lessens the amount of field work that is required.

10.2 Value Proposition

The purpose of EPIC funding is to support investments in R&D projects that benefit electric utility customers. The utility EPIC activities are limited by the EPIC ordering decisions to precommercial demonstrations of technologies and integration solutions that provide benefits to customers by promoting greater reliability, lower costs, increased safety, and other designated benefits. This EPIC project contributes to these benefits in the following ways:

Safety

The use of UAS technology enables remote asset management and keeps utility personnel away from hazardous and dangerous terrain. In addition, advanced data analytics lessens the amount of field work needed to identify change, features and equipment within the network area. During emergencies, such as wildfires or other natural disasters, UAS technology can act as a first line of defense in monitoring and tracking the situation remotely, therefore ensuring the safety of personnel and limiting harm to people and property.

Reliability

When collected frequently, UAS data can improve the reliability and accuracy of system data. Having current data is essential in the decision-making process and allows personnel to make business decisions that are reliable and supported. Advanced data analytics can be used to identify issues before they become critical and allows stakeholders to take mitigating action at an earlier stage. This improved ability to plan and predict, in turn increases the reliability of the service offered.

Efficient use of ratepayer monies

The technologies and tools demonstrated in this project significantly reduce the number of physical inspections that need to be conducted. Inspection crews can be deployed more effectively, with a more focused remit, which reduces the time, resources and costs involved, thereby making efficient use of ratepayer monies.

Environmental benefits

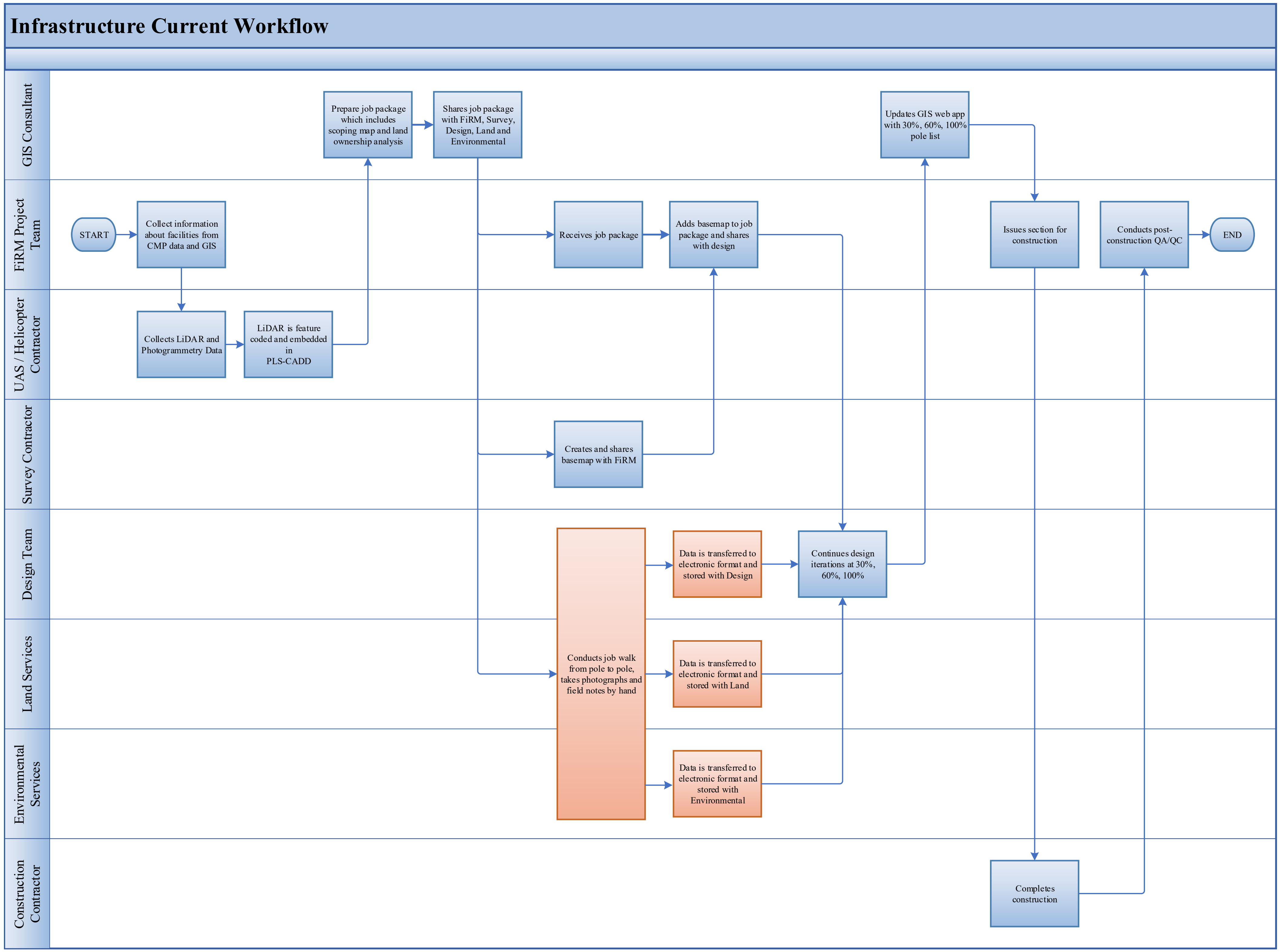
The technologies and tools demonstrated in this project will benefit the environment by reducing the amount of physical activity in remote areas and the resulting disturbance to flora and fauna. The demonstrated solutions will also become part of a larger capability to fight wildfires, vegetation diseases, and other major disasters which would damage the environment.

Barriers and issues resolved that prevented widespread deployment of technology or strategy

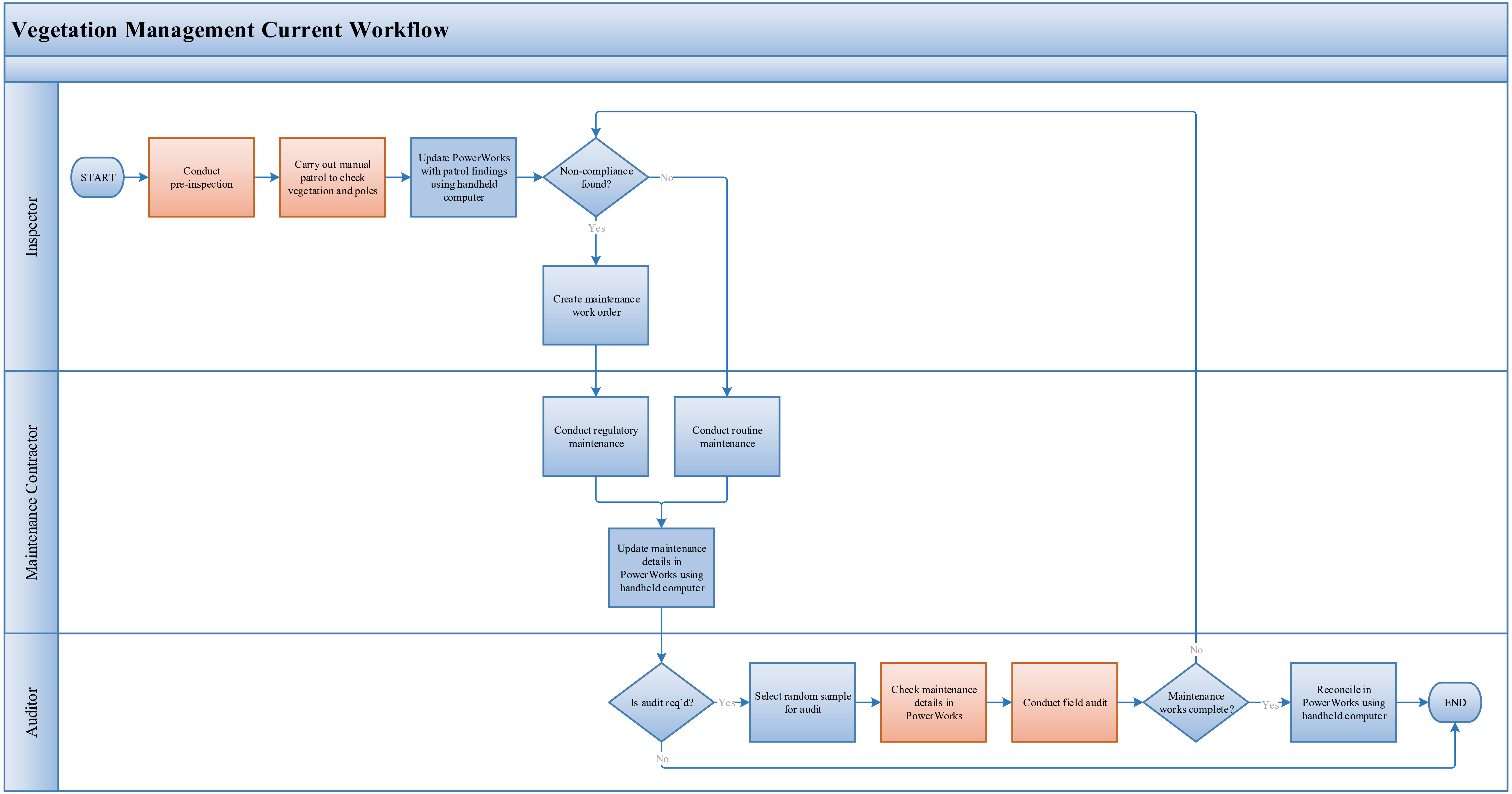
The demonstration work performed in this project confirmed that a major issue that needs to be resolved to enable more widespread use of UAS is improvement of the data handling capabilities. The needed capabilities include an efficient central data repository and better tools for analyzing the data for application in solving specific engineering and operations problems. The demonstration work evaluated specific concepts to aid in decisions on commercial choices for large-scale use. But, more work is needed by the industry to develop better tools.

11.0 Appendices

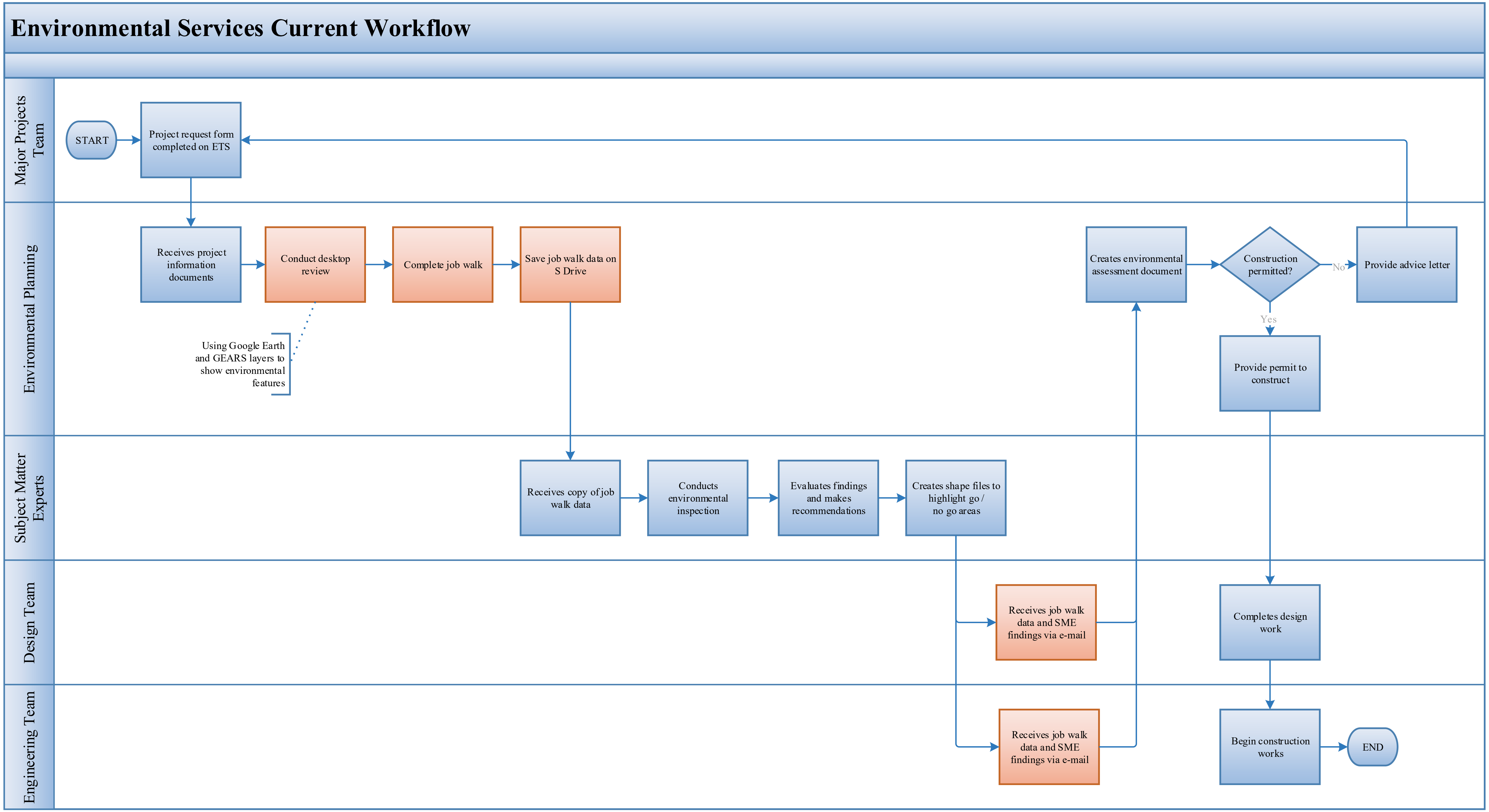
11.1 Appendix A – Infrastructure Current Workflow



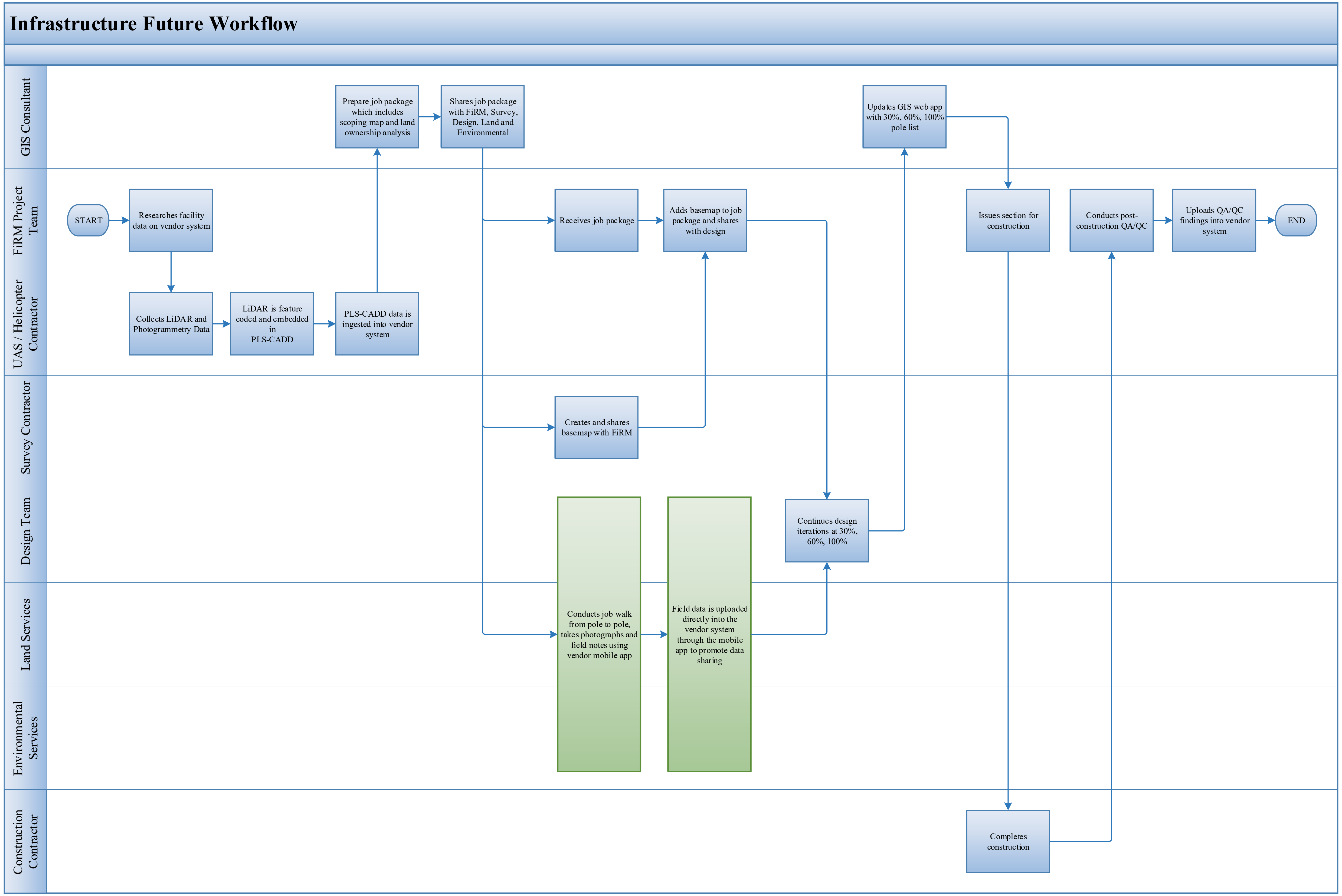
11.2 Appendix B – Vegetation Management Current Workflow

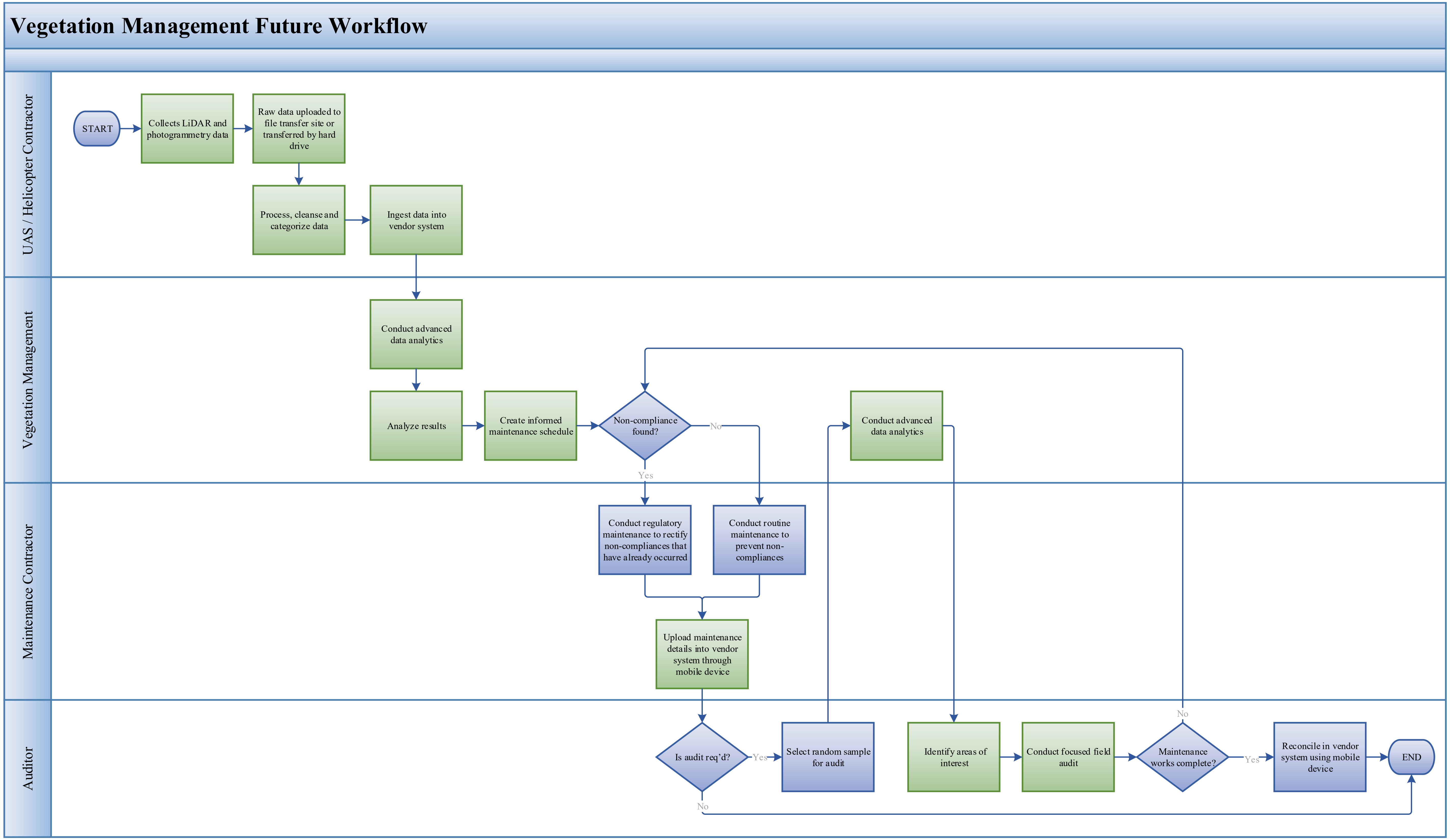


11.3 Appendix C – Environmental Services Current Workflow

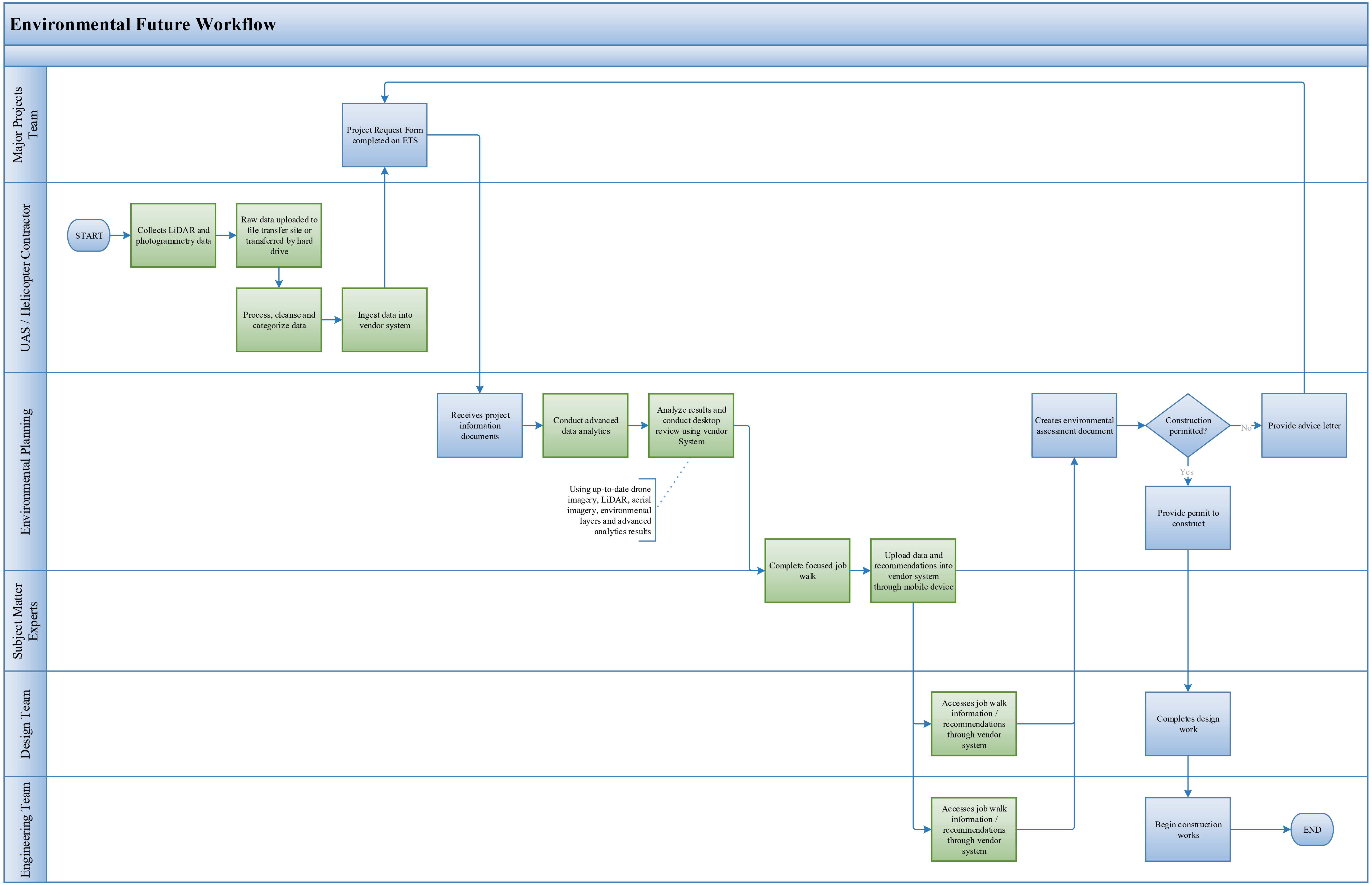


11.4 Appendix D - Infrastructure Future Workflow




Vegetation Management Future Workflow
UAS / Helicopter Contractor
Vegetation Management
Maintenance Contractor
Auditor
START
Collects LiDAR and photogrammetry data
Raw data uploaded to file transfer site or transferred by hard drive
Process, cleanse and categorize data
Ingest data into vendor system
Conduct advanced data analytics
Analyze results
Create informed maintenance schedule
Non-compliance found?
No
Yes
Conduct advanced data analytics
Conduct regulatory maintenance to rectify non-compliances that have already occurred
Conduct routine maintenance to prevent non-compliances
Upload maintenance details into vendor system through mobile device
Is audit req'd?
Yes
No
Select random sample for audit
Identify areas of interest
Conduct focused field audit
Maintenance works complete?
No
Yes
Reconcile in vendor system using mobile device
END

11.6 Appendix F – Environmental Services Future Workflow



11.7 Appendix G – Vendor / Stakeholder Use Case Matrix

Vendor A	Vendor B	Stakeholder Use Cases	
		3.1.1 – Data Collection	Infrastructure
X	X	3.1.2 – Data Ingestion	
X		3.1.3 – Data Storage	
X		3.1.4 – Data Visualization	
X		3.1.5 – Data Retention	
X		3.1.6 – Data Removal	
		3.2.1 – Identifying Hardware and Firebreaks	Vegetation Management
X		3.2.2 – Identifying Tree Growth Patterns	
X		3.2.3 – Identifying Areas of Tree Health	
X	X	3.2.4 - Identifying Changes in Pole Lean	
	X	3.2.5 - Maintenance Audit	
		3.3.1 - Identification of Potential Pole Sites	Environmental
	X	3.3.2 - Identification of Water Bodies	
		3.3.3 - Identification of Vegetation Community	
		3.3.4 - Identification of Birds' Nests in Vegetation	
		3.3.5 - Identification of Noxious Weeds and Invasive Species	
		3.3.6 - Identification of Staging Yards	
		3.3.7 - Comparison of Pre- and Post-Construction Work Areas	
X	X	3.3.8 - Pole Accessibility from Road	
X		3.3.9 – Capture of Pole Accessibility Field Notes	

Common use cases between stakeholders are shown in red.