



Continuous overlapping high-resolution imagery enables detailed inspections of the right-of-way from the office.

Aerial Laser Surveying

Data enables Arizona Public Service to locate and eliminate Clearance 2 violations and facilitate long-range planning.

By **Mike Neal**, *Arizona Public Service*

IF A TREE FALLS IN THE FOREST AND NO ONE HEARS IT, IS THE TREE REALLY A HAZARD?

If a tree causes a Clearance 2 violation and no one knows it happened, is it really a violation? Of course it is! The “hear no evil, see no evil, speak no evil” philosophy cannot apply to utility vegetation management. In fact, utility foresters lie awake at night wondering if they may have a potential violation out there that could lead to the next blackout.

Arizona Public Service (APS; Phoenix, Arizona) recently completed acquisition of aerial LiDAR and imagery data of 4,400 of the 5,000 miles of statewide transmission rights-of-way (ROW) ranging from 69 kV to 500 kV. APS requested rate relief for the LiDAR survey from the Federal Energy Regulatory Commission (FERC), which has approved rate relief for vegetation management practices. Many other utilities have had success getting rate relief from FERC for vegetation management activities since the 2003 blackout.

APS could not honestly say it was in compliance be-

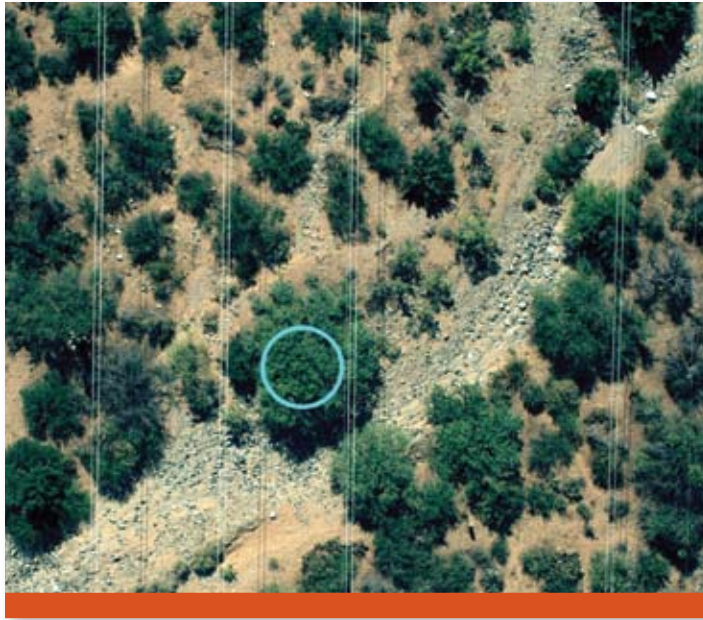
fore getting the data. LiDAR was the only way to know for sure.

VEGETATION MANAGEMENT

APS, Arizona’s largest and longest-serving electric utility, provides electricity for 1.3 million customers in Arizona. The utility’s service territory covers 34,645 sq miles (approximately 32%) of the state of Arizona and provides 13 counties with transmission and subtransmission networks. The transmission networks cover elevations ranging from 6 feet above sea level in the lower deserts to more than 8,000 feet in the mountain areas; lines crisscross with portions of the network extending into the Four Corners area of Northwest New Mexico.

Vegetation management is one of the largest maintenance functions of electric utilities. It is estimated that in excess of \$2 billion is spent annually in the U.S. on preventing and keeping vegetation and trees from conflicting with power lines.

A large number of APS transmission corridors are



LiDAR surveys enable vegetation managers to immediately identify violations that could otherwise go unnoticed.

located on public and Native American lands, making vegetation management work complicated due to environmental and cultural regulations. In addition, North American Electric Reliability Corp. has adopted very detailed vegetation management guidelines that, if not followed, could lead to significant monetary sanctions.

APS is fully committed to comply with all applicable vegetation management standards and regulations by collecting the data necessary to provide digital vegetation clearances with which to identify hazard trees, vegetation encroachments, terrain features, span lengths, sag distances, structure heights and additional critical information using aerial LiDAR and imagery surveys.

AERIAL SURVEYS

APS's knowledge base is dwindling through attrition and retirement. Furthermore, the absence of accurate, current information digitally recorded in a GIS increases the difficulty of covering thousands of miles of remote native and federal lands, which are some of the most beautiful yet dangerous geography and treacherous terrain in the U.S.

Aerial surveys are increasingly being accepted as the most reliable and effective means to monitor vegetation threats to transmission lines. Field crews cannot tell by manual inspection where the conductor will be under all rating conditions without LiDAR. So, APS contacted GeoDigital International (Lompoc, California) to conduct its aerial survey.

As the routes were flown, GeoDigital was able to give APS any Clearance 2 violations at the time of flight and provided a report of GPS locations of all Clearance 2 violations within 48 hours. APS and its contract crews then were able to cut the located vegetation within 24 hours.

LEVERAGING DATA

The aerial survey also provided related information, geospatial features and additional intelligence. This data is extremely useful not only for vegetation management purposes, but also to help better understand and analyze the impact of forest fires that threaten the reliability of the APS transmission system.

Forest fires can disrupt electrical service when they burn under high-voltage lines. In the past, APS relied on the forest service to determine the proximity of forest fires to certain transmission lines that could be affected by raging fires. With the data gathered from the LiDAR survey, APS can address the need for fire-related transmission outages in real time. Now APS is able to provide the forest service with critical information about the exact location and nature of its lines and facilities as well as the terrain and environment, such as slope analysis, vegetation type and health.

The survey data was also very helpful in determining plant health. For example, in the APS service territory, the Bark Beetle kills trees, which only adds fuel to the growing wild fire problem. These dead and dying trees are easily located by aerial surveying.

APS Forestry initiated a pilot LiDAR project in September 2007 on two transmission lines of approximately 100 miles in order to understand and implement a plan for statewide data collection.

GeoDigital International was contracted to implement a project plan to collect the necessary data to conduct vegetation modeling, vegetation management, vegetation clearance reporting and transmission facilities collection for both the pilot line and the statewide collection.

GeoDigital provided high-resolution LiDAR data, ortho images, high-resolution oblique images of each structure and each power-line corridor in a single flight pass, reducing acquisition and processing time, which are key elements in delivering rapid critical vegetation clearance reports within 48 hours of a survey.

Simultaneous LiDAR and multi-sensor data acquisition allows for the creation of true digital orthos and the accurate classification of features being inspected.

LIDAR STEP BY STEP

For the APS project, the imagery was processed using custom software, and LiDAR data was pre-processed to ensure coverage. The post-processing of GPS and aircraft-orientation data generally ran overnight after each flight.

The next day, LiDAR data was post-processed to classify data for ease of use. The tower locations were determined and any available client data such as tower numbers were preloaded. Towers and wires were classified, and line (circuit) data were vectorized using the LiDAR.

Using a custom application, GeoDigital ran a rapid search for Clearance 2 violations based on surveyed conditions and generated screenshots of violations in the LiDAR data, providing the positions of violations in oblique and nadir (downward) imagery. The imagery was then combined with LiDAR screenshots and preloaded APS data to generate the reports, which were then uploaded to a secure FTP.

Many of the tasks associated with the rapid violation reports are automated, taking advantage of the fact that the imagery and LiDAR are collected at the same time from the same system.

CRITICAL DELIVERABLES

The rapid Clearance 2 – Grow-in violation reports are one of many important deliverables specified as part of the APS project to identify and locate all vegetation management issues of their 69-kV to 500-kV electric power transmission ROW. The project includes the collection of vegetation inventory, physical transmission 2-D and 3-D line features, physical transmission structure, and basic transmission feature attributes and numerous additional features.

GeoDigital's Grid[^]Intel generates detailed corridor and power-line models that can be used to predict current and future vegetation clearance issues, and enables APS to effectively plan clearance work and subsequent cyclical maintenance activities, while minimizing the need for confirmatory ground survey activities.

The Grid[^]Intel viewer allows easy access to 3-D LiDAR, ortho image and oblique image on a span-by-span basis. It comes with data defined by 3-D layer points, transmission structure, transmission lines, substations center point and boundary, transmission lines out of substation, intersecting lines to transmission lines, Clearance 2 grow-in and fall-in violations at surveyed and at rated temperature, and Clearance 1 violations at surveyed and at rated temperature.


Another critical deliverable was sag analysis. The analysis was conducted and took into account transmission-line voltage and line-

loading characteristics. Key inputs were temperature, wind speed and line load. GeoDigital software recalculates catenaries to the rated temperature. Danger object detection models were rerun using feature-coded LiDAR data based on line loading.

The results were provided as Clearance 1, Clearance 2 Grow-in and Clearance 2 Fall-in violation reports at estimated rated temperature reports and compiled according to specific APS Clearance Report Criteria, delivered in spreadsheet format and loaded in a GeoDatabase.

A variety of imagery products were critical elements of

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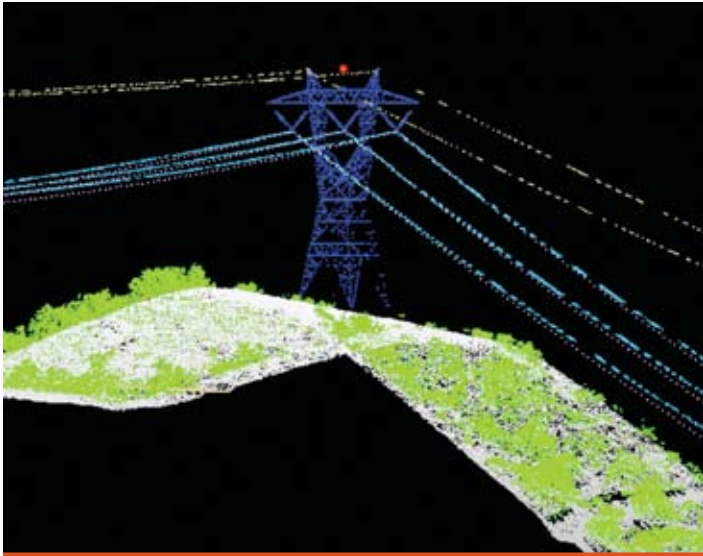


A typical AVMS report showing vehicle location and activity (dots on a map).



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The 3-D LiDAR model is designed for comprehensive vegetation inspection as well as traditional engineering tasks.

virtually every aspect of this project. Digital ortho photos were collected over a 200-ft to 300-ft-wide swath of 6-inch resolution tiff images with world file. Digital photos of transmission structures were linked to physical point location of the structure. The images were linked to GPS, and using the GeoDigital viewer application, APS was able to select a transmission structure point or transmission line to actually see the linked structure photograph. Digital oblique and vertical color photos of ROW are linked to physical point locations, and near-infrared photos are used to visually assess vegetation health.

A Triangular Irregular Network (TIN) was included with points thinned leaving more points in sloped areas and less in flat areas, approximately 1 point in 20-ft by 20-ft area for flat terrain, and 1 point per 5-ft by 5-ft area in steeper terrain. Ground contour data derived from TIN were data delivered at 5-ft intervals.

Landbase deliverables were provided in either ArcGIS 9.2 or 9.3 File GeoDatabase format as required. These deliverables included fences, overhead line crossings,

overhead line crossings above 69 kV, as well as any additional crossings of 69 kV and above that were found in the field. The landbase also included the location and attributes of encroachments and restrictions to vehicle access within the ROW, such as unauthorized man-made encroachments, bird nests, erosion impacting a structure and debris. Access barriers were to include but are not limited to gates, fences, boulders, berms, fallen trees, water, visible erosion and rail crossings.

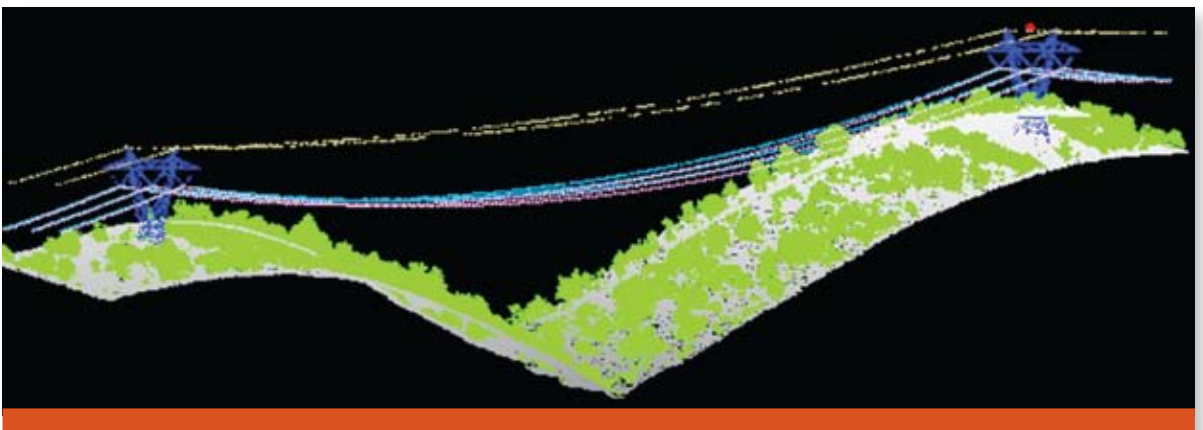
Transmission GIS-related deliverables were provided in ArcGIS 9.2 or 9.3 file Geo-Database format. Transmission-line features provide conductor, shield wire and centerline data to model the transmission network in the GIS. The transmission structure features entailed location and attributes of structures, insulators and attachments. Feature classes included structures, anchor guys, span guys, transformers, fuses and switches.

Vegetation-related deliverables included vegetation location points. This GIS information on clearance violations was used for predictive modeling and further analysis. Clearance 1 and Clearance 2 grow-in and fall-in violations were entered into the GeoDatabase.

Vegetation polygons were created based on the outline of the vegetation features that are taller than 3 feet. These polygons were then split and aggregated to form "units" that stretched from structure to structure along the ROW. The polygons were then further split to form three zones: wire, border and outside of ROW. The dominant species was determined with a percentage, and any other species that are predominant in the polygon are represented by the secondary species fields.

A FUTURE PLAN

The APS project helped establish methodologies for managing vegetation around the utility's power lines and facilities to reduce the overall cost associated with vegeta-



The 3-D LiDAR model allows span-to-span measurable inspection between infrastructure and vegetation. Customized viewers allows easy access to 3D LiDAR and imagery on a span-by-span basis.



Arizona Public Service/GeoDigital International Project Team has helped to establish methodology for managing vegetation around their power lines and facilities by using technology to reduce the overall cost associated with vegetation management maintenance.

tion management maintenance. APS Forestry & Special Programs department is drawing up recommendations to increase its efficiency and effectiveness by optimizing the use of vegetation data. Further, the creation of an inventory that includes mapping of transmission lines, structures and facilities, combined with the ongoing

maintenance of statewide vegetation in a GIS, will allow for continued reuse of the collected data.

APS now knows where biota communities are located within the APS system, which encompasses seven climate zones, and now knows where to concentrate vegetation activity, while assuring compliance to vegetation-clearance requirements. TDW

Mike Neal, Arizona Public Service's manager of Forestry & Special Programs, is an ISA Certified Arborist, an ISA Utility Specialist and a qualified party with the Arizona Structural Pest Control Commission. Neal is a past-president of the International Society of Arboriculture, the Utility Arborist Association and the Arizona Community Tree Council. He currently serves on the ISA Certification board and the ISA Finance committee. He is vice president of the TREE Fund, and treasurer for the Western Chapter of the ISA. In addition, he serves on Governor Brewer's Forest Health Oversight Committee and the EEI Vegetation Management Task Force.



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