

# Applications of LiDAR in seismic acquisition and processing

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## Summary

As land seismic acquisition projects become more complex, technology that allows the ability to plan on, model or otherwise visualize the acquisition area can contribute to making the program a success. Airborne Light Detection and Ranging (LiDAR), with its capability of producing accurate, high-resolution land surface representations, is a tool that supplies valuable information about terrain and vegetative canopy conditions. The application of products derived from LiDAR data can provide significant benefits throughout the acquisition and processing of the project. Specifically, operational cost savings can be realized through source position “preplanning” and elevation substitution.

## Introduction

A relatively new technology, airborne LiDAR, is gaining widespread use in a variety of industries including seismic acquisition. LiDAR accurately measures surface elevation using a laser scanner mounted on a fixed wing aircraft or helicopter. After post-flight processing, high-resolution Digital Elevation Models (DEM's) depicting ground and vegetation surfaces are generated (figure 1). From these, numerous products can be derived using robust Geographical Information System (GIS) software including:

- Contour and slope maps
- Hillshade models which simulate surface terrain illuminated by various angles and heights of the sun (figure 2)
- Elevation values at given locations
- Fly-through simulations
- 3D digital terrain models (DTM)
- Radio Frequency (RF) shadow zone models
- Vegetation extent and height for coniferous forest

LiDAR is capable of imaging beneath vegetation as long as light can penetrate it. Coniferous-type forests generally accommodate this condition while denser deciduous and/or multiple canopied jungles are usually not as amenable.

## Applications

Applications of LiDAR products to land seismic acquisition operations include the following:

- Slope determination - preplanning of source locations, source type identification, locating staging areas, positioning crews to work in downhill directions and illustrating regulation compliance (figure 3)
- Survey efficiency – using LiDAR derived elevation (Z) value for seismic points, instead of acquiring Z with Global Positioning System (GPS) units, can increase the efficiency of survey crews, especially in conditions of heavy vegetative canopy
- Identification of operational hazards – steep terrain, thick vegetation and oilfield infrastructure such as pipelines, well pads and roads
- Map creation – LiDAR DEM's serve as a backdrop and provide the capability to create various themes
- Radio communication - radio transmission and reception models help locate ideal signal repeater locations
- Logistical and safety planning – fly-through simulations on DTM's provide a visualization of ground conditions and hazards that occur on any travel route

## **Background of the LaBarge 3D project**

The LaBarge 3D project covering 240 square kilometers was acquired during summer and fall of 2004. The project was located in the Green River Basin of Wyoming, with surface topography ranging from open prairie to steep foothill-type terrain. The U.S. Bureau of Land Management (BLM) provided permits and regulations covering access to wildlife habitats, operating timeframes and land use restrictions. The project location provided challenging operating conditions with elevation ranging from 2100 to 2750 meters, carbonate outcrops and a thick tree canopy of pine and aspen stands. LiDAR data was collected over the project area well in advance of recording operations. The applications of LiDAR data on the LaBarge program consisted of source preplanning and elevation substitution.

### **Source Preplanning**

The varying terrain allowed for vibrators in some areas and required a dynamite source (buggy or heliportable-drilled) on the remainder. Due to numerous sections of steep terrain and a BLM restriction on vehicles traversing slopes exceeding 14 degrees, heliportable-drilling was required on a large part of the program. The price difference between drilling a shotpoint with a heliportable-rig instead of a buggy-rig was an additional \$470.00 US, necessitating a source preplanning effort to reduce the number of heliportable-drilled shotpoints.

A series of map layers were built including theoretical "preplot" source locations, hazards and avoidance areas. Based on the LiDAR data, layers depicting slopes exceeding 14 degrees and heavy vegetation were also created. Where possible, source points were moved from areas requiring heliportable drilling to areas accessible by buggy drills or vibrators. All source moves were closely monitored in order to maintain the geophysical integrity of the seismic data. The new locations of moved points were provided to the survey crew.

The ability to preplan offered some advantages over making source point moving decisions in the field. It was easier to monitor the source point distribution required to maintain adequate geophysical coverage. When relocating points in the field, it was often difficult to judge slope angles and direction the points should be moved. Additionally, hazardous steep slopes could be avoided entirely.

### **Elevation Substitution**

Surveying on the LaBarge 3D utilized GPS receiving Real Time Kinematic (RTK) corrections from base stations on the project area. A comparison of source and receiver elevation values obtained from the GPS survey against the LiDAR-derived elevations for those points revealed significant differences (3 to 20 meters) on approximately 15 % of the points. These points were concentrated in steep terrain coupled with thick canopy, causing them to be collected in GPS code phase mode due to satellite signal blockage.

Could LiDAR produce accurate elevation values in areas where conventional GPS surveying was unreliable? We conducted a test where we re-occupied several of the points with elevation discrepancies. Three different methodologies (conventional optical, inertial and under canopy GPS™) were applied to re-survey the test points. We found good correlation between the LiDAR-derived elevation values and those obtained by all three methods. With confidence in the LiDAR established, LiDAR-derived elevations were substituted for GPS-surveyed values whenever their differences exceeded three meters.

Elevation substitution was applied during the first stage of data processing, as well. During geometry building, actual first break arrival times were compared to predicted times as a positional check for each source and receiver point. When significant discrepancies were encountered, points were shifted in the processing system to achieve a best-fit solution. An elevation value for the new position was then extracted from the LiDAR data. This process proved beneficial as it provided accurate elevation values for re-positioned points while avoiding costly and hazardous re-surveying.

### **Economics**

The cost to acquire LiDAR data depends on many parameters and varies from project to project. When considering only direct cost savings such as increased survey efficiency, it may be difficult to justify obtaining LiDAR data. It is also difficult to quantify cost savings on factors such as improved safety awareness and better logistical planning, though such benefits exist.

On the LaBarge program, 6780 source points would have required heliportable-drilling in their preplot positions as they were on steep terrain or in heavy vegetation. The final number of heliportable points was 4365 (731 were dropped), resulting in a drilling cost savings of over \$790,000.00 US. While this was over seven times the cost of LiDAR data acquisition, it was impossible to determine how much of the cost reduction was directly attributable to LiDAR. Another economic consideration in acquiring LiDAR data is the potential benefits in downstream operations including planning rig sites, roads, pipelines and flow simulation modeling.

## Conclusion

As land seismic projects are conducted in increasingly difficult environments, it is beneficial to apply technologies that improve logistics planning and data quality. Airborne LiDAR is most applicable in conditions of steep terrain and/or coniferous-type canopy. LiDAR data provides significant benefits throughout the acquisition and front-end processing phases of seismic exploration.

## Acknowledgements

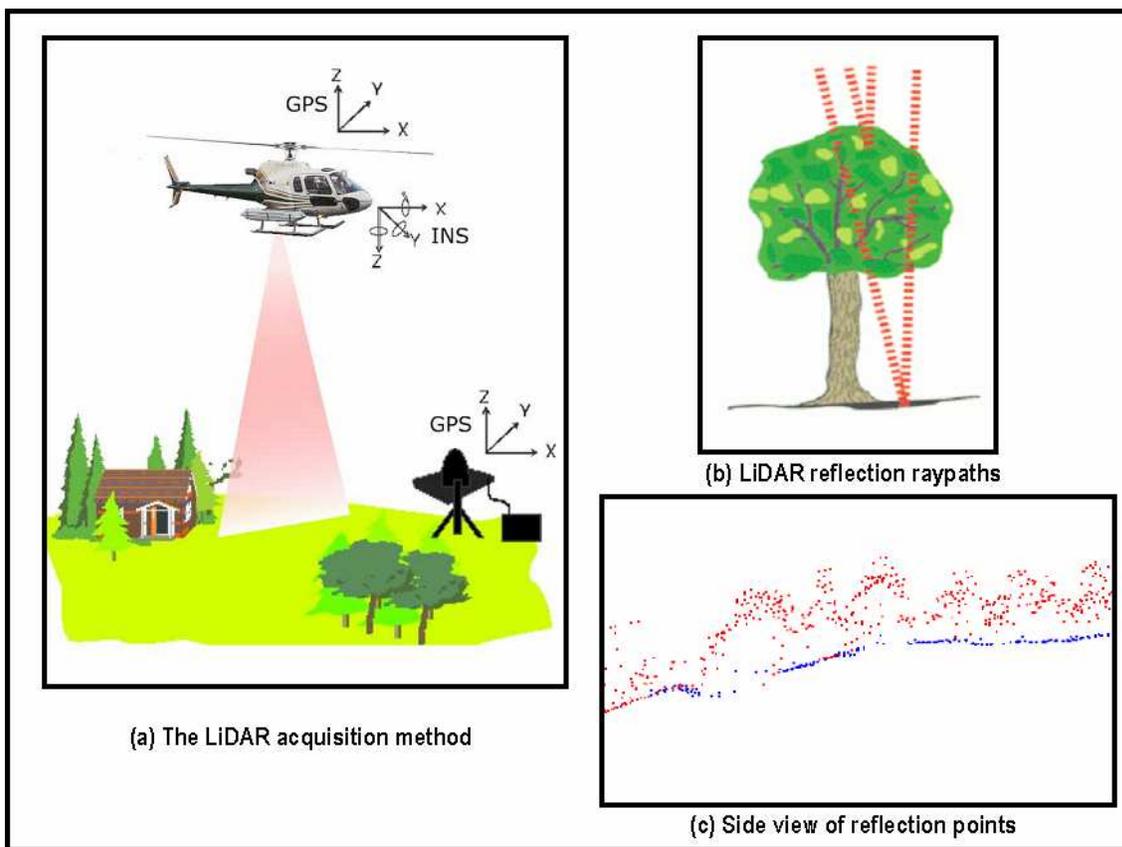
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## For Further Reading

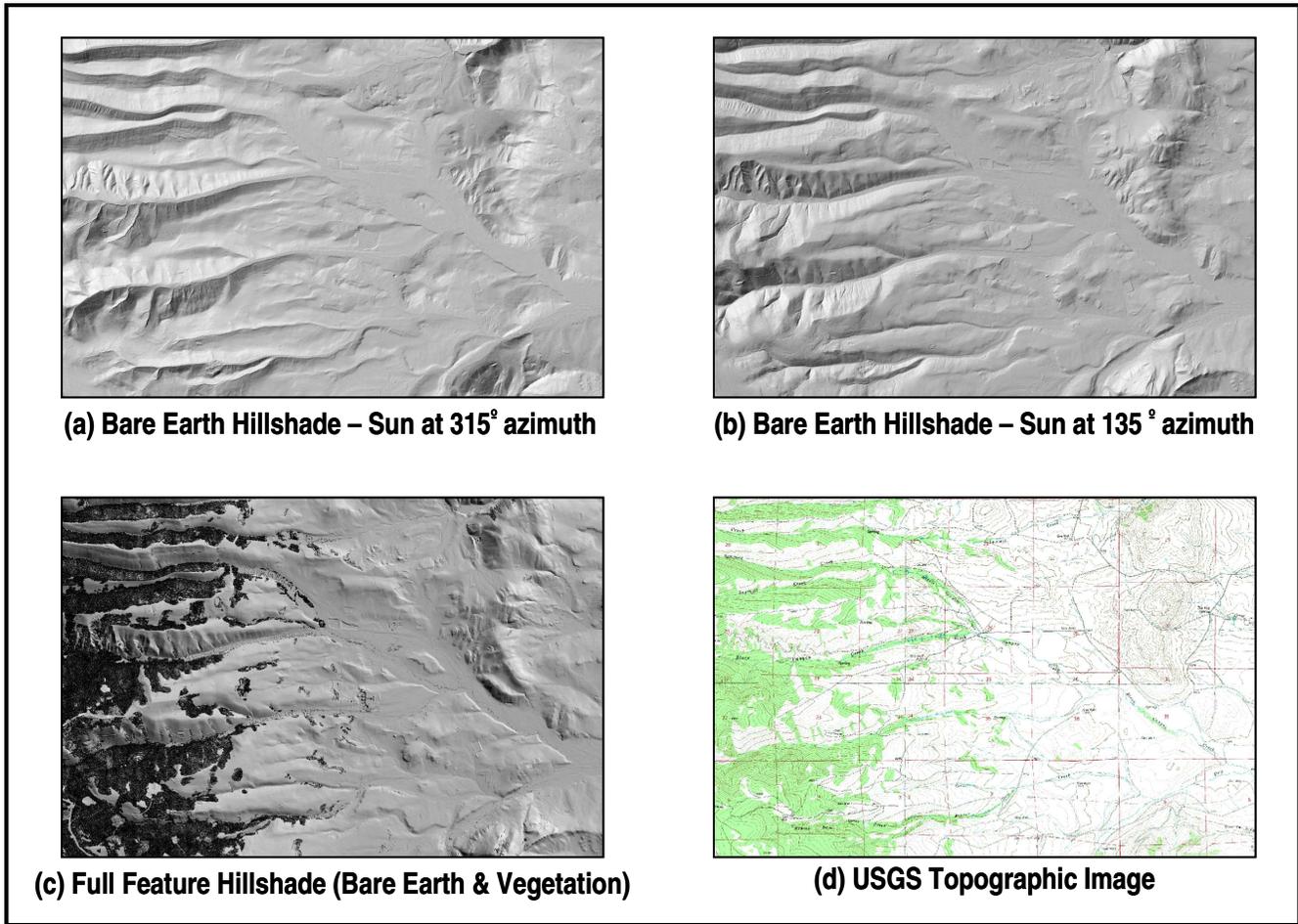
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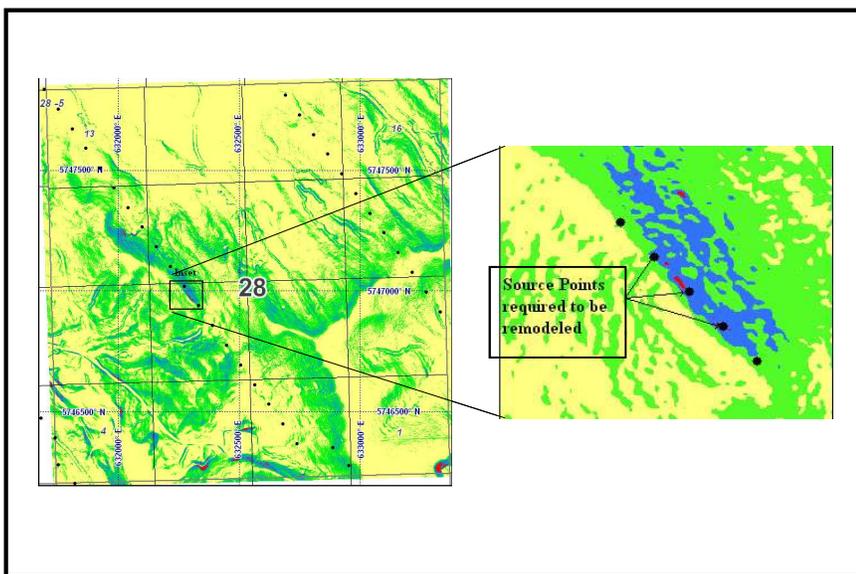
## Figures



**Figure 1.** The LiDAR method. (a) Helicopter-mounted laser scanner is recording the ground and surface object elevations at various scan angles. The positioning components and control are also illustrated. (b) LiDAR reflection points from treetop and ground surface. (c) Side view categorizing ground reflections in blue and canopy in red.



**Figure 2.** Various LiDAR images compared to USGS topographic quadrangle. (a) LiDAR bare earth hillshade image (sun position toward NW). (b) LiDAR bare earth hillshade image (sun position toward NE). (c) Full feature hillshade image. (d) The corresponding USGS topographic image. Note similarity in vegetation with the topographic image.



**Figure 3.** LiDAR shaded relief map with a set of preplot source points overlaid. The blue-colored shade depicts slope conditions too steep for wheeled vehicles. The three points affected can either remain as more expensive heliportable drilling points or be offset to gentler terrain and made vibrator or buggy-drilled points.