New imaging gives close-up look at gas pipeline corridors

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During late spring 2011, two small airplanes flew dozens of sorties over key transportation corridors bisecting Alaska.

Seated in the back of each plane was a technician, surely with an iron-lined stomach and extraordinary sense of equilibrium, enduring the pitching, rolling and yawing while the pilot maintained a nearly constant altitude above terrain that is anything but constant.

Source: Alaska Division of Geological & Geophysical Surveys
A Cessna Caravan loaded with lidar gear.

Like bombardiers dropping payloads on air-raid targets, the technicians released millions of laser pulses from the planes' bellies, pelting the ground and capturing the pulses' echoes.

The entire mission involved a relatively new technology called lidar. It was part of a multiagency effort to understand, map and put into the public realm the precise landscape a North Slope natural gas pipeline would cross.

The data gathered – trillions of bytes of data – is now getting posted on a **state of Alaska website**. And state geologists and geophysicists who commissioned the lidar research – their first foray into the technology – are now getting an extraordinary look at the Earth's surface in a swath of Alaska never before detailed in such sharp relief.

INSIDE STONEHENGE

The term lidar stands for "**li**ght **d**etection **a**nd **r**anging," and it formerly was known as LIDAR or LiDAR – reflecting its birth as an acronym. But like its cousins radar (**ra**dio **d**etection **a**nd **r**anging) and sonar (**so**und **n**avigation **a**nd **r**anging), lidar over time has segued for many into common use and lost its capitalization.

The concept of lidar dates to the invention of lasers about 50 years ago. Soon the military was equipping tanks with laser range finders, and NASA advanced the technology in the 1970s for all sorts of uses in space (including an exact measurement of the distance between the Earth and moon).

But lidar's use in topographic mapping really didn't take off **until the 1990s** as three factors converged: Manufacturers developed sensors that could handle 2,000 to 25,000 pulses per second, global positioning systems and onboard inertial navigation systems could be used to determine the location of each laser-pulse reading, and computers became robust enough to process the data.

Since then, the technology has become more refined.

Mapping the Alaska gas pipeline routes

Rod Combellick with the **Alaska Division of Geological & Geophysical Surveys** said that a decade ago a typical survey would collect, at best, one lidar pulse per square meter of land. Lidar then wasn't very effective in mapping the ground surface if trees had leaves. Because lidar also cannot penetrate snow, its use in many Alaska forested areas was limited. Today, lidar will shoot eight pulses or more per square meter, and even amid leafy trees some of those pulses will reach the ground.

"The high-resolution lidar of 10 years ago is low-resolution now," said Combellick, whose agency commissioned the new lidar mapping of the gas pipeline corridors.

Lidar is put to a **myriad of uses** these days worldwide. Lidar measures changes in glaciers and shorelines due to climate change. It's used to measure forest canopies, model flood zones and watersheds, detect water and air pollution, and plan cellular-phone networks. Archaeologists use it to identify promising dig sites. Urban planners use it for zoning and placing new roads. Police use it to catch speeders (radar guns are used, too). Even automotive engineers have hopped aboard – lidar is at the root of technology that brakes a car automatically when it gets too near the vehicle in front.

Lidar helped find **previously undiscovered topographic banks** defining the Stonehenge monument. In Seattle, it penetrated second-growth forests and urban development to **unmask a dangerous seismic fault** running east-west through town. In New York City, **lidar readings of the World Trade Center ruins** in 2001 aided rescue workers by finding debris likely to shift or collapse.

You get the idea: Lidar has a broad and growing reach.

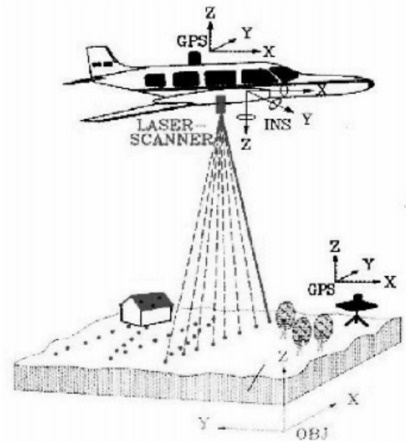
In Alaska, lidar mapping is spotty. The U.S. Geological Survey, U.S. Forest Service and National Oceanic & Atmospheric Administration all have used lidar, Combellick said. So have the Kenai and Matanuska-Susitna boroughs; the latter recently partnered with the Alaska Energy Authority for lidar mapping of the borough's more populated areas, the lower Susitna River valley and the site of the proposed Watana hydroelectric dam.

Some lidar mapping around Anchorage, Fairbanks and coastal communities is available as well.

Lidar mapping that is not in the public domain also has occurred. Both the BP-ConocoPhillips and TransCanada-ExxonMobil gas pipeline projects commissioned lidar mapping of the natural gas pipeline routes they proposed in 2010. **TransCanada and ExxonMobil said this year** that lidar imagery helped discover an active seismic fault in Interior Alaska along the pipeline corridor.

The latest gas pipeline corridor lidar survey was the state Division of Geological & Geophysical Surveys' first venture with lidar, Combellick said.

150,000 PULSES PER SECOND



A diagram of how lidar works.

The pipeline corridor lidar data gathering ran for three weeks in early fall 2010 before weather shut down the work for the season. Lidar imaging resumed on May 17, 2011, and concluded two months later.

Watershed Sciences Inc., an Oregon business specializing in lidar work, won the state contract, priced at about $2.35 million. Funding came from three agencies, two of them connected to a major gas pipeline project from Alaska's North Slope – the state's **Gas Pipeline Project Office** and the **Office of the Federal Coordinator** – and the **Alaska Gasline Development Corp.**, a state agency proposing a smaller, state-sponsored gas pipeline project.

The agencies hope publicly available detailed mapping of pipeline corridors' terrain, based on evaluation of lidar, will help ease agency review and permitting of a pipeline project. Steep slopes vulnerable to landslides that would threaten a pipeline could be avoided. Earthquake faults could be mapped and engineered around or over. Wetlands could be better identified. River crossings planned more astutely.

Source: Alaska Division of Geological & Geophysical Surveys
Cessna Caravan 208B.

Watershed flew two planes equipped with Leica sensor systems: A single-engine Cessna Caravan 208B and a twin-engine Partenavia P-68.

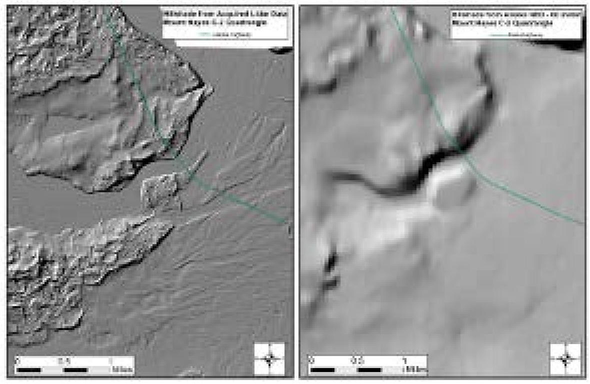
The planes covered three pipeline corridors under consideration: From Prudhoe Bay to the Canadian border, from Delta Junction to Valdez and from Livengood to Big Lake – the last two are possible routes for a pipeline to a tidewater gas liquefaction plant for LNG exports. Flying was good most days. But lidar data couldn't be collected reliably when it was rainy, misty or smoky or when small clouds would drift below the aircraft, said Trent Hubbard, a state geologist overseeing the lidar project. The corridors span over 1,000 miles, so the planes usually could find somewhere to work on any given day.

Source: Alaska Division of Geological & Geophysical Surveys
Partenavia P-68.

The pilots flew their aircraft about 4,900 feet above the ground, an altitude kept nearly constant as the terrain rose and fell because the Leica system was calibrated for readings from that height. The planes' speed was as close to 105 knots as possible.

The aircraft position was measured twice per second. The altitude was recorded 200 times per second, according to Watershed.

As for the Leica system, it strafed a swath of ground, at least a mile wide, with 150,000 laser pulses per second along the entire corridor, covering about 3,000 square miles of Alaska from Prudhoe Bay south.



Source: Alaska Division of Geological & Geophysical Surveys
Image from lidar (left) with one-meter resolution improves on USGS national dataset image (right), which has 60-meter resolution.

Blended together, all these measurements provide a very accurate picture of the ground.

Like its radar cousin, lidar essentially fires a wavelength at an object and times its return. But the lidar pulse is a laser bullet, giving an exact reading of the spot it strikes, providing more precision for mapping the ground than the broad beam of radio waves used in radar.

Over Alaska, each laser pulse provided up to four returns. Each return had its own intensity value that varied with the amount of light absorbed by the object the pulse struck on or near the ground, Hubbard said.

"The returned lidar pulses provide information about the locations and intensity values of the surfaces from which they are reflected," he said.

Raw data then is analyzed. Did the pulse hit bare earth, vegetation, buildings or other man-made structures, water, snow or above-ground pipelines? he said. After the data is classified, a variety of programs can interpret the data and produce topographic contour maps.

A geologist can use the data to identify river terraces, abandoned stream channels, dune fields, glacial moraines, alluvial fans, landslides, faults, permafrost and other features. Engineers can use the data to analyze surface drainage or design bridges. And so on, depending on the user's specialty and interest, Hubbard said.

NEW INSIGHTS

Staffers at the Division of Geological & Geophysical Surveys have begun processing lidar data amassed in 2010 and 2011 and **releasing it to the public**.

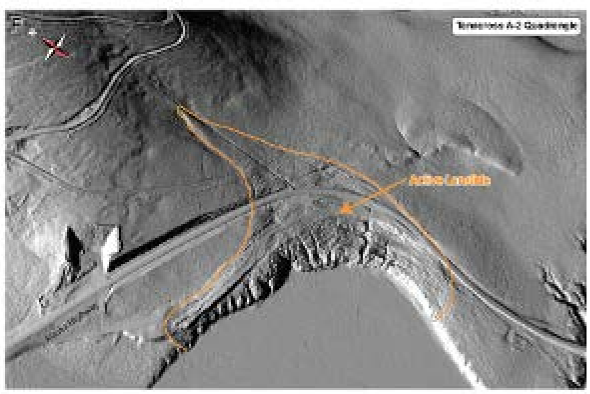
In all, Watershed delivered 11 hard drives full of data – totaling about 5.4 terabytes, or 5.4 trillion bytes of data (think of it as roughly 1.3 million iTunes songs).

So far the division has made available a variety of products derived from the lidar – "digital surface models" containing accurate three-dimensional coordinates, including elevation, and "digital elevation models" showing bare-earth topography. It's possible now to "see" the elevation of the bare earth free from vegetation or buildings, a record of everything above the ground, vegetation, canopy cover, water bodies, hills and laser-intensity images.

Still to come will be release of the raw "point-cloud" data – or the three-dimensional coordinates of the data the laser pulses returned and other information, including the aircraft pitch, yaw and heading.

Ultimately, the division staffers hope to refine how the public can access the imagery, to make it more like how Google Maps works – a detailed, zoomable satellite or map view. The raw data likely will be released through a couple of public-data outlets.

"We don't have a timeline for this yet," Hubbard said.

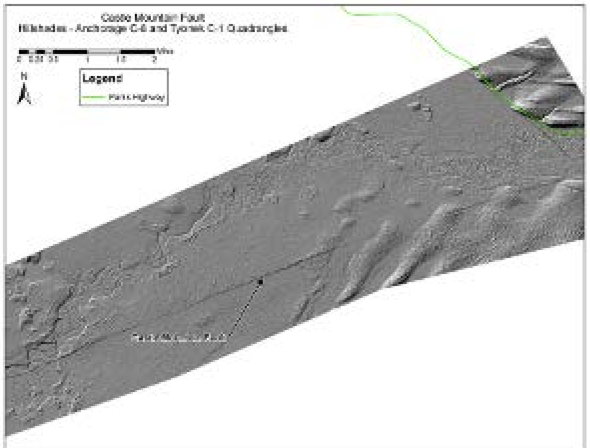


Source: Alaska Division of Geological & Geophysical Surveys
Lidar image showing an active landslide crossing the Alaska Highway.

Separate from the gas pipeline projects, the division is using the lidar data for its ongoing evaluation of active faults and other geologic hazards. In particular, before the lidar project division geologists had been working to improve their mapping along the Alaska Highway from Delta Junction to the Canadian border. That's also a possible pipeline corridor, so now they're delighted to have lidar data from that swath as well.

Already the lidar confirmed a hunch that geologists had about whether the state successfully skirted an unstable slope when rerouting of a section of highway near Northway Junction. Cracks that quickly formed in the new roadbed suggested otherwise. The lidar data showed the instability extends much farther up the slope than previously believed, Combellick said.

Another discovery could change their whole view of the Castle Mountain Fault. That 125-mile fault crosses the lower Susitna valley from southwest to northeast about 25 miles north of Anchorage. It runs between the towns of Houston and Wasilla. A gas pipeline to the Anchorage area from the north would **span the fault**.



Source: Alaska Division of Geological & Geophysical Surveys
Lidar image of the Castle Mountain Fault.

Geologists thought they understood this fault.

But shaded-relief images of the ground surface derived from the new lidar are providing new insights. The images show features along the fault in great detail – abandoned stream channels that cross the fault, tension cracks and tears.

This fresh look will let geologists re-evaluate their previous interpretations of how this fault behaves. And that will help if a gas pipeline is engineered across it.