INTRODUCTION OF AERIAL BASED AND LASER SCAN TOPOGRAPHICS SURVEY FOR USE IN PIPELINE ROUTE SELECTION

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ABSTRACT
An innovative technique for rapid and accurate collection of preliminary survey and mapping in pipeline route selection has been developed by Aerotech L.L.C. and implemented by Lakehead Pipe Line Company, Limited Partnership. The technique involves GPS referenced digital imagery and laser scanned topographical data collected on an aerial platform. Accuracy of laser scanned topographical features up to ± 10 cm absolute ± 2 cm relative can be easily achieved. The data is processed and formatted for AutoCAD and GIS applications such as ArcView.

INTRODUCTION
Lakehead Pipe Line Company, Limited Partnership, an affiliate of Enbridge Inc., owns the US portion of the world’s longest petroleum pipeline. Combined with the Canadian portion of the pipeline system operated by Enbridge Pipelines Inc. the system spans 3200 miles from western Canada through the Great Lakes states, to eastern Canada. The total system transports over 1.5 million bbls of crude oil per day.

Lakehead Pipe Line is currently evaluating several opportunities to expand crude oil deliveries to existing and new markets. Lakehead Pipe Line has contracted with Aerotec, L.L.C. to provide aerial mapping services for a number of proposed pipeline projects across the United States. Aerotec’s mapping service includes conducting aerial based laser scan surveys along the proposed pipeline corridors to establish highly accurate ground contours and topographical features. Additionally, high-resolution digital color imagery is collected along the corridors to provide information for engineering design and route selection and to assist with environmental permitting.

In today's competitive marketplace, it is crucial for pipeline companies to be prepared to quickly react and evaluate business expansion opportunities. To be successful, these evaluations must be efficient and accurate. Combined with the competitive nature of the business, regulatory demands are becoming more complex and demanding of the pipeline developer.

PLANNING AND APPLICATION
Typically, the planning of modern projects requires significant allocation of resources due to regulatory demands thereby adding an extensive amount of time to the early phases of these projects. As regulatory and economic demands often conflict, the resultants are often challenging to manage. Engineers and planners struggle with these factors, and are often challenged to develop innovative methods to reduce costs, and drive accelerated schedules. Opportunities to shorten the planning schedule, or better manage the project cost, without sacrificing safety or reliability, is highly desirable.

Traditional methods for planning typically used during the planning and design phases include (Right of Way acquisition excluded):
1. General route layout utilizing existing corridor route sheets or topographic maps.
2. Surveyed ground targets for traditional B/W aerial photography.
4. GPS ground survey to locate all adjacent structures, utilities, property lines, etc.
5. Semi automatic generation of route sheets using traditional CAD methods.
6. Regulatory permitting including detailed ground surveys, wetland delineation, archeological surveys, etc.
7. Several iterations of steps 4-6 based on reroutes and relocations as a result of data collected above.

The new planning and design process utilizing aerial based laser scan surveys follows a similar, but accelerated process.
1. General route layout utilizing existing corridor route sheets or topographic maps.
2. Fly corridor with laser scan and high-resolution digital imagery.
3. Data processing and reduction.
4. GPS ground survey to locate adjacent buried utilities only.
5. Development of route sheets in CAD/GIS format from data collected (processed ground contours and imagery).
6. Regulatory permitting including wetland delineation and archeological surveys. Environmental scientists and regulatory agencies may be provided access to processed imagery and contours for evaluation and interpretation.
7. Minor iterations of steps 5 and 6 based on reroutes and relocations as a result of data collected above.

The utilization of aerial based laser scan survey allows the designer/planner to bring the field into the office. Color imagery and 3-D relief modeling allow the designer to make design revisions in the office with much less field input and re-survey. Traditionally, design revisions require significant resources and time, sometimes involving several field trips, and re-surveys. With the use of aerial surveys and laser scanning, significant reductions in time and resources can be realized. Table 1 compares traditional planning to advanced planning using aerial surveys and laser scan as realized by LPL. This table shows how the project schedule may be accelerated by 6 – 12 months with savings of up to 6% of the total project cost without adversely affecting the quality of the overall design.

Environmental scientists can also utilize this tool to study and evaluate the proposed route to determine potential sensitive areas, and recommend changes to the route early in the design process. Making changes at this point can usually be implemented without significant impacts to the cost or schedule of the project. Although this tool has yet to be used by environmental scientists in practice, early opinions of some environmental scientists are highly optimistic for the benefits of color and IR imagery and highly accurate contours during the permitting process.

DATA COLLECTION
Aerotec, L.L.C. is headquartered in Birmingham, Alabama with flight centers in Spokane, Washington and Calgary, Alberta. Aerotec began commercial operations in March of 1996 supplying transmission line survey (path-mapping) data to the electric utility industry. After a couple generations of technology evolved, Aerotec began providing path-mapping and large-area mapping services to a variety of industry customers, including the pipeline, electric, mining, highway, forestry and airport industries.
Planning Step | Time required | Cost as a Percentage of Total Project | Accuracy of Project Estimate
--- | --- | --- | ---
Traditional Summary Methods
Preliminary Planning using existing or Topographic Maps | 2 months | < 0.5% | ± 50%
Preliminary Survey and Aerial Photography | 10 months | 0.5% - 2% | ± 20%
Route Sheet Generation | 6 months | 2% - 5% | ± 10%
Permitting | 18 Months | 5% | --

New Aerial and Laser Scan Survey Method
Preliminary Planning using existing or Topographic Maps | 2 months | < 0.5% | ± 50%
Aerial and Laser Scan Survey | 2 months | 0.5% - 1% | ± 20%
Route Sheet/GIS Generation | 3 months | 1% - 2% | ± 10%
Permitting | 14 months | 2% | --

Table 1: Time and cost savings recognized by Lakehead Pipe Line using Aerial and Laser Scan Survey Method

the position of the aircraft and an inertial guidance system is used to measure the roll, pitch, and yaw of the aircraft. On board computers collect, correlate, and record laser scan and GPS data for post processing.

The development of a practical and reliable laser-scan instrument was pursued through Saab Survey Systems (a military division of Saab). The TopEye system, a rugged, commercially viable instrument was developed, complete with an inertial stabilized (INS) platform, highly accurate dual-frequency GPS positioning, and a highly accurate pulsing/scanning laser range-finding system.

4. Navigation control inside helicopter

The TopEye instrument is flown aboard a helicopter to provide a stable airborne platform and to provide the agility necessary to acquire accurate laser-scan survey data in a variety of real-world circumstances.

Subsequently, a military-style pilot navigation system installed on the helicopter controls the flight path so the pilot does not have to rely on ground-based landmarks. The geographical position of each video frame (photograph) is tracked by time stamping with the GPS-time. The video cameras are augmented by the use of high-resolution color digital framing cameras.

DATA PROCESSING

A ground reference station is positioned over a known monument in order to correlate the collected data with the monument's given horizontal and vertical geographic position. This level of geo-referencing ensures the highest practical accuracy during post-processing of the GPS data.

The geographical positioning of objects in the field of view of the cameras is greatly enhanced during post processing. No special equipment is required to handle the digital aerial images. However, to make the system commercially viable, computer software was developed to classify the laser-scan survey data into "ground", "vegetation", and "man-made object" categories and to reduce the data volume to a manageable quantity. After the post processing, the data is ready to be used for engineering and mapping applications.

GROUND SURVEY AND MAPPING

Concurrent with the aerial survey, a ground survey is conducted to provide a checking system for the newly developed aerial survey. The ground survey is used to correlate easily identifiable objects on the digital imagery such as roads, fences, etc., and to accurately locate adjacent underground utilities, which the aerial survey is unable to locate. The ground survey is also used to verify the accuracy of ground elevations and contours as developed by the laser scan survey.

5. Plan & profile used for route sheet

It has been determined one GPS monument is required for every 10 miles of corridor to ensure adequate accuracy. It has also been determined a corridor width of 2000 feet is optimal for aerial imagery and 500 feet for the laser scanned contours. Wider or narrower corridor widths can be collected for specific project requirements. The individual State Plane Coordinate system for the state in which the data is collected is used for both the ground survey and the aerial survey.

Ground survey data is collected and compiled into a CAD system. All existing features collected are drawn and maps are produced from this data. The aerial photos are compiled into TIFF files and overlaid onto the existing ground survey file thus providing the final comparison of the data. The combination of the ground survey and the aerial images provide the ability to create very detailed and accurate maps of...
the corridor. A three dimensional model and a profile of the ground is created, thereby providing the ability to view the corridor of the proposed pipeline in a manageable view.

6. Pipeline profile

The CAD software provides the ability to zoom and pan throughout the route and focus on specific critical areas in the corridor on the computer screen. The high-resolution color images provide the capability of readily identifying obstacles such as overhead power lines, water bodies, and edge of roads in great detail.

After studying the details of the corridor the preliminary route of the proposed pipeline is developed. Creating cross sections where necessary along the proposed route allows the engineer to see the affect of the new line on other adjacent utilities and topographical features.

7. Pipeline corridor section

The route sheets are easily developed and other necessary information such as pipe materials, crossing information, wetland information, are filled in.

8. 3-D topographical scan survey

Laser scan terrain model data and digital imagery can be combined within a pipeline geographical information system to provide several useful applications. High resolution color digital imagery allows for effective planning and timely assessment of environmental conditions, right-of-way encroachments and access restrictions in the vicinity of pipelines. Laser scan terrain model data provides very detailed elevation contours and ground profiles which are useful for determining possible valve and pump station locations along the pipeline.

SUMMARY

Lakehead Pipe Line has implemented the laser scan survey methods to evaluate two proposed projects, and will continue to utilize this technique in the future. The information and data collected with this technique is of higher quality and collected in a shorter period of time, resulting in significant cost savings for the project. The results have been very impressive and it is anticipated this technology will have far-reaching benefits through construction and well into the operation of the pipeline facilities.