Airborne LIDAR for Obstruction Mapping: Enabling Flight Safety

Key points
- Airborne LIDAR is an effective tool for collecting airspace obstruction data at airfields, leading to safer airspace navigation
- The FAA has recently adopted LIDAR as a key technology to be utilized in the detection and mapping process of obstructions as laid out in (draft) AC 150/5300-17C
- Further developments are in the works and research continues to refine the efficiencies of operation and the accuracy of data collected

Introduction
As laser scanning has evolved and matured, it has increasingly become a new and eventually necessary tool in many industries. One area that has benefitted from the application of laser scanning is aviation safety. Airborne LIDAR (Light Detection And Ranging) is used to detect and map obstacles that intrude into the airspace through which aircraft fly (Figure 1). Ground-based LIDAR (mobile and static scanning systems) technology also has recently been used to map/image ground objects such as taxiway signage, lighting fixtures, weather and communications structures, aids to navigation (NAVAIDS) and other manmade and natural features on and immediately adjacent to the airport. Additionally, there is growing use of mobile and static scanners to image and map airport infrastructure such as the interior and exterior of airport terminals as well as apron, baggage-handling and other ancillary structural features found at an airfield.

The application of airborne LIDAR to obstacle detection and mapping provides...
critical information for flight safety as the FAA uses the information to make decisions about flight procedures at and around the airfield. In addition to mapping obstructions, airborne LIDAR utilization provides the airport operator and the FAA with detailed data for input to airport layout plans (ALP) and geographic information systems (GIS). The FAA sets out a guide for contractors and sponsors looking to fulfill the requirements for these surveys and data collection: Guide to Airport Surveys.

**FAA and LIDAR**

Safety of flight is an obviously paramount concern of the FAA (14 CFR Part 77, updated July 21, 2010; Safe, Efficient Use and Preservation of Navigable Airspace). One aspect of ensuring safety (avoidance of flight into fixed objects) to all landing and departing aircraft requires determining the location of obstacles (sometimes referred to as obstructions) located in the airspace navigated by aircraft. Specifically, the geo-positions of the obstructions are evaluated against a virtual “surface” to determine whether they penetrate the 3D area known as an Obstruction Identification Surface (OIS)—also sometimes referred to as an “intrusion surface”—http://www.ngs.noaa.gov/AERO/OIS/ois.html. Figure 2, depicts such an OIS, which may have as much as a 40:1 or 70:1 slope relative to the runway and typically includes the airfield and approaches.

The OI surface provides a limit (plus a safety margin—CFR 77.19) to where aircraft may operate. The integration of the various surfaces can be complex as seen in Figure 2. Obstructions consist of everything from terrain, buildings, towers, poles, antennas and trees to impermanent structures such as construction cranes. Flight procedures are then developed for aircraft to avoid the obstructions using FAA obstruction evaluation requirements. The FAA spends many man-hours developing airport obstruction charts (AOCs) and other products such as eALPs that ultimately allow pilots to avoid these obstacles and fly with confidence and certainty to and from airfields.

Currently, the FAA relies on an Advisory Circular process (AC) regarding airports and activities around the airport. Specifically, AC 150/5300-17B which addresses the use of remote sensing technologies in collecting data describing the physical attributes of an airfield and related. These AC’s guide the users in the acceptable methods and standards in the data collection process while employing remote sensing technologies.

Until recently, LIDAR was not considered an (officially) acceptable method to collect geo-data regarding obstructions. While many contractors who were tasked with providing obstruction information for the FAA to incorporate into flight procedures and aeronautical charts actually employed LIDAR, they have not typically labeled it as LIDAR-derived. Rather, the contractor only needs to submit a list of obstructions and the associated geo-coordinates and feature attributes.

In 2011, following more than a decade of research (some of it initially sponsored by FAA) a draft version of the replacement AC (AC150/5300-17C) was released for review. In the draft AC, there is new, detailed language specifically concerning the use of LIDAR as a remote sensing tool for the collection of geo-data about airport obstructions. In addition to the historical use of aerial imagery, LIDAR is now described as another technology which airport survey contractors...
may utilize. Also, the draft release is intended to provide the contractors submitting the obstruction data with “the standards and recommended practices for using remote sensing technologies in the collection of airport data.”

The replacement AC goes on to discuss some of the major changes to sections covering the uses and limitations of technologies other than aerial imagery (including satellite imagery).

Advisory groups, such as the Transportation Research Board (TRB), AV070 Airports GIS Subcommittee (DA0301) have played a significant role in advancing the acceptance of LIDAR as a remote sensing tool for airport obstruction mapping and identification. Their work was wrapped up this summer and feedback submitted to the FAA for review.

Furthermore, GPS navigation technology has enabled tighter and more numerous approach procedures at airports (GPS Approach Minima). This means lowering the clearance minima and at the same time broadening the area where approaches and maneuvering may take place. Therefore, a greater area surrounding the airfield must be now checked for obstructions. Also, as the FAA moved from the older 405 aeronautical standards (FAA405, rescinded in 2006) to the newer area navigation approach (ANA) standards (described in AC 150/5300-17B and AC 150/5300-18B), a greater area surrounding the airfield than before must now be considered for obstruction analysis under the newer standards. These factors directly lead to a greater amount of survey work, likely made more efficient through the use of airborne LIDAR.

**Role of NOAA-NGS**

Traditionally it has been the responsibility of NOAA NGS’ Aeronautical Survey Program (ASP) to find and survey these obstacles and then to provide the FAA with geo-information regarding the location and dimensions of the objects. With so many airports to survey, NOAA has assisted the FAA in using contractors to conduct many of these surveys. Relying on their extensive capabilities in precise positioning and remote sensing, NOAA has developed and provided guidelines for conducting everything from ground-based obstruction mapping to airborne data collection with aerial photography and (more recently) airborne LIDAR mapping. A recent revision to the statement-of-work (SOW) for collecting data for airport obstructions now includes extensive guidelines on the use of airborne LIDAR. (http://www.ngs.noaa.gov/RSD/AirportSOW.pdf). The NGS team continues to provide support to FAA in the form of recommendations on collection specifications and procedures as well as supplying accuracy assessment and QC of the data supplied to FAA by contractors. This necessitates the retention of...
in-house airborne LIDAR technology expertise, which NOAA possesses and continues to upgrade constantly. NOAA also provides cutting edge research to FAA (for airborne LIDAR survey) by experimenting with new technology, software and data collection techniques.

**Researching Critical Aspects of Obstruction Mapping with LIDAR**

Past and current research elements relating to utilizing LIDAR for vertical obstructions include:

1. Density (spot) analysis
2. Sensor configuration and orientation tests
3. LIDAR waveform deconvolution
4. Radiometric intensity evaluation

Dr. Chris Parrish of NOAA-NGS has been researching the effectiveness of airborne LIDAR for OIS detection and identification. In 2001 at the University of Florida, he conducted some of the first tests evaluating the impact of spot spacing and spot diameter on detection rates, as well as sensor orientation. These experiments led to interesting conclusions on the relationship between vertical and horizontal point density and success rates of object detection. About the same time, Dr. Waheed Uddin at the University of Mississippi began investigating the utility of LIDAR for airspace management (Airport Obstruction Space Management). Additionally, Dr. Uddin recently completed a research project for the TRB (ACRP 03-01 LIDAR Deployment for Airport Obstruction Surveys, National Academy of Sciences (NAS)) that focused on the “development of a cost-effective methodology that airports and their consultants can adopt to procure, process, and use LIDAR data” in furtherance of cost reductions and accuracy enhancements.

By its nature, an airborne LIDAR system geo-references the point data, so ascertaining the geo-location of the objects was relatively straightforward. What was less evident in the initial phase of the research was the confidence in detecting the upper most extent of vertically oriented objects (such as antennas). This is important information because it is the elevation at which the obstruction rises above the OIS surface that concerns the FAA.

A second phase of research conducted by Dr. Parrish focused on “densifying” the point data. The Phase II experiments used a dual sensor configuration, with each sensor supplying 50kHz of emitted points. This resulted in an aggregate pulse rate of 100 kHz and allowed for significant density on the terrain and horizontal surfaces. Additionally, one of the sensors was mounted in a “pitch-up” orientation (**Figure 3**), thereby allowing the scanner to sweep up vertical objects as the aircraft flew forward and then over them. This configuration aided in the elimination of “false positives” (returns that were logged but were from birds or from dust or smoke). It also enabled the scanner to distribute more points on the vertical object than in the nadir-pointing configuration (**Figure 3**).

The third phase of the research evaluated newly developed routines for extracting detailed information from the LIDAR return waveforms (see **Figure 4**). The techniques employed were able to tease out information that was not readily available in the discreet return data normally output by an airborne LIDAR unit. The research was very successful, showing that by deconvolving the waveform, additional geo-referenced data from objects could be extracted and subsequently improve the confidence in determining the
absolute “top” of vertical obstructions (Waveform).

The latest research being conducted is attempting to characterize the impact of radiometric issues on detection. There are many complicated factors that come into play when a laser pulse interacts with a fixed object. Size, shape, orientation, surface roughness and composition (among the main aspects of an obstruction) directly impact the amount of returned pulse energy available for detection by the LIDAR sensor.

The results of these areas of research have contributed to a greater understanding of the benefits tradeoffs involved in using airborne LIDAR for obstruction detection and mapping. The 2009 version of the NOAA-NGS SOW now reflects some of the information gleaned from this research.

Conclusions
As the new standards and guidelines are rolled-out, a greater number of airports will be mapped using LIDAR. As research is refined, the ability of the airborne sensors to more finely detect and characterize obstructions will become enhanced. Contractors will have the ability to streamline the process with faster more accurate procedures, tools and software and this will result in more and better obstruction information supplied to the FAA as well as quicker turnaround on survey projects. Ultimately, a greater number of airports can be mapped in a shorter time frame, producing more accurate information resulting in much enhanced navigation safety for aircraft.

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