Final Report

Submitted by:
Brian Fish, Project Manager
Design Survey Support Services
Michigan Dept. of Transportation
Van Wagoner Building
425 W. Ottawa
Lansing, MI 48909

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Description of Project:

MDOT acquired a UAS, Unmanned Aircraft System, with LiDAR for mapping. MDOT has been utilizing its own Terrestrial LiDAR and consultants Mobile LiDAR with very good results. UAS is an attractive option as it can fly over areas that are difficult to access and provides a better perspective for LiDAR to quickly map areas where terrestrial and mobile LiDAR would have limited visibility.

This project will involve preparing and testing guidelines and aiding in the development of a workflow and specifications for safely using UAS LiDAR to obtain high quality mapping results. The guidelines developed for UAS LiDAR include but are not limited to target types for horizontal/vertical control, spacing of targets, flightpath spacing/overlap, flight speed, flight height, safe flight path planning and LiDAR point density.

Overall Budget:

The overall budget for this project was $55,000 and the project stayed within budget. The Project received authorization for $44,000 in National STIC Incentives Program funding. The budget considered the chosen consultant and necessary miscellaneous equipment. Below is a breakdown of the budget.

CONSULTANT	HOURS/AVG. PER HR.		
PROJECT SURVEYOR	307.5/$59.42		
CREW CHIEF	51/$30.38		
TECHNICIAN	110.25/$19.06		
EXTRACTOR	15.25/$41.38	LABOR COST	$22,552.62
		LABOR AND DIRECT COST	**$48,953.33**
MDOT			
MISCELLANEOUS*	$3,452.67	NECESSARY EQUIPMENT	**$3,452.67**
		TOTAL	**$52,406.00**

NOTE * Monitor with protective case, generator for battery charging and canopy for field work.

How the work specifically meets criteria:

This project was developed to prepare standard operating procedures and technical guidance for the use of the MDOT's latest mapping tool, UAS LiDAR, Unmanned Aircraft System with LiDAR capability.

The consultant tested many scenarios to determine best practices that are detailed in their final report. The report provides specifications and workflows for flight and data collection to ensure a quality product efficiently by only setting the necessary amount of ground control points.

The report also details situations where the UAS LiDAR is not a good mapping option, for instance in areas of thick foliage. This will save time when planning.

Results of the Project:

The result of the project was a final report developed by the consultant which detailed their findings and included procedures, workflow, and recommendations; briefly summarized below.

A test site was established at MDOTs Dewitt Rest Area, providing a good mix of topography including hard surface, grassy area, tall weeds, trees, and water. 56 control points were set around the site which was more dense than necessary but helpful to determine optimal control point densification. 500-foot spacing of control was determined enough to ensure the scan data didn't have "bubbling" errors. Bubbling is where the processed ground model separates from the actual ground model. This was observed using our check measurements taken with conventional survey equipment around the site.

Target types for control points were determined from a series of short flights using different colors, shapes, and sizes of targets for hard surface and grass areas. The targets need to be easily identified in the point scans from LiDAR. Eight-inch-wide reflective yellow chevrons were found to be the best target for hard surfaces and three-foot-wide targets with reflective yellow and black contrast were found best for grassy areas.

A flight speed of the drone at 3.5 meters/second worked well with a flight height of 150 feet. That speed and height provided an acceptable swath of coverage while provided adequate point density along the scan lines. Additionally, 150-foot height is above most obstructions on a typical site.

Keep in mind the speed and height will change as technology improves. These specifications were created using a DJI Matrice 600M UAS platform with Riegl miniVUX-2UAV for LiDAR Scanner with the Applanix APX-20 UAV IMU.

A minimum overlap of 50% was determined necessary between flight paths for enough redundant data to create a good ground model. Additionally, two separate flight missions with a 60-degree angle between flight paths allows most obscured areas to be mapped properly.

Challenges:

The question is not "if" but "when" the UAS will have an accident. Unfortunately, there was a failure during a mapping flight causing the parachute to deploy and the UAS to drift dangerously close live traffic before landing hard in a ditch. Complications from the accident caused some damage to the UAS, requiring repair that grounded the UAS for the rest of the project. Fortunately, enough data had been collected to continue.

For safety, MDOT needs to decide how close to live traffic is acceptable. There are many factors, including wind direction, that can contribute to the severity of accidents.

Lessons Learned:

Best practice was found to turn off the LiDAR while the UAS slowed, stopped, or turned around for the flight path. This helped prevent LiDAR point errors, called "hot spots". Hot spots occur where the UAS pitches or rolls and continues to collect data over an area already mapped. The IMU will correct for some movement, but excessive movement will cause erroneous data so there will bad points collected over good data, "hot spot".

Another lesson was good data comes from good equipment. Not all LiDAR systems are equal. Another vendor provided data from a much cheaper UAS LiDAR system for comparison. The data is processed differently and though it was tied down at control points there was significant bubbling of data between control points.

With proper techniques this is a useful tool. We recorded multiple check measurements around the site using conventional survey equipment. This provided checks for the computed ground model and we found grass and thick foliage were not penetrated by the LiDAR, preventing a true ground map. These were summer conditions so it will work better in Spring and Fall when the foliage is off the trees and the grass is matted down. The LiDAR measurements of hard surface fit very well with check measurements.

UAS LiDAR is an effective mapping tool in many situations but not all. When combined with other mapping methods it will be a great asset.