All-in-One Systems for Airborne Remote Sensing

Technology revolution delivers high-accuracy aerial orthophotos… fast!

Tahir Shafiq, Mohamed MR Mostafa, and Andrew Stott

Tshafiq@applanix.com, 85 Leek Crescent, Richmond Hill, ON L4B 3B3 Canada
Applanix Corporation

ABSTRACT

Airborne Remote Sensing – a method for acquiring highly accurate information about ground objects from a small plane or helicopter - is an increasingly important tool for obtaining situational awareness and site-specific geospatial data. Geospatial professionals today are frequently required to deliver this data in the form of orthorectified imagery, quickly and efficiently. Applanix has developed economical, compact, all-in-one airborne digital imaging technology that uses Direct Georeferencing to deliver accurate orthophotos in near-real time without the need of Ground Control. Unlike traditional systems with their high operational costs, these “All-In-One” systems are designed to operate efficiently on even the smallest of aircraft and offer the most cost-effective, practical, and easy-to-execute solutions possible – perfect for small and medium sized mapping projects. These new and innovative technologies enable more groups to participate in airborne mapping with high efficiency and profitability. Applications include but are not limited to:

- Pipeline and Corridor Mapping
- Change Detection and Infrastructure Management, including gas and other facilities
- Emergency Response, where data collection and imagery evaluation is required for providing direction and coordination to emergency first-responders
- Commercial ortho mapping requiring rapid and efficient product delivery

In this paper we discuss the power, productivity, and ease-of-use of these systems, referencing a specific case study where they are applied to full effect.
Introduction:

Revolutionary turn-key solutions for airborne mapping and remote sensing are changing the industry. By offering complete, turnkey aerial mapping systems that include all necessary components (digital metric camera, flight management system, GPS-inertial system, and complete software workflow), companies such as Applanix are enabling more groups to participate in airborne mapping with high efficiency and profitability.

Applanix DSS enables its user with the following advantages:

- A Turnkey solution
- An economical, compact, all-in-one airborne digital imaging System
- Includes a Direct Georeferencing System
- Orthophoto production (within hours of landing
- No need for Ground Control Points.
- Installed on the smallest of aircraft
- A cost-effective, practical and easy to use system

First introduced in 2002, the DSS™ is the industry’s leading medium-format digital aerial camera system. Integrated with a complete Direct Georeferencing workflow and flight management technology, it is a mapping-quality alternative to large-format digital cameras, and offers important advantages including the ability to produce ultra-fast results that are certified as mapping-grade by the USGS. Light weight and ruggedized for use even under adverse conditions, the system is purpose built for the airborne environment with custom-designed and engineered components for tight integration of all technologies that make up the complete solution.

These solutions can also be integrated with different sensors to fulfill special application requirements. Some options include a DualCam, where a dual camera system is used to simultaneously collect RGB images and Near Infra-red (NIR) images, and a Riegl LMS-Q560 LIDAR option for high accuracy corridor mapping. For high altitude LIDAR applications, the DSS OEM version is being used on the Optech ALTM LIDAR systems. The all-in-one system captures and generates high-resolution colour (RGB) and colour-infrared (CIR) digital orthophotos and orthomosaics from the air, producing an accurate and radiometrically consistent product with 0.033 m to 1m GSD (ground sample distance, or size of each pixel on the ground). Orthophotos are created using raw imagery captured by the camera combined with the Applanix POS AV™ direct exterior orientation and a digital elevation model (DEM). The DEM can be pre-existing, or automatically extracted from the DSS stereo imagery. Additionally, the workflow from data capture to
georeferenced and calibrated imagery is optimized by Applanix software resulting in an efficient and accurate way of rapidly producing product.

**Get Results FAST:**

DSS RapidOrtho produces accurate ortho products FAST. The recently developed workflow integrates enabling technologies and advanced workflows to generate application-specific map products for commercial rapid response and disaster management applications. Images can now be developed and orthorectified in seconds: this means that a mapping mission of 3 hours flight time can be taken to full orthophoto product in as little as 3 hours after landing. In addition, an optional High Precision RapidOrtho workflow enables DTM extraction from the mission’s stereo imagery, supporting rapid 3D visualization and complete self-sufficiency in mission data collection.

**Case Study: The Arabian Canal in Dubai**

**Project Overview:** Limitless, a Dubai World business unit based in Dubai, UAE, is a global integrated real estate developer, specialized in master-planning of large-scale, mixed-use projects and conceptualization and execution of waterfront developments. The Arabian Canal, one of its current projects, is one of the largest developments of its kind in the world.

![Figure 1: The Arabian Canal in Dubai (www.arabiancanal.com)](image)

It is also perhaps the most complex civil engineering project in the Middle East. Limitless manages the design and construction of the canal to develop an area in excess of 10,000 hectares through which the canal will flow. Construction involves
several challenges, including the need to accurately measure the amount of earthwork moved each day: a total of one million cubic meters of earthworks will be moved every day or about 5,000 to 10,000 trucks. The task is to remotely monitor the daily terrain changes to compute the amount of earthworks done every day.

The Challenge:

Limitless established a Geomatics Information System (GIS) Department to manage its various Geomatics activities across its worldwide projects. The GIS department identified the necessity to utilize state-of-the-art technology to monitor the Arabian Canal earthworks, thus allowing project managers to accurately track the project and to quickly identify any variances that need addressing to meet three critical requirements: Progress Against Plan, As-build Against Plan, and Invoice Approvals. The following are required for conducting the earth work monitoring for this project:

1. Orthophoto Maps of the construction area for planning and visualization, with Ground Sample Distance of 10 cm (max), and Ortho accuracy at 12 cm RMS.

2. Point measurements for volume calculations of cut/fill areas including Points every 1-1.5 m, 10-12 cm RMS (max), based on flying heights from 200 m up to 450 m and with Point density ranges of 25 cm to 150 cm interval.

Further, methods used for these measurements must be very fast and effective i.e. Accurately measure the topography of 100 hectares within hours.

For smaller construction projects, earthwork monitoring is often carried out using traditional survey equipment such as total stations or GPS, or more recently with 3D static laser scanners that produce highly accurate point clouds from which geometric measurements can be made. However for such a large area, and given the
constraint that measurements could only be made between shift changes (approx 1.5 hours every 12 hours), it was quickly determined that traditional static survey methods would require large number of crews and static survey equipment, all at great expense. Even more troublesome was the risk that the area might not be able to be surveyed within the time constraint.

**Mobile Mapping vs. Traditional Surveys:**

Traditional methods and/or Static surveys such as Total Stations/GPS/3D static Scanners, while considered proven methods that deliver high accuracy and relatively low capital costs, have several significant problems for a project of this size and scope. For instance, they require many crews and equipment for covering such a large area and they produce many datasets to merge, thus raising the cost and complexity. In addition, they require manual setup of equipment, which is very time consuming. On the other hand, although using the mobile mapping technologies is requires relatively higher capital it is justifiable when looking at the number and consequence of the advantages they hold:

- Doesn’t need certain set up and very fast in data acquisition and area coverage
- Need to only merge 1 or 2 data sets to perform quality control and delivered very high reliability in terms of data accuracy and precision
- Requires only one single pilot or driver and thus has low personnel costs
- Requires one set of equipment can cover large area and thus it is efficient
- Does not need staff presence in the field and all measurements are done in remote acquisition mode and thus more safe.

**The Solution:**

The decision was made to use two mobile mapping instead of static surveying techniques. Mobile mapping represents an optimal convergence of Digital Photogrammetry with other positioning technologies such as laser scanning, GNSS and inertial. Mobile mapping reduces both the cost and the schedule risk by increasing the efficiency of the collection process.
Two mobile mapping platforms were chosen including a helicopter based Applanix DSS integrated with LMS-Q240 LIDAR for producing orthomosaic color image maps and an Applanix land-based system for oblique imagery. Both systems produce directly georeferenced high-resolution 3D terrain model in the form of laser point clouds and finally filtered digital surface models. The land and airborne data sets complement each other to produce full coverage and a high-accuracy, high-density 3D terrain model of the dig with built in redundancy.

**Airborne Mobile Mapping (Applanix DSS 439 system) Specifications:**

The system includes a rugged medium-format of 39 mega pixel aerial camera, a flight management system, a GNSS-Aided INS Direct Georeferencing system and a full suite of processing software. These components are custom-designed and engineered to be tightly integrated with the Riegl LMS-Q240 LIDAR system. The Applanix DSS produces directly georeferenced high-resolution orthomosaic color image maps and high-accuracy 3D terrain measurements in the form of laser point clouds and digital surface models. In terms of production process, flying the helicopter at 450 meters above ground, Limitless GIS Department is able to deliver within one week from the flight mission an Orthophoto and a DSM/DEM with 10cm precision along the X, Y, and Z axes.

**Methodology:**

The process of measuring excavation sites within the time frame highlights the strength of such a system. The Arabian canal development area is divided into four phases; each phase is about 25 to 35 squares Kilometre. Using the airborne mobile mapping system, four hours flying time is needed to cover phase I which is of about...
25 km\(^2\). This operation is done bi-weekly. The Land based system is used to cover the occluded area when using the airborne system or to get a higher density points in some areas of interest and also updates or some excavation area that are needed because of various reasons such as progress follow up, 3D visualization, invoicing slope monitoring, boundaries limitations. In a normal scenario, where accessibility is maintained, one can, in one hour, accurately measure about 200 hectares with the mobile mapping landmark system. Out of both systems, a DEM is created accurately with a 10 cm precision. Another important achievement is that within one week of conducting our image/LIDAR scans we are able to deliver the accurate topography as a final product. So far, this technology has highlighted the ability to produce accurate measuring in a short time, reinforcing our distinctive, innovative approach to development. During a daily data acquisition scenario, the airborne system covers an area of 25 km\(^2\) within four hours of flying, while the Land system covers 100 hectares mapped in an hour. Weekly 3D mapping products have been successfully delivered with the following accuracy consistently:

- Average height: 6-8 cm
- Standard deviation: 3-6 cm
- RMS: 8-9 cm

**Results:**

Figure 5 illustrates some of the system deliverables. Figure 5a shows the mapped area with our system (e.g. more than 4500 images), knowing that the produced pixel size precision is 10 cm. Figure 5b shows the active excavation and filling sites within phase one of our development. Figures 5c, 5d and 5e illustrate area 1 progress level with 3d model and color coded image. Figure 5f, 5g and 5h illustrate another active site that reached -6.5 meters below mean sea level with 5d model and color coded image. It is a 40 meter deep dig within the Canal rout, which illustrate the resultant excavation.
Conclusions:

Traditional earthwork monitoring surveying techniques impose a significant risk as far as data acquisition completion during the allocated time. Traditional techniques could have resulted in huge cost overruns if earthwork progress has been delayed and not detected on time. Mobile mapping represents an optimal convergence of Digital Photogrammetry with other positioning technologies such as laser scanning, GNSS and inertial. Mobile mapping reduces both the cost and the schedule risk by increasing the efficiency of the collection process. Mobile Mapping systems provide high accuracy and short turn around compared to traditional techniques.
References


