CHAPTER 4 – PROJECT STUDY APPLICATION: PHOTOGRAMMETRIC AIRBORNE POSITIONING

Figure 15. Photo. Inertial measurement unit combined with GPS provides a complete position and attitude solution for airborne platforms.

Airborne LiDAR is an advanced application of airborne positioning technology. The ability to precisely position a moving platform, particularly an aircraft where stop-and-go is not a possibility, is a very recent innovation. Hydrographic surveying vessels were tracked with high-speed total station instruments, and sometimes with radio ranging equipment, but it was not until dual-frequency kinematic GPS receivers were matched with advanced ambiguity resolution software solutions in the mid 1990's that precise airborne positioning became practical. Prior to this advancement loss of lock on the GPS satellites would force abandonment of a flight to have the aircraft land and reacquire signal lock. Ambiguity resolution is for all practical purposes a pass or fail condition for precise GPS positioning. As long as the receiver successfully maintains lock on the integer ambiguities, sub-decimeter positions can be generated from each successive GPS measurement epoch. Failing successful ambiguity resolution, the GPS position immediately degrades to sub-meter reliability. With the ability to reacquire integer ambiguities in flight, photogrammetrists immediately began to experiment with precise airborne positioning to enhance aerotriangulation solutions used in photogrammetric mapping. One of the unknowns solved for in analytical aerotriangulation is real-world (or project) coordinates and elevation of the camera focal point at the instant of exposure. Deriving this value directly from GPS offers potentially increased accuracy and less need for ground control.

Figure 16. Photo. One-second GPS solutions are interpolated to obtain positions at the camera exposure centers.

Airborne GPS has found great success in minimizing the need for ground control in photogrammetric mapping where multiple flight lines are employed to map large regions, as in base mapping for GIS projects. The typical airborne project includes north-south flight lines, with east-west cross-flights to strengthen the analytical bundle adjustment. This has been necessary because the GPS positioning provides only discrete points for the photo centers, and the analytical solution must also solve for the rotation angles of the camera photographic plane. This geometric weakness has until recently left linear route surveys less applicable for airborne GPS. Inertial measurement technology combined with kinematic GPS offers the solution to airborne positioning for linear routes. In the combined solution, the IMU records the angular velocity, while the GPS records the photo center positions. Combined the two systems are complementary in that the discrete point positioning of the GPS constrains the drift common in inertial measurement. GPS on the other hand, is subject to instantaneous loss of lock and positioning accuracy. Reacquisition of integer ambiguities is aided in post processing by the more continuous data flow of the IMU. The IMU also records at a much higher data rate (100 Hz typically) than GPS, thereby minimizing the problems associated with erratic movement of the aircraft during flight.

FIELD DEMONSTRATION: SEVENMILE-GOOSEBERRY ROAD

Photogrammetric mapping for Sevenmile-Gooseberry Road in Salina, Utah was selected as a target demonstration project for inertial-aided airborne GPS positioning. The conventional photogrammetric mapping project included six (6) flight lines and 26 stereo models at 1:4,800 photo scale. Ground control was established sufficient to meet traditional analytical aerotriangulation needs. This included 27 aerial premarks along the 9 Km route. Two GPS base stations, set on previously established primary control, and one GPS receiver on board the plane aided the aerial photography mission. GPS data was recorded at one-second intervals throughout the flight. An Applanix PosAV system provided integration of GPS data with the inertial measurement unit mounted on the camera. A traditional aerotriangulation adjustment was performed without the aid of airborne positioning data providing mapping-quality results with an RMS of fit of 10 cm.

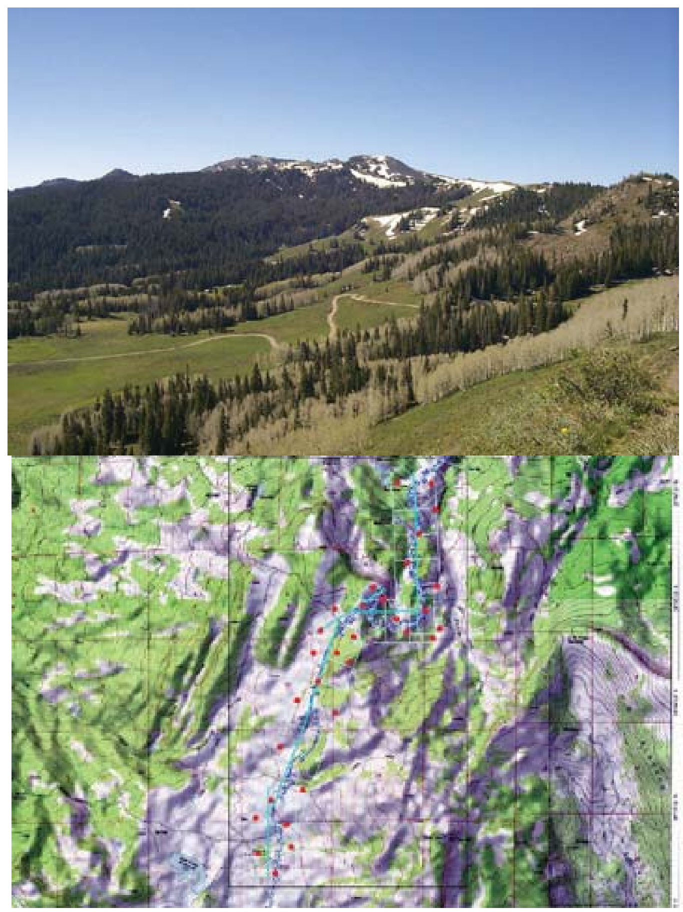

Figure 17. Photo and Map. Full analytical ground control was established along Sevenmile Road for the baseline data set. The flight plan included six flight lines and 26 stereo models.

The airborne positioning solution was processed in GrafNav software integrating the GPS observation data with the IMU data stream. Surveyed offsets from the aircraft GPS antenna to the camera focal point allowed computation of coordinates and elevations for the exact photo center at the mid point of the exposure time. The GrafNav solution includes position and orientation parameters of the camera film plane (Northing, Easting, Elevation, Phi, Kappa, Epsilon) in the project coordinate frame.

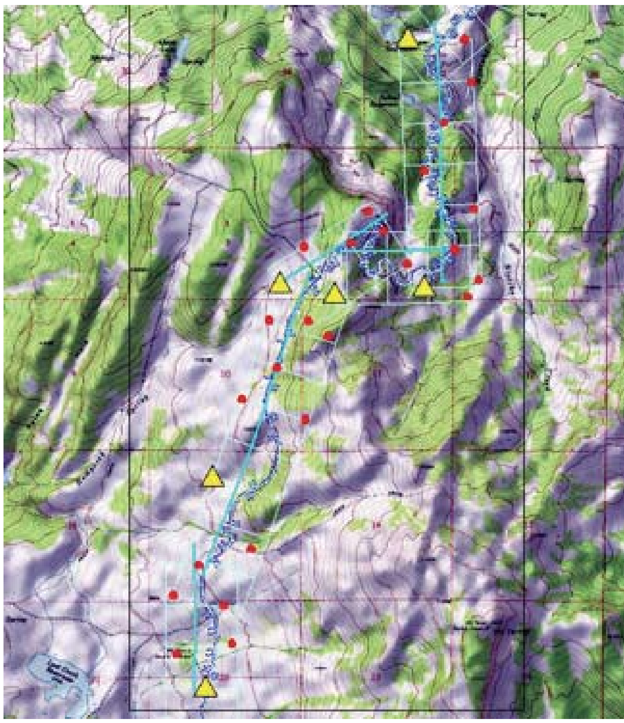

Figure 18. Map and Photo. Optimum photogrammetric solution, using inertial-aided airborne GPS, was found using 6 of the 27 aerial premarks. This methodology offers reduced cost along with reduced impact to the natural environment.

Three separate aerotriangulation adjustments were run including the airborne solution data. Each successive adjustment removed additional ground control points. An optimum solution was found with 6 of the 27 aerial premarks removed from the adjustment. This adjustment produced an RMS of fit of 7 cm in horizontal and 12 cm in vertical, with a 75% reduction in the required ground control. This is particularly significant in that much of the redundant control is found in the wing-points that often are difficult and costly to target, and could reside in sensitive areas. In this demonstration, the additional cost for airborne positioning and processing amounted to $6,500. The equivalent cost for the 21 aerial premarks eliminated was over $10,000.

FIELD DEMONSTRATION: LAVA BEDS NATIONAL MONUMENT

The combination of airborne inertial aided positioning combined with LiDAR and simultaneous aerial photography becomes very attractive for mapping solutions. The systems, as described, provide complimentary functions, and by themselves have proven gains in efficiency and economics. Aerial photography is needed to provide real-world imagery and to compile breaklines. LiDAR is very efficient at collecting digital terrain data; the exact data needed to ortho rectify aerial imagery. And GPS with inertial provides the geometric relationships necessary to compile photogrammetric mapping. In theory, an airborne platform collecting stereo imagery, point cloud data, together with position and attitude information, has everything necessary to compile topography and orthophotography. Merrick and Associates in Denver, Colorado is one of the first innovators to assemble such an aircraft. The single engine aircraft is equipped with a high-resolution digital mapping camera, inertial-aided GPS, and LiDAR system. A demonstration project using this system was flown in over a portion of Lava Beds National Monument in August 2003. A dense grid of mass points, provided from the LiDAR system, was supplemented with breaklines collected interactively from the stereo photogrammetry. Initial quality control checks against field surveying indicated an RMS of fit of 5 cm.