Map Accuracy Report
Burlington, Iowa
Imagery Collected by Aerial Services using the Leica ADS80/SH82 Camera System

Contact Person:	Chris Berggren	Contractor:	Aerial Services Inc.
Type of Mapping:	Orthophotography	Acquisition Date:	Mar 31–Apr 10, 2010
Authors:	Chris Berggren	Delivery Date:	Aug 13, 2010

Objective of this report

The purpose of this report is to independently test the horizontal and vertical accuracy of the Leica ADS80/SH82 Digital Sensor using a traditional 50-scale mapping project, and to determine how much control is needed to achieve geometric accuracies for a 50-scale vector mapping project with 1' contours.

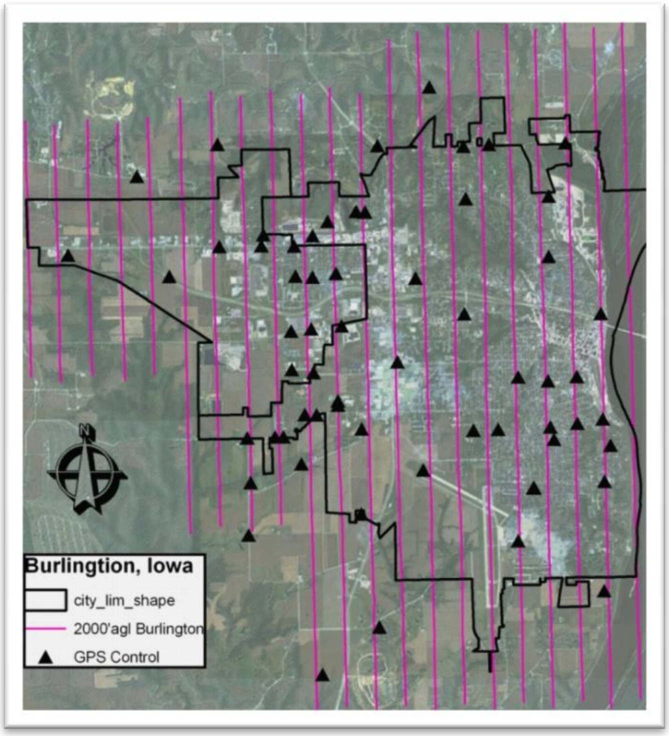

Figure 1 Burlington, Iowa flown at 2,000' agl with GPS surveyed monuments and photo identifiable control.

The Flight and ABGPS/IMU

Color aerial photography was acquired for the City of Burlington, Iowa at 2000' agl (Figure 1). The control points consisted of both photo identifiable points and targeted GPS monuments.

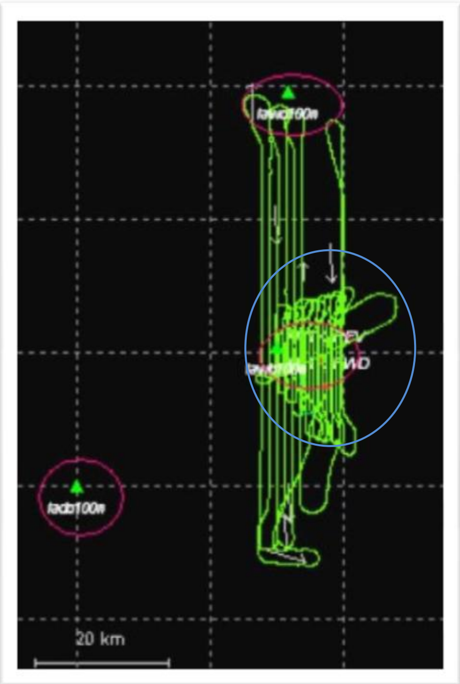

Figure 2 GrafNav Trajectory: the featured mission (blue) was flown April 10, 2010 and covered the city of Burlington, Iowa (3 base stations are circle in red).

The City of Burlington, Iowa was flown with another project and the trajectories of both flights are depicted Figure 2. Three base stations within or near the project area were used for processing and were part of the Iowa Department of Natural Resources (DNR) statewide real-time GPS network (maximum distance to Burlington was 39 km). The 3 base stations included were: IAWB (West Burlington, IA), IADO (Donnellson, Iowa), and IAWO (Wapello, Iowa). (Information regarding the IaRTN network can be found at:

http://spiderweb.iartn.com/spiderweb/frmIndex.aspx)

The ABGPS/IMU was processed using the Leica Inertial Position and Altitude System (IPAS) (v1.33) and NovAtel's GrafNav (v8.20). All ABGPS/IMU data was processed in the native collection datum WGS84.

The results from the ABGPS processing indicate that the forward and the reverse solutions are in constant agreement throughout the mission, differing by only 2-3 centimeters. The quality of the solution is reported at 99.0% accurate. The horizontal position of the solution falls less than 10cm 100% of the time.

The Ground Control

A total of 58 monuments and photo-identifiable ground control points (Figure 3) established by the City of Burlington were used for testing. Only check points that could accurately be measured in 2D were used for testing, because Leica XPro v4.4 provides no 3D measurement tool.

Datum Information

The mapping products were assigned the Iowa State Plane, Iowa South (FIPS 1402 Survey Feet) projection and the NAD83 (1996) horizontal datum and the NAVD88 (Geoid 03, and U.S. Survey Feet) vertical datum. Aerotriangulation (AT) was performed using Leica Xpro v4.4. The same 20 unmeasured check points (Figure 4) were utilized to determine accuracies in all the tests.

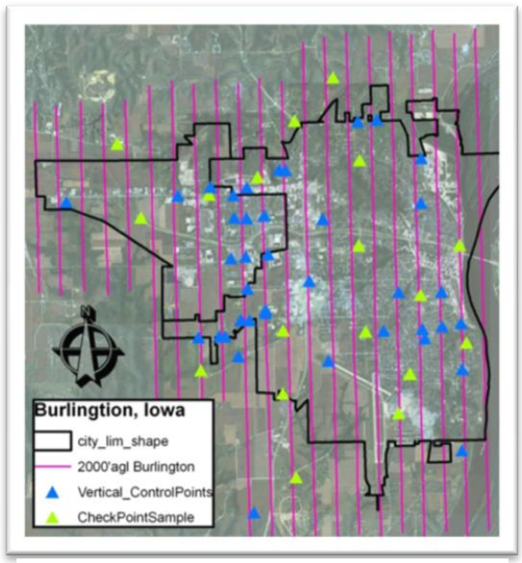

Figure 3 Control Layout: 58 available points, the green points are the 20 preselected check points, the 38 blue points are available to be held in the AT solution.

Positional Accuracy Assessments

The objective of these test was to determine the achievable positional accuracies using the Leica ADS80/SH82 for a typical 50-scale mapping project using three different configurations of ground control: none (Figure 4), minimal (Figure 5), and vertical (Figure 6). In each test the same 20 photo identifiable check points were measured to test the positional accuracy. In all three tests, horizontal measurements of the orthophotgraphy were performed using Arc Map 9.3. The orthophotgraphy produced was a three-band (RGB) image, with a 0.5' GSD. The DEM used during generation was acquired in 2006 at 1"=50' scale with 25' point spacing and supplemental breaklines. The DEM was tested to meet or exceed NSSDS standards of 1.67' horizontally at a 95% confidence level. Vertical measurements were made from the stereo-models using Cardinal Systems VR v5.0. All NSSDA statistics used here are reported for well- defined features at a 95% confidence interval.

The first test, ("None,") consisted of processing the project area with only the ABGPS/IMU data and no control. After AT was completed, horizontal and vertical measurements were recorded at each of the 20 checkpoint locations. Table 1 below shows the accuracy statistics generated from test 1.

The second test, ("Minimal,") consisted of using 5 full (XYZ) control points. These were positioned with one point in each of the four corners and one in the center of the block. After AT was completed, horizontal and vertical measurements of the 20 check points were measured (Table 1).

The third test, ("Vertical,") included no horizontal control and 38 vertical control points distributed throughout the project area. The results of the three tests are reported in Table 1.

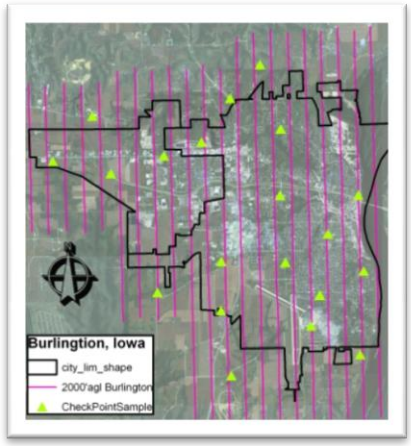

Figure 4 Test #1, "None" no control held during AT, and 20 check points measured in ortho.

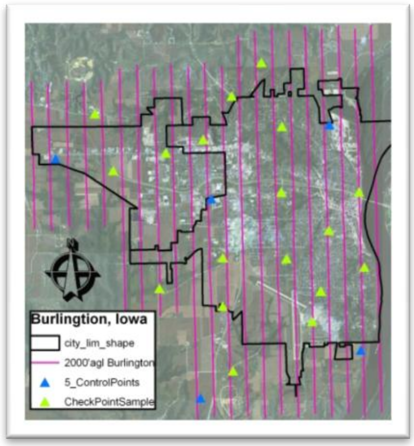

Figure 5 Test #2, "Minimal" 5 control points held during AT, 20 check points measrued in ortho.

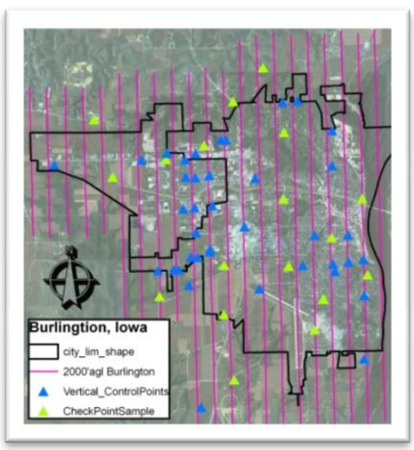

Figure 6 Test #3, "Vertical" 38 vectical only control points held during AT.

Test	Total Check Points	$RMSE_X$	$RMSE_Y$	$RMSE_{XY}$	XY NSSDA (95%)	$RMSE_Z$	Z NSSDA (95%)
1:600 mapping, map accuracy standards	--	--	--	0.50	1.90	0.33	0.60
"None" No Control:	20	0.36	0.29	0.39	0.68	0.5	0.97
"Minimal": 5 control pts.	20	0.24	0.30	0.29	0.50	0.51	0.99
"Vertical": 38 vertical control pts.	20	0.26	0.37	0.39	0.68	0.21	0.41

Table 1 Accuracy Results and Industry Standards

Positional Accuracy Test Results

The purpose of the first test, "None," was to determine if orthophotography could be produced using the Leica ADS80/SH82 that met or exceeded NSSDA standards for a typical large-scale ortho project. An NSSDA statistic of 1.90' at 95% confidence level or better is the standard. Our results had an $RMSE_{xy}$ of 0.39 feet (NSSDA statistic of 0.98') clearly exceeding this.

Stereo images from the aerotriangulation block were then generated using Leica Xpro. Horizontal and vertical measurements of the 20 check points were performed in the stereo pairs using Cardinal System's VR v5.0. The results showed that the $RMSE_{XY}$ equal to 0.39'.

The vertical $RMSE_Z$ was 0.5 feet. (NSSDA = 0.97 feet). This did not meet the ASPRS Class I vertical accuracies of one-third the contour interval or 0.33 feet.

Vertical Tests

The objective of the “Minimal” control test was to add a few strategic points and improve the vertical accuracies. The results showed that using only five vertical control points did not improve the vertical accuracies ($RMSE_Z$ = 0.51) and they were still below accuracy standards.

A subsequent test (“Vertical”) was performed using 38 vertical control points (Figure 6) and no horizontal control. The resultant geometric accuracies improved ($RMSE_{XY}$ = 0.39ft, $RMSE_Z$ = 0.21ft) when applying the additional vertical control and both the horizontal and vertical positional accuracy (Table 1) exceed industry standards.

Results, Conclusions, & Suggestions

The objective of the three tests was to determine the positional accuracy of the ADS80/SH82, and determine how much ground control is needed to achieve map accuracy specifications. Orthophotography was produced using only the ABGPS / IMU data with no ground control. The control points were measured and had an $RMSE_{XY}$ of 0.38' at 95% confidence level (NSSDA= 0.68 feet). An NSSDA statistic of 1.90' at 95% confidence level or better is the standard. This result clearly exceeds this and indicates that horizontal accuracies needing 50-scale orthophotography are easily achieved using this camera system and no ground control.

These results indicate that when using the ADS80/SH82 with only the ABGPS/IMU data and no ground control, orthophotography can be generated that meets or exceeds accuracy specifications for 50-scale orthos. However, vertical accuracies for mapping could not be achieved. Therefore, additional tests were performed to determine the minimal ground control needed to meet or exceed vertical accuracies. The “Minimal” test results showed a horizontal $RMSE_{XY}$ = 0.39 feet (NSSDA = 0.68 feet) which compared closely to the horizontal accuracy measured in the orthophotography. This clearly exceeds required ASPRS Class I horizontal accuracies of 0.5 feet. The resultant vertical $RMSE_Z$ was 0.50 feet (NSSDA = 0.97 feet). This does not meet the ASPRS (Class I) vertical accuracies of 0.33 feet.

In our experience, when using a frame based camera system, we estimate that no fewer than 160 horizontal and vertical control points would be needed to ensure 50-scale vertical accuracies requirements are met.

“Vertical” Control

The "Vertical" test used 38 vertical control points distributed throughout the project area. The horizontal $RMSE_{XY}$ was 0.39 feet and the vertical $RMSE_Z$ improved to 0.21feet (NSSDA = 0.41 feet). The addition of 38 vertical control points throughout the project area succeeded in improving vertical accuracies that meet or exceed ASPRS Class I vertical specifications $RMSE_Z$ = 0.33 feet.

Summary

In conclusion, horizontal accuracies required to produce 50-scale orthophotos were easily achieved using only ABGPS/IMU data and no ground control. In practice, minimal ground control should always be used to ensure the ABGPS/IMU components are performing within industry specifications. If projects require only orthophotography these tests confirm that the Leica ADS80/SH82 camera system is capable of creating orthophotography without any ground control using a quality DEM/DTM and still meet or exceed ASPRS Class I accuracies.

Vertical accuracies are generally much harder to achieve. Typically, a minimum of 160 expensive ground control would be to ensure the mapping products can meet the more difficult vertical ASPRS class I accuracy requirements. These results indicate a minimal configuration of vertical control in the corners and center of the block are insufficient to meet those specifications. However, using 38 vertical control points distributed throughout the project area achieved the desired ASPRS Class I vertical specifications (NSSDA 0.41 feet at 95% confidence). This supports the practice of using significantly fewer vertical control points for mapping when using the ADS80/SH82. Surveying photo-identifiable control points may cost approximately $100 per point. So the cost advantages of using only 38 points is approximately $12,000 and significant.

The Leica ADS80/SH82 and Xpro are excellent tools for producing orthophotography and topographic and planimetric mapping. The cost advantages of using minimal ground control for orthophoto production and still easily achieve horizontal map accuracies are important. However, when this camera system is used for mapping projects that require high vertical accuracies additional ground control must be incorporated into the project design, but it will generally require much less than using traditional film cameras and aerotriangulation.