ICC

Schiphol Aerial Photography 2015

Aerotriangulation Report

Heiloo

Our Ref: 00/006/15

Date: April 2015

1.0 Introduction

The purpose of this report is to describe the processes and procedures used to observe and compute the aerial triangulation for the 2015 Schiphol Aerial Photography project.

The 4cm resolution digital vertical stereo photography was acquired between the 6th March 2015 and 16th April 2015.

A number of ground control points surveyed by Facto during February 2015 were used to control the photography during the aerotriangulation.

1.1 Equipment

The table below describes the equipment utilised in the production process:

Item	Manufacturer
Aerial survey aircraft equipped with 195 mega pixel digital camera	1 x Cessna 402B 1 x Vexcel UltraCam D 1 x Applanix POS AV 510 1 x Trimble GPS System
GPS Processing Software	1 x Applanix POSPac 1 x Leica Geo Office
Global Positioning Systems	2 x Leica SX1230 Leica Geo Office
Aerial triangulation	Inpho Match-AT/InBlock

2.0 Method

2.1 Airborne GNSS/INS Processing

Observations were recorded throughout the acquisition of photography using the on-board GNSS/INS navigation system. These observations, coming from both the GPS and inertial measurement unit (IMU), were combined during post processing to give a precise determination of position and orientation of each image.

The Applanix POSPac software was used to process the GNSS/INS observations together with the Leica Smart Net active GPS network base stations. The resultant camera positions (Easting, Northing, Height) and rotations (Omega, Phi, Kappa) were then exported for inclusion in the aerial triangulation block adjustment.

2.2 GPS Ground Control Point Survey

The ground control points collected by Facto were surveyed using a combination of static and RTK observation using a Leica SX1230 and supported by observations from the active network.

2.3 Measurement of Aerial Triangulation

2.3.1 Photography Tie and Strip Point Measurement

The 4cm digital images were first re-formatted to a tiled TIFF format and JPEG compressed prior to importing into the Inpho Match-AT digital stereo workstation.

The interior orientations for the digital imagery were calculated as part of the initial image processing. The connections between the photographs and between strips (pass and tie points) were measured using the automatic correlation techniques within Match-AT. Match-AT measures a large number of points in each Von Gruber position.
Where there were any areas in which no points were automatically measured, additional points were measured manually by the photogrammetric operator. The operator also checked to ensure that points falling within the overlap between adjacent strips were measured on all the photographs on which they fell.

2.3.2 Ground Control Point Measurement

The photogrammetric operator manually measured the positions of ground control points (GCPs) on the photography using the descriptions and co-ordinates provided by the field surveyors. All control points were measured on every photograph in which they fell.

Once all of the tie-points and ground control points had been measured, an initial block adjustment was calculated using the adjustment software within Match-AT to determine if there were any blunders remaining within the block.

Where blunders were detected, the problem was investigated and the point (tie-point or ground control point) was checked and if necessary, re-measured. This process was repeated until no blunders were present.

2.3.3 Bundle Block Adjustment

The final bundle block adjustment was calculated using Inpho's bundle block adjustment program InBlock. The block adjustment was made without using the so-called 'additional parameters for self-calibration'. Compensation for earth curvature and atmospheric refraction was made during the block adjustment.

The photo centre coordinates and rotations obtained from the GNSS/INS data were used to support the ground control points in the final adjustment. The accuracy weightings used and final residuals can be found in the log file.

On the successful completion of the bundle block adjustment, exterior orientation parameters were exported for use in orienting the stereo pairs in our digital photogrammetric workstations for the subsequent photogrammetric processing.

3.0 Geodetic Parameters

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GEOGCS["Amersfoort",
DATUM["Amersfoort",
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AXIS["Geodetic longitude",EAST]
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PARAMETER["latitude_of_origin",52.15616055555556],
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PARAMETER["false_northing",463000.0],
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AXIS["Northing",NORTH]
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VERT_DATUM["Normaal Amsterdams Peil",2005,
AUTHORITY["EPSG","5109]],
UNIT["metre",1.0],
AXIS["Gravity-related height",UP]
AUTHORITY["EPSG","5709]],
AUTHORITY["EPSG","7415]],
```

4.0 Camera Rotations

There are a number of different ways in which the camera rotations and GNSS/IMU rotations are handled during the aerotriangulation process and subsequent setting up of the stereo models.
The manufacturers of digital stereo workstations have their own unique methods and philosophies regarding the handling of digital imagery, Vexcel themselves provide four alternative sets of Principle Point of Auto-collimation (PPA) offsets.
The following describes the methods used in the production of the aerotriangulation and guidance on how to obtain correctly orientated stereo models from the adjusted exterior orientation (EO).
All of the sorties for the 2015 project were flown with the same camera; Vexcel UltraCam D, serial number UCD-SU-2-0012. This camera was calibrated on 25th February 2015 and uses the 'Revision 17.0' calibration report of 6th March 2015.

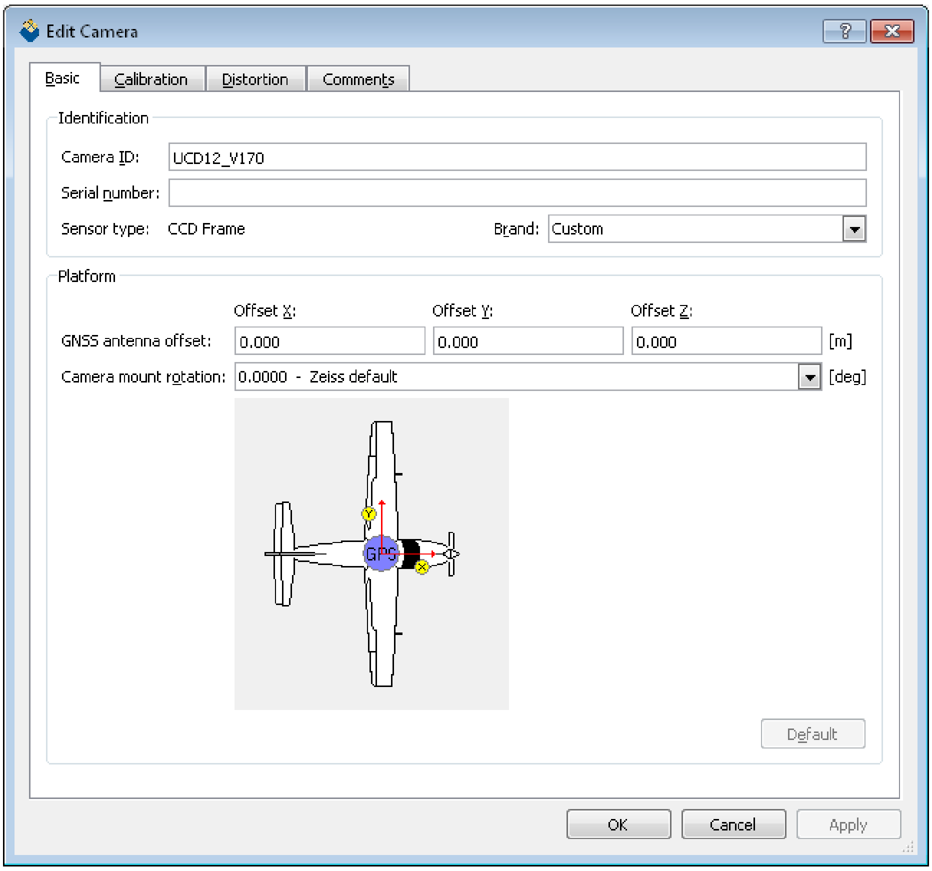
Camera Orientation

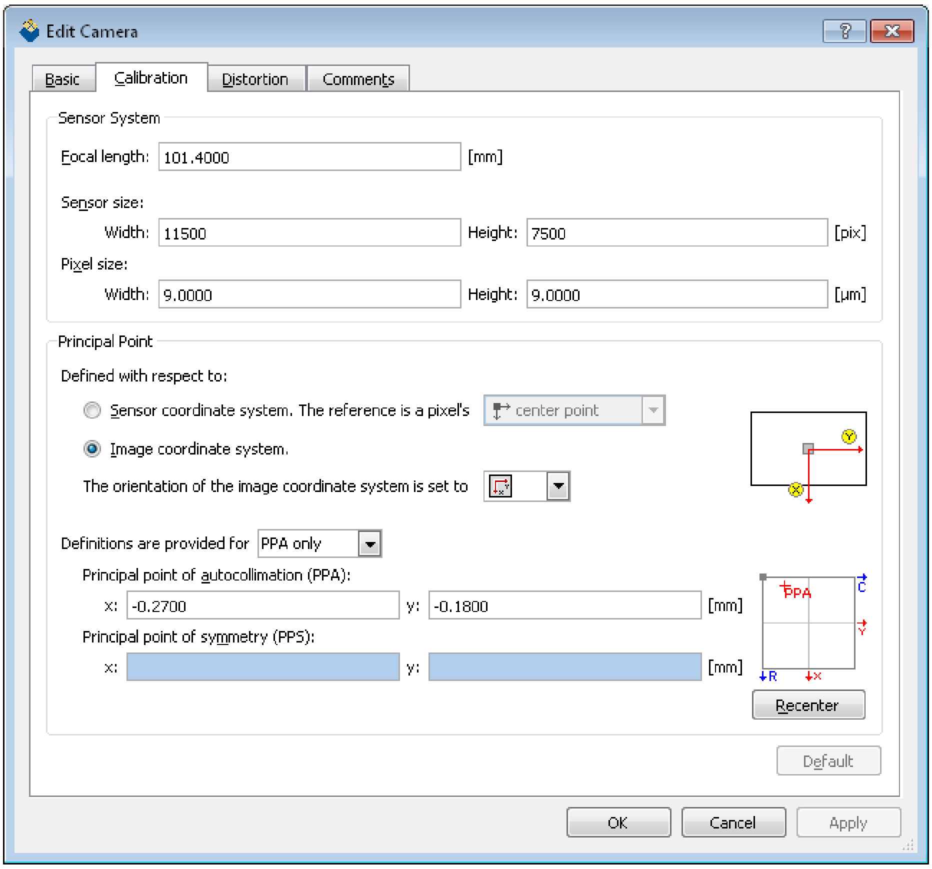
The usual practice for Blom is to orient the camera coordinate system so that the positive X direction of the camera always coincides with the direction of flight. This has many benefits when reviewing the results of the bundle block adjustment and when investigating errors in the stereo models due to incorrect handling of the camera calibration data.

Setting up a Stereo Model

The exact method for inputting the camera calibration data into a digital stereo photogrammetric workstation varies depending upon the software used. In general terms the camera should be set up as follows:
Focal Length: **101.4** mm
Sensor Width: **11500** pix
Sensor Height: **7500** pix
Pixel size: width **9** um
Pixel size: height **9** um
Orientation of Image Sensor: X = DOWN
Principle Point of Autocollimation (PPA) X: **-0.270** mm
Principle Point of Autocollimation (PPA) Y: **-0.180** mm
The order of the columns in the adjusted EO file is as follows:
Photo, Easting, Northing, Height, Omega, Phi, Kappa

An example of the correct camera orientation when using INPHO software is shown below:





5.0 Municipalities and AT Blocks

The following table describes the relationship between the aerotriangulation blocks and the municipalities of Parcel1:

AT Block	Sorties	Municipality
AT_Block02	AF15D795, AF15D796	Heiloo, Heerhugowaard, Alkmaar, Castricum
AT_Block03	AF15D795, AF15D796, AF15D797, AF15D798, AF15D801, AF15D806	Heerhugowaard, Alkmaar
AT_Block05_1	AF15D796, AF15D797, AF15D801, AF15D802, AF15D807, AF15D808	Beemster
AT_Block05_2	AF15D807, AF15D808	Purmerend
AT_Block05_3	AF15D808, AF15D814, AF15D815	Edam-Volendam
AT_Block05_4	AF15D808, AF15D815	Zeevang
AT_Block08	AF15D796, AF15D801, AF15D817, AF15D818	Alkmaar
AT_Block09	AF15D808, AF15D809, AF15D814, AF15D815	Waterland
AT_Block10	AF15D801, AF15D802, AF15D807, AF15D808, AF15D809, AF15D819	Landsmeer, Oostzaan
AT_Block11	AF15D796, AF15D817, AF15D818	Castricum
AT_Block12	AF15D801, AF15D802, AF15D807, AF15D818, AF15D819	Wormerland
AT_Block13	AF15D817, AF15D818, AF15D819	Uitgeest
AT_Block14	AF15D807, AF15D818, AF15D819	Zaansted
AT_Block15	AF15D805, AF15D807, AF15D819	Beverwijk, Velsen

6.0 Heiloo

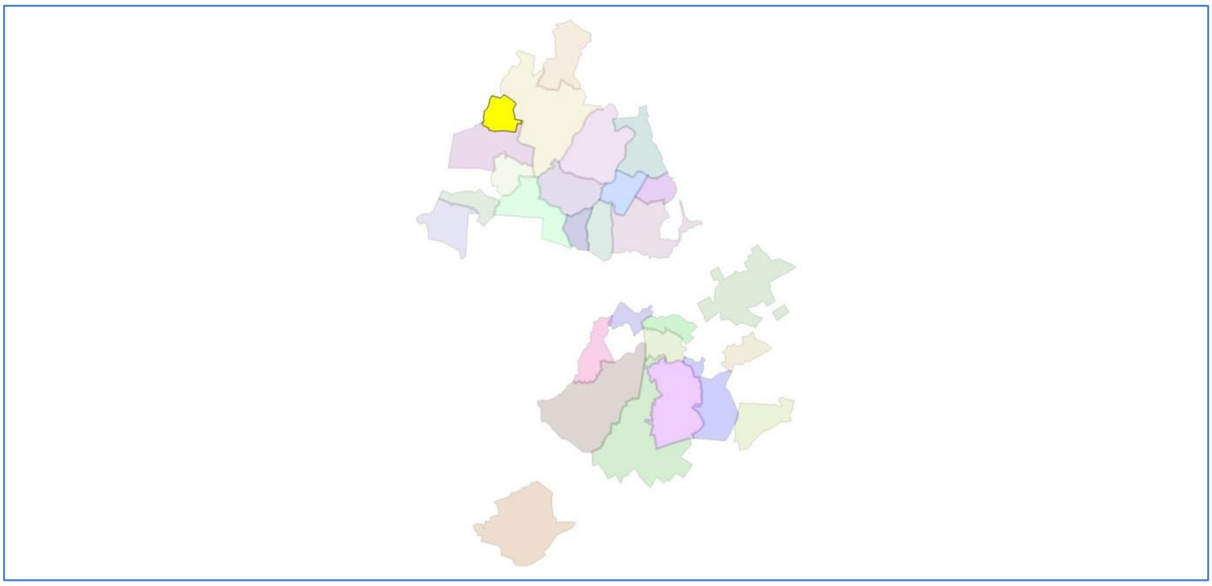


Figure 1: Overview

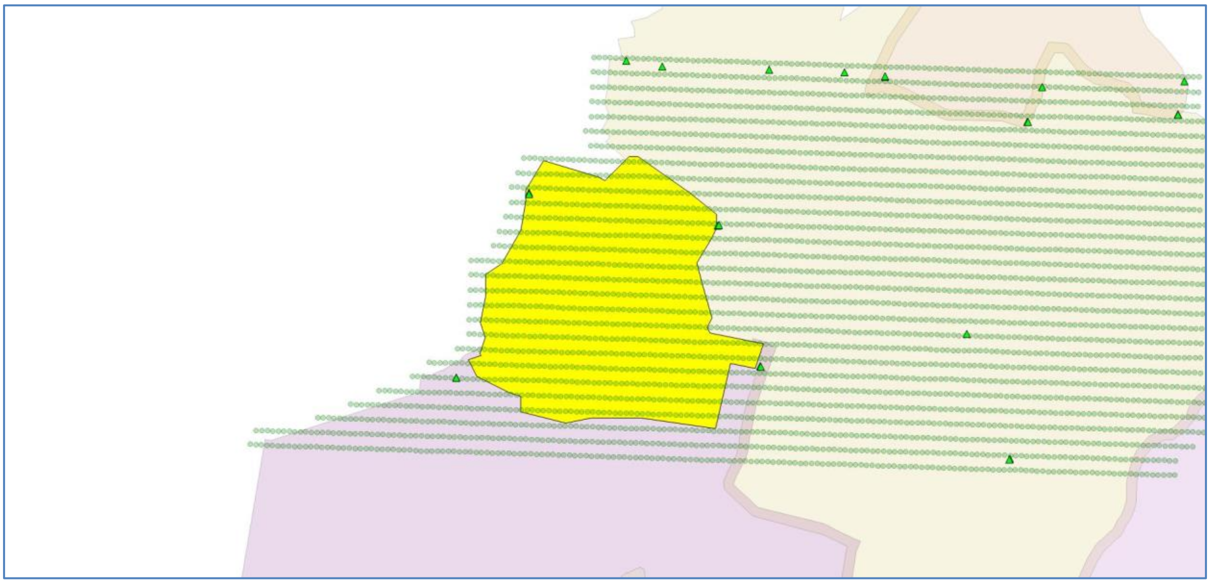


Figure 2: Detail

The imagery for Heiloo was triangulated as part of a larger block consisting of two sorties; AF15D796 and AF15D797, which also partly covers the neighbouring municipalities of Alkmaar, Heerhugowaard and Castricum.

The statistics and results are for the complete aerotriangulation block.

7.0 Statistics and Results

Number of photos	3936
Number of strips	28
Number of observations	945007
Number of unknowns	362439
Redundancy	582568

A priori Standard Deviations	x/omega	y/phi	z/kappa
Ground control [meter]	0.060	0.060	0.030
Derived control from adjacent block *	0.120	0.120	0.060
Image Observations [mm]	0.009	0.009	
GNSS X Y Z [m]	0.100	0.100	0.100
INS omega phi kappa [deg]	0.005	0.005	0.008

	x/omega	y/phi	z/kappa
RMS of Image Points [micron]	0.916	1.160	
RMS of Control Points [meter]	0.080	0.055	0.020
RMS Photo Position [meter]	0.078	0.026	0.021
RMS Photo Attitude (deg)	0.001	0.002	0.006
Mean Std Dev of Image Points [meter]	0.026	0.029	0.081
Max Std Dev of Image Points [meter]	0.069	0.171	0.352
Mean Std Dev of Control Points [meter]	0.025	0.025	0.031
Max Std Dev of Control Points [meter]	0.032	0.052	0.058

Residuals control points in [meter]			
BL23_1 *	-0.202	-0.091	-0.019
BL23_3 *	-0.147	-0.084	-0.025
BL23_4 *	-0.143	-0.073	0.001
BL23_5 *	-0.128	-0.085	-0.046
BL23_7 *	-0.153	-0.073	-0.028
BL23_8 *	-0.097	-0.079	-0.066
2015-09	-0.031	-0.031	-0.013

2015-10	-0.028	-0.007	-0.010
2015-11	-0.019	0.042	-0.004
2015-13	-0.011	-0.113	-0.004
2015-14	-0.020	-0.017	0.000
2015-15	0.019	0.044	0.004
2015-16	0.045	0.024	0.016
2015-59	0.043	0.055	0.004
2015-65	0.065	0.008	0.006
2015-68	0.021	0.058	0.002
2015-09X	-0.061	-0.024	-0.019
2015-10X	-0.051	0.008	-0.008
2015-11X	0.006	0.016	-0.001
2015-13X	-0.002	-0.103	0.005
2015-14X	-0.033	-0.003	0.002
2015-15X	0.039	0.045	-0.001
2015-16X	0.050	0.028	0.014
2015-59X	0.126	0.014	0.003
2015-60X	0.028	0.044	0.002
2015-65X	0.018	0.014	0.014
2015-68X	0.014	0.019	0.033