SimActive and PhaseOne Workflow case study

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Revision 1.0

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1. Introduction

1.1. SimActive

SimActive is the developer of Correlator3D™ software, a patented end-to-end photogrammetry solution for the generation of high-quality geospatial data from satellite and aerial imagery, including drones. Correlator3D™ performs aerial triangulation (AT) and produces point clouds, dense digital surface models (DSM), digital terrain models (DTM), orthomosaics and vectorized 3D features. Powered by GPU technology and multi-core CPUs, Correlator3D™ ensures matchless processing speed to support rapid production of large datasets.

SimActive has been selling Correlator3D™ to leading mapping firms and government organizations around the world, offering cutting-edge photogrammetry software backed by exceptional customer support.

1.2. PhaseOne Industrial

Phase One's medium format iXU-RS1000 series cameras, have earned a worldwide reputation and are used in small and medium size area mapping projects, corridor mapping, LiDAR mapping, urban mapping, 3D City modeling and oblique imagery capturing, constructions and infrastructure monitoring and inspection.

The 100MP cameras specifications include: pixel size of 4.6 µ, very high image capture rate -1 frame every 0.6 seconds, exposure time of up to 1/2500, a set of metric lenses with different focal lengths (50, 70, 90, 110, 150 mm). This provides an effective solution in many areas of aerial mapping, monitoring and object inspection.

Small form size (10x10x20cm including lenses) and extremely light weight (less than 2 kg) are significant advantages of the camera allowing an easy installation in every small and light aircraft, gyrocopters, medium size drones or UAVs. These physical attributes essentially increase the range of airborne vehicles utilized for mapping, and significantly reduces operational costs of mapping projects.

The main goal of this report is photogrammetric accuracy analysis and assessment of IXU-RS1000 camera.

2. Testing Procedure

The photogrammetric accuracy assessment was done according to an aerial survey camera testing procedure, which includes the following steps:

- Test field establishment
- Flight planning and flight execution

- Automatic image matching and aerial triangulation (AT)
- DSM and DTM production
- Orthophoto creation
- AT accuracy analysis with different GCP & ChP configuration
- Orthomosaic accuracy including cut-line accuracy
- Final conclusions

The following steps were executed in the project:

1. Test field preparation
   a. Planning – Dr. Yuri Raizman, PhaseOne.Industrial (http://industrial.phaseone.com/)
   b. Geodetic measurements – ARMIG Geodetic Engineering Ltd. (www.armig.co.il/english)
2. Test flight planning, flight execution and image preparation – Oodi Menaker, PhaseOne.Industrial
3. Photogrammetric processing (AT, DSM, DTM, Orthophoto, GCPs measurements, cut-line checking) – Francois Riendeau, SimActive Inc. (www.simactive.com)
4. Accuracy analysis and report preparation – Dr. Yuri Raizman and Francois Riendeau

The following software was used for the project:

- iX Capture – original image processing and export to TIFF format
- Correlator3D™ - AT, DSM, DTM, Orthophoto

3. Test Field

3.1. Area

The test field is situated in the vicinity of Kfar-Vitkin, Israel. It covers 2.0 km form the West side to the East side of the village, and 1.2 km from the South-to the North side of the village. It is predominantly an urban area with low height of up to two-story buildings.

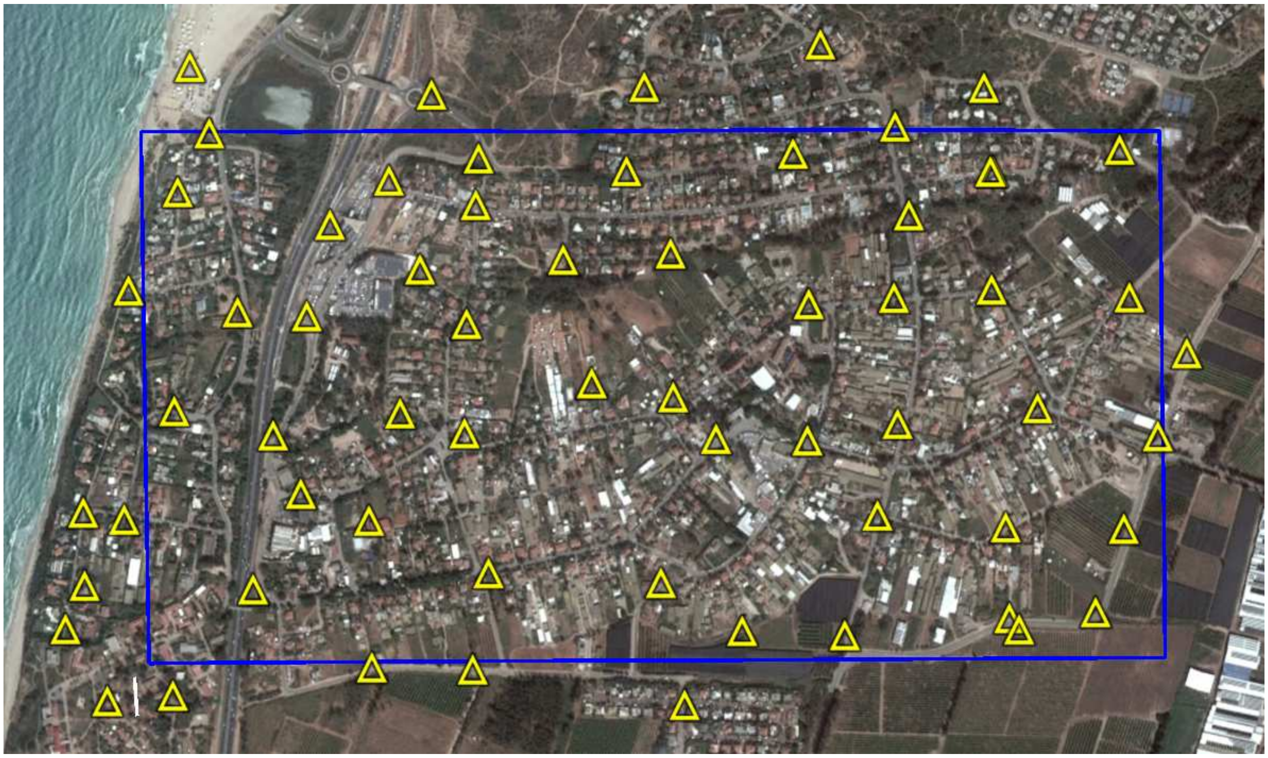


Figure 1: Test field

The area is characterized by visible manmade features and manholes, which were chosen to serve as signalized GCPs. All GCPs are located on the ground. The following manmade features and manholes were used mainly as GCPs:

There are 53 GCPs in the test field

3.2. Geodetic Measurements

Before performing the field measurements, all GCPs were identified and marked on Phase One's images of the area. The geodetic observations were made according to static GPS survey procedure with one reference station 903AGR. The reference station was established at the high and open area in the north part of the test field. The reference station was measured against CSAR permanent GPS station by two independent 1-hour long observation sessions. Each GCP was measured by two independent half-hour long observation sessions.

The following accuracies of the GCPs were received after processing all the observations:

	RMSxy (cm)	RMSz (cm)
CSAR	± 0.3	± 0.5
903AGR vs CSAR	± 0.1	± 0.1
GCPs internal between observations	± 0.7	± 1.2
GCPs absolute	± 0.8	± 1.3

4. Flight Planning

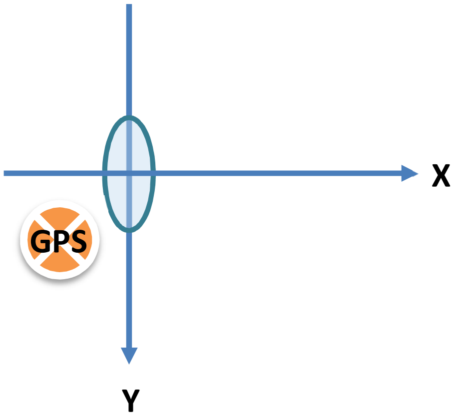
4.1. Aerial Camera

An iXU-RS1000 aerial camera with a focal length of 90 mm was used for the test. The main parameters of the camera are as follows:

Camera Specifications	
Lens type	Rodenstock
Focal length (mm)	90
FOV (across flight, deg)	33.0
FOV (along flight, deg)	25.1
Aperture	f/5.6
Exposure principle [1]	Leaf shutter
Exposure (sec)	1/2500 to 1/125
Image capture rate (sec)	0.6
Light Sensitivity (ISO)	50-6400
Dynamic Range (db)	>84
Sensor Specifications	
Sensor type	CMOS
Pixel size (µm)	4.6
Array (pix)	11,608 x 8,708
Array volume (MP)	100
Analog-to-digital-conversion (bit)	14
Frame / Image Specifications	
Frame geometry	Central projection
Typical image size (MB) for TIFF	300
Image format	PhaseOne RAW, Undistorted TIFF, JPEG
Frame Coverage	
Frame width for 10 cm GSD (m)	1,161
Frame height for 10 cm GSD (m)	871
Frame area for 10 cm GSD (sq.km)	1.01

4.2. Aircraft Installation

A Cessna 172 aircraft was used for the flight. The camera was installed at the rear part of the plane with the following parameters of lever arm (distance between GPS antenna and the exit pupil of the camera):



dX (cm)	-15.4
dY (cm)	10.1
dZ (cm)	0.99

4.3. Aerial Survey Parameters

The flight was planned and executed with the following aerial survey parameters:

- Flight altitude (above ground) - 2,500 feet / 760 м
- GSD – 4 cm
- Distance between flight lines – 230 m
- Distance between projection centers at 60% forward overlap – 135 m
- Side overlap – 49%
- Forward overlap – 80%
- Frame size – 450m x 340m
- Orthophoto angle - 17°
- Building lean – 15%
- Ground speed – 100 knot
- Strips: SN – 9; WE – 2;

Figure 2: Test field with flight lines

5. Correlator3D - Aerial Triangulation

There were 192 images in the project and 3345 tie points were automatically created. The image coordinates of all GCPs were manually measured using the GCP editing module of Correlator3D. Bundle-block adjustment was performed for self-calibration and exterior orientation of the block with different number and configuration of used GCPs. Photogrammetric accuracy of the block is estimated by residuals on tie points. Geodetic accuracy of the block is estimated by residuals on GCPs, which were not including during the adjustment – Check Points (ChP).

There were three runs of the Correlator3D software for different purposes:

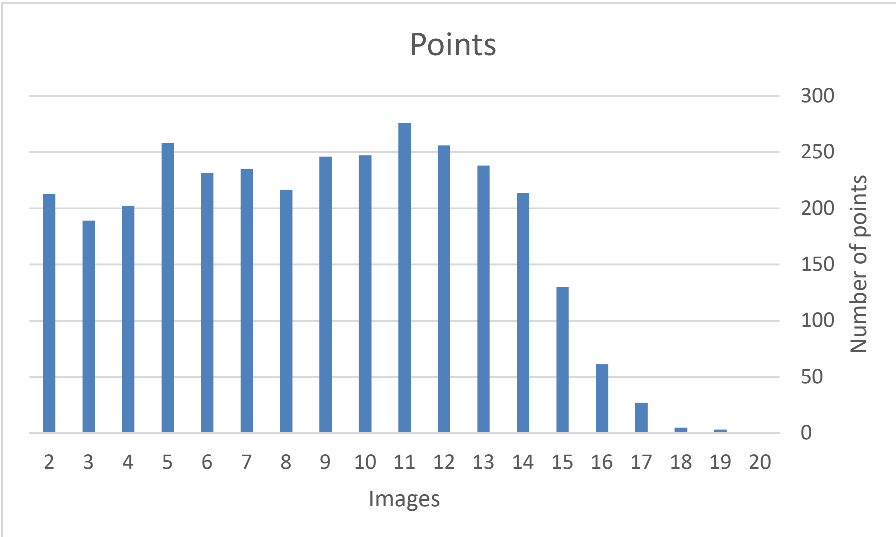
1. Tie points, 5 GCP and 48 ChP for the block geodetic accuracy estimation
2. Tie points, 9 GCP and 44 ChP for the block geodetic accuracy estimation
3. Tie points, 15 GCP and 38 ChP for the block geodetic accuracy estimation

Common parameters of the block for the above Correlator3D runs are as follows:

- Number of images – 192
- Number of used tie points – 3248

- Number of skipped tie points - 97
- Mean number of points per image – 147
- Number of measured GCPs - 53

The following graph presents a tie points distribution per image:



6. AT accuracy analysis for different GCP & ChP configurations

Three different GCP and ChP configurations were chosen for testing geodetic accuracy of the block.

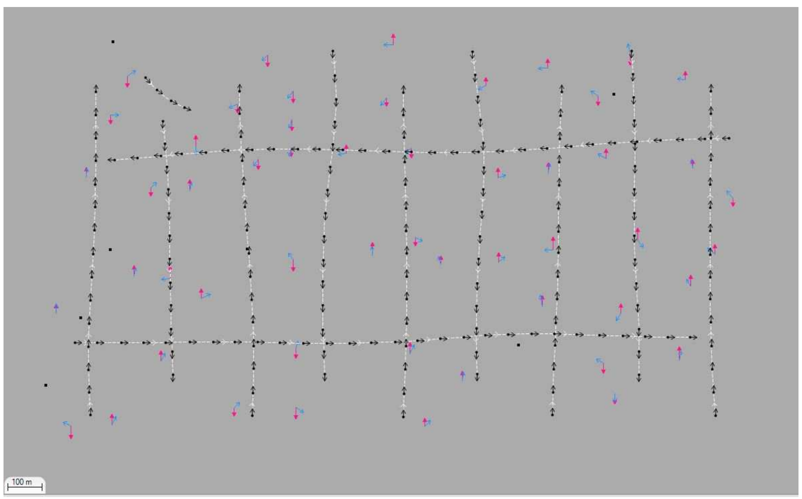
The first one is based on 5 GCP and 48 ChP:

The following results were obtained:

	5 GCP			48 Check Points			
	dX (cm)	dY (cm)	dZ (cm)	dX (cm)	dY (cm)	dXY (cm)	dZ (cm)
MIN	-1.4	-1.3	-7.8	-4.6	-3.1	0.5	-11.8
MAX	0.9	2.1	0.0	5.4	9.1	9.2	13.7
Mean	-0.3	0.0	-2.9	-0.2	1.0	2.9	1.2
STDEV	0.8	1.0	3.1	2.2	2.4	1.7	9.0
RMS	**0.7**	**0.9**	**4.0**	**2.2**	**2.6**	**3.3**	**7.0**

With 5 GCPs and for 48 Check Points, the RMSxy was ± 3.3 cm (0.8 pix) while the RMSz = ± 7.0 cm (1.75 pix).

The following chart is a graphical representation of the residuals on Check Points:



The blue vectors represent XY residuals while the red ones correspond to Z residuals.

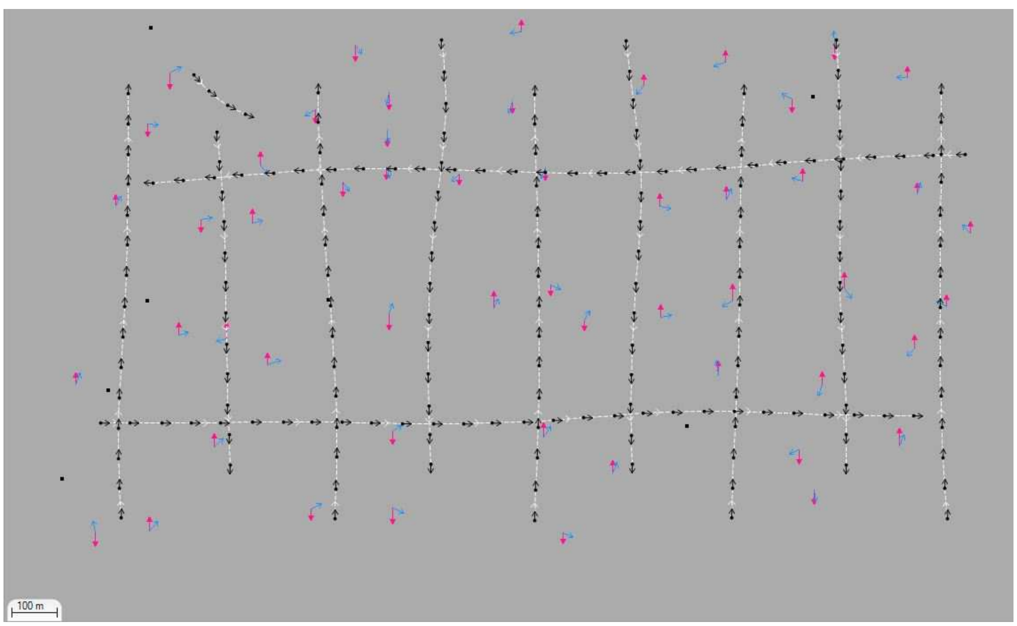
The second configuration is based on 9 GCP and 44 ChP:

The following results were obtained:

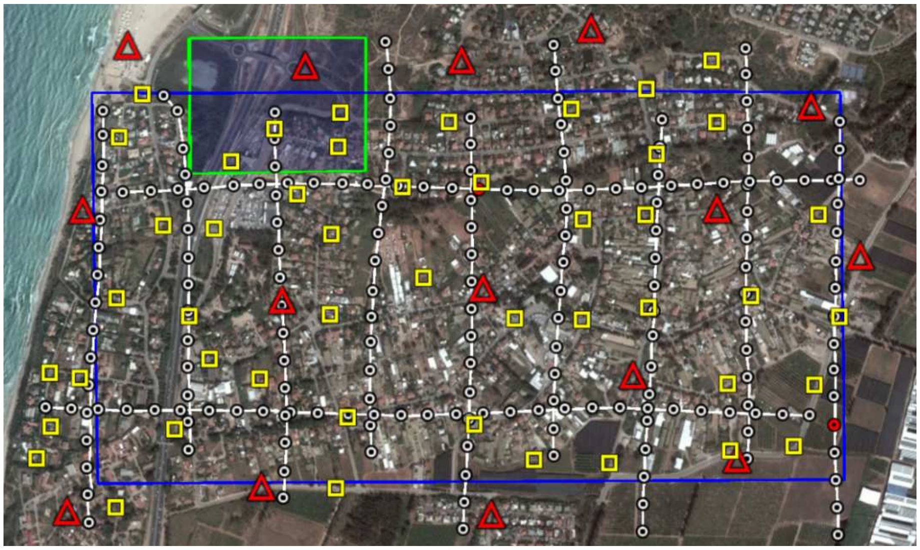
	9 GCP			44 Check Points			
	dX (cm)	dY (cm)	dZ (cm)	dX (cm)	dY (cm)	dXY (cm)	dZ (cm)
MIN	-3.1	-2.2	-7.7	-3.5	-3.6	0.1	-11.6
MAX	1.1	1.6	3.0	5.9	8.3	8.3	12.3
Mean	-0.2	0.1	-1.5	0.5	0.3	2.7	0.3
STDEV	1.3	1.2	3.9	2.1	2.4	1.7	6.9
RMS	**1.3**	**1.1**	**4.0**	**2.1**	**2.4**	**3.2**	**6.8**

With 9 GCP and for 44 Check Points, the RMSxy was ± 3.2 cm (0.875 pix) while the RMSz was ± 6.8 cm (1.7 pix).

The following chart is a graphical representation of the residuals on Check Points for 9 GCP configuration:



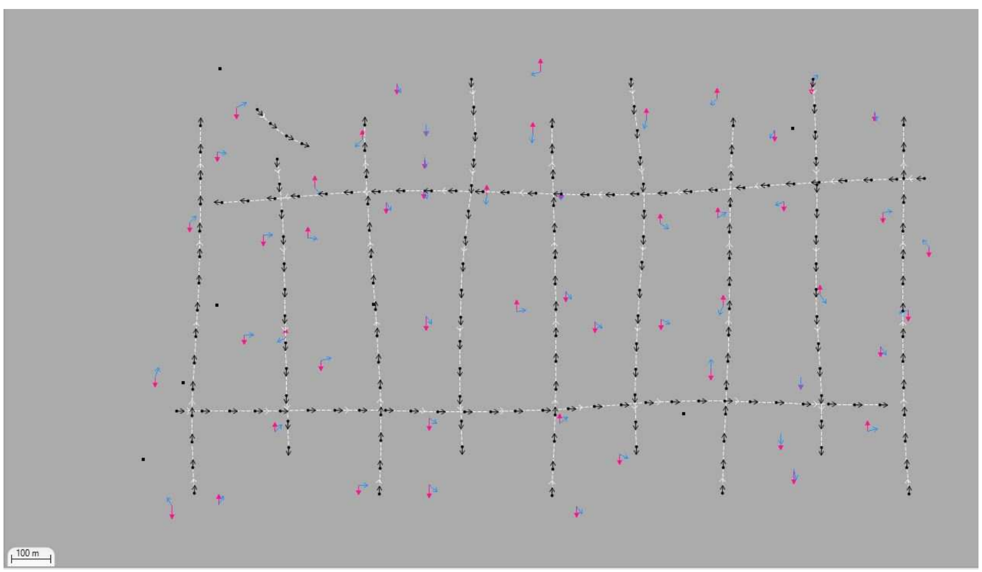
And the last configuration is based on 15 GCP and 38 ChP:



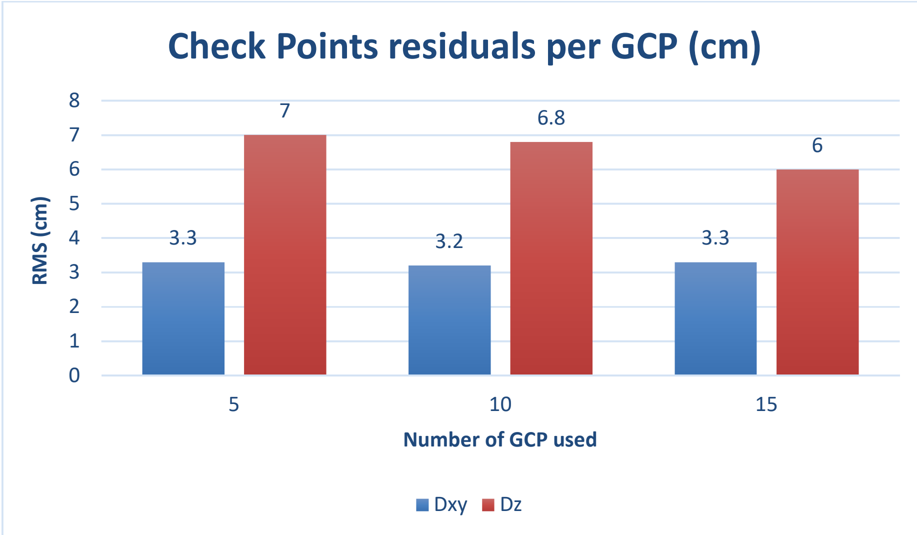
The following results were obtained:

	15GCP			38 Check Points			
	dX (cm)	dY (cm)	dZ (cm)	dX (cm)	dY (cm)	dXY (cm)	dZ (cm)
MIN	-2.4	-4.7	-16.2	-2.5	-5.2	0.5	-17.1
MAX	1.4	5.0	11.2	5.9	4.5	6.7	7.5
Mean	0.0	0.2	-2.1	1.2	-0.9	2.9	-2.3
STDEV	1.0	2.0	6.2	1.7	2.3	1.6	5.6
RMS	**1.0**	**2.0**	**6.4**	**2.1**	**2.5**	**3.3**	**6.0**

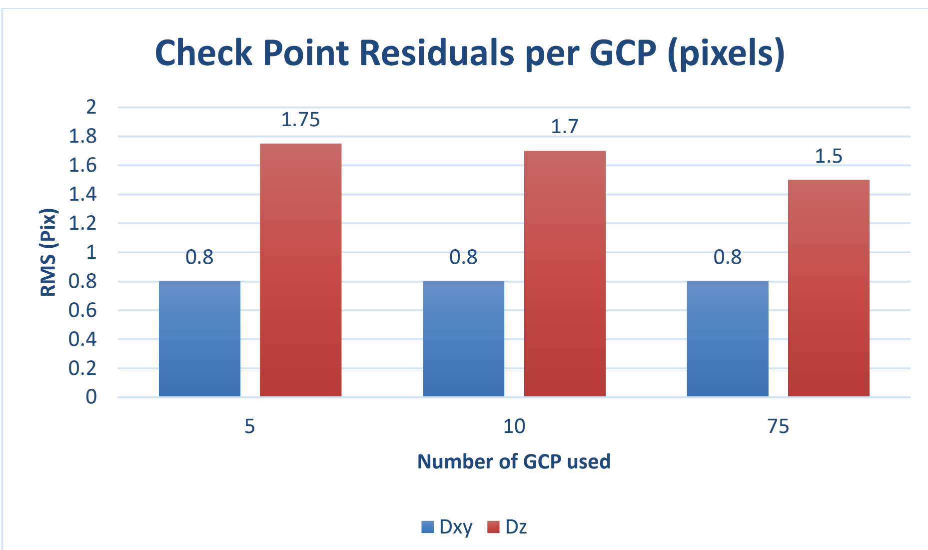
With 15 GCP and for 38 Check Points the RMSxy = ± 3.3 cm (0.825 pix) and RMSz = ± 6.0 cm (1.5 pix) were obtained.



The chart below presents the results of the accuracy analysis:

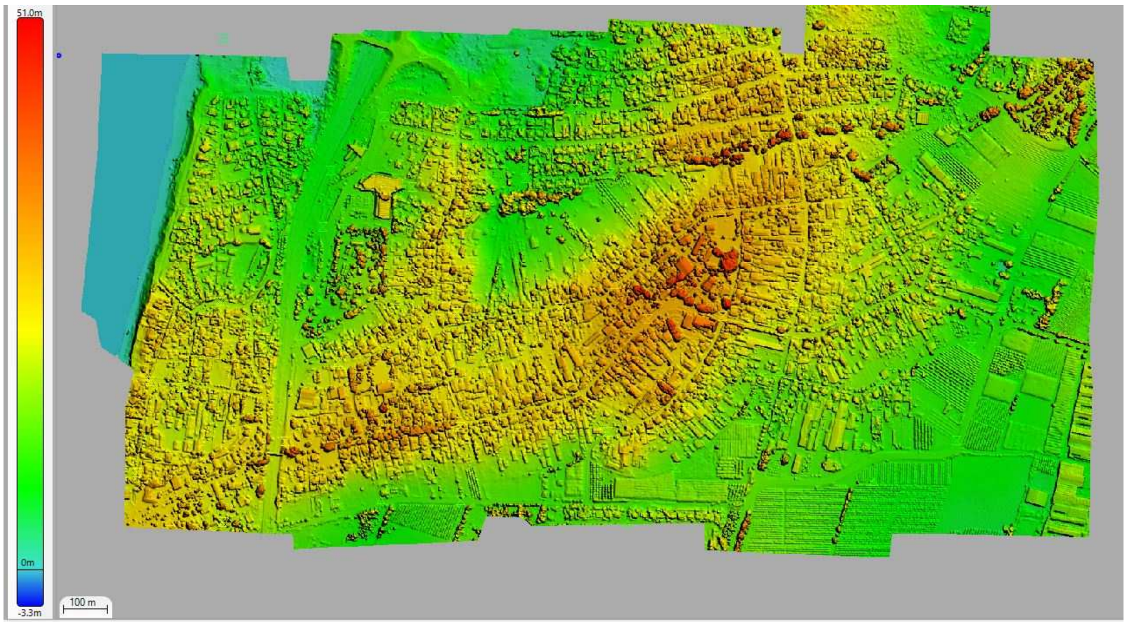


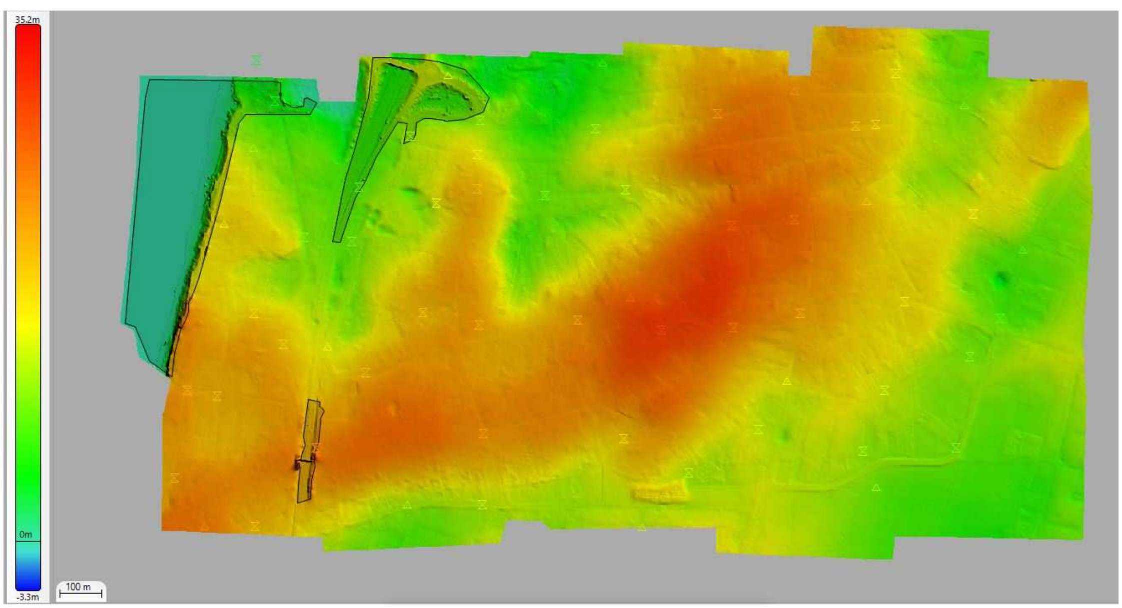
Planimetric accuracy of the block on Check Points is always at the level of 0.8 pixel independently of the number and configuration of GCPs used for adjustment and exterior orientation of the block. Altimetric accuracy of the block on Check Points starts from 7 cm (1.75 pix) with 5 GCPs, and reaches to 6cm (1.5 pix) with 15 GCPs. This altimetric accuracy is considered as high accuracy and even may be improved by using a high accuracy GPS data.



7. DSM and DTM accuracy analysis

A digital surface model (DSM) and a digital terrain model (DTM) were generated by Correlator3D using the aerial triangulation solution with 15 GCPs. Both were produced at a resolution of 10 cm, corresponding to 2.5 times the resolution of the input images.





The two figures above show the DSM and the DTM, with a color scheme stretched from minimum elevation to maximum. On the DTM, the overlaid polygons correspond to exclusion areas that were used during the DTM extraction process to avoid unwanted filtering on specific features (bridge overpass, natural cliffs and ridges). The DTM extraction was entirely automatic and no manual editing was performed.

The resulting DSM and DTM were compared to vertical check points. According to ASPRS standards for vertical accuracy assessment, "*The QC (quality control) checkpoints should be selected on open flat terrain, or on uniformly sloping terrain for x-meters in all directions from each checkpoint, where "x" is the nominal spacing of the DEM or mass points evaluated*".

25 check points were selected from the measured ground control points to meet this criterion and were used them to evaluate the elevation models. The DEM Inspection tool of Correlator3D was used to perform this task.

The following results were obtained:

	DSM	**DTM**
Resolution	10 cm	10 cm
# of check points	25	25
Z RMS	6.2 cm	8.6 cm
Bias error	-0.3 cm	1.4 cm
STDEV	6.2 cm	8.5 cm
MAX	12.2 cm	19.5 cm

Note that the DSM accuracy is very consistent with the aerial triangulation residuals, with virtually no bias on the elevation extracted.

8. Orthophoto accuracy analysis

The individual orthophotos were created using the orthorectification module of Correlato3D. The DSM was used to generate true orthophotos.

To evaluate the horizontal accuracy, the same 25 check points used to evaluate the DSM and DTM were re-measured on the resulting 2d orthos. The new coordinates were extracted and compared to the original check points coordinates. The XY combined (circular) error was calculated for each points and the average of all check points XY combined errors was found to be 2.8 cm.

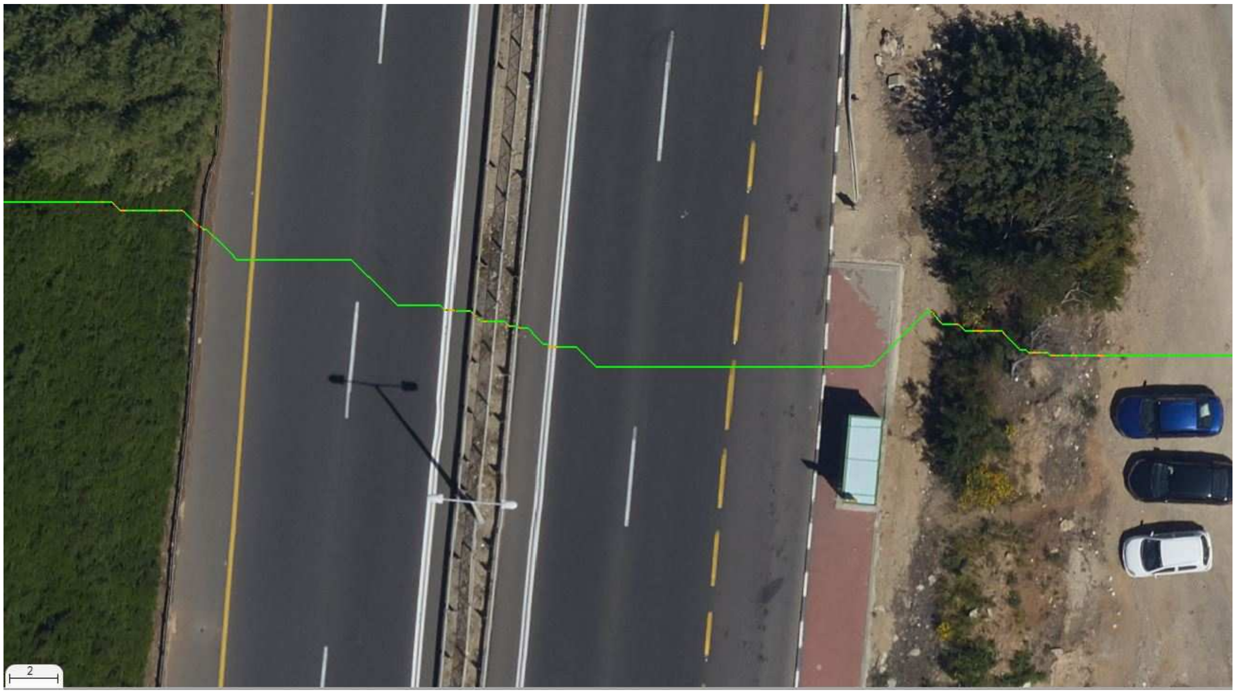
- Number of horizontal check points – 25
- Average of the XY circular errors – 2.8 cm
- Maximum XY circular error : 5.7 cm
- Standard deviation : 1.2 cm
- X RMS error : 2.5 cm
- Y RMS error : 2.0 cm

The error magnitude is exactly as expected following the aerial triangulation results.

9. Mosaic and cut-lines accuracy analysis

The final mosaic was assembled with the color balancing option enabled and automatic seamlines generation. The Mosaic Creation tool of Correlator3D was used.

Inspection at the junctions of the seamlines revealed no planimetric issue and matching along the roads for example appeared to be seamless.



Further analysis of results in natural areas showed very good color balance as well as seamless transitions.

The final mosaic of Phase One images generated with Correlator3D was thus shown to meet high standard of quality and accuracy.

10. Conclusions

This workflow and accuracy assessment report was to validate SimActive's software workflow and accuracy capabilities in conjunction with PhaseOne camera for mapping projects. The results obtained are a clear evidence that:

1. SimActive software coupled with the Phase One leads to accurate mapping products.
2. Phase One iXU-RS1000 is a metric camera with stable and clearly definable interior orientation parameters
3. Images captured by the camera are of a high geometric and radiometric quality ensuring the use of the camera in high accuracy mapping projects, including stereocompilation
4. Photogrammetric accuracy can reach mapping standards with only 5 GCPs with a mean XY RMS of 2.9 cm. SimActive's aerial triangulation provides a consistent and robust solution, even with a minimal number of GCPs.

5. Output product accuracy (DSM, DTM, Orthomosaic) has proven to be inside the expected accuracy following the aerial triangulation results with little added errors coming from the processing itself. The final mosaic quality is high with seamless color balance and no planimetric errors between orthos.