INITIAL RESULTS FROM THE VEXCEL ULTRACAM D DIGITAL AERIAL CAMERA

M. J. Smith [a, *], K. S. Qtaishat [a], D. W. G. Park [a], A. Jamieson [b]

[a] IESSG, The University of Nottingham, University Park, Nottingham, NG7 2RD UK –
(martin.smith, isxksmq1, david.park)@nottingham.ac.uk
[b] Simmons Aerofilms Ltd, The Astrolabe, Cheddar Business Park, Wedmore Road, Cheddar, Somerset, BS27 3EB UK
- ajamieson@simmonsaerofilms.com

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ABSTRACT:

A variety of digital airborne imaging systems are now in operation. Many are being integrated with in-flight control systems consisting of GPS and inertial measurement units (IMU). Many are multiple lens systems producing 'larger' digital image formats than from a single lens system. The Vexcel UltraCam D is such an imaging system.

The IESSG have been working with the initial test flight data captured by Simmons Aerofilms Limited as they introduce the new Vexcel UltraCam D digital camera and the GPS / IMU position and attitude system into their aircraft, product range and photogrammetric work flow. The introduction of new technology necessitates a steep learning curve in technical expertise, new production methodologies and quality control. Fundamental to this learning process is the need to understand the capabilities of the camera and imagery.

This paper presents results from the early flight trials which have started to explore the potential of the UltraCam D digital camera. The quality of products produced from imagery is often dependent on a variety of parameters and influences whether they have been produced from a digital or traditional film camera. This research will be starting at the beginning of the photogrammetric processes by investigating initial results primarily from aerial triangulation. Some good results have been achieved so far even though the imagery was not taken specifically for the purpose of this scientific trial. Further scientific analysis is required to fully appreciate the capability of this powerful mapping tool.

1. INTRODUCTION

1.1 Introducing New Technology

There are now a wide range of digital imaging systems available for use on an airborne platform. These range from single lens 'small' format digital cameras typically used by the general public through to 'larger' format multiple lens systems and linear array 'push boom' scanners. With the change in imaging system come a new range of issues that have to be addressed to use the images for the collection of geospatial information. The purchase of the image capture system can be just a part of the overall cost of introducing the technology into a production environment.

Although the photogrammetric community is familiar with handling digital images from scanned film based cameras, existing production methods may not lend themselves to accommodate different scales and formats of imagery often found when using digital imaging system. Alterations in photogrammetric work flow and product range need to be optimised to ensure the highest economic benefits of the new technology.

The introduction of new technology necessitates a steep learning curve in technical expertise, new production methodologies and quality control. Fundamental to this learning process is the need to understand the capabilities of the technology which often comes from experience and specific trials.

An important outcome of increased expertise and testing is the development of confidence in the reliability and the quality of the product being produced. This confidence in turn has to be transferred to a potential client before they will purchase the product. Simmons Aerofilms Limited (Simmons) have recently introduced the new Vexcel UltraCam D digital camera integrated with GPS and an Inertial Measurement Unit (IMU) into one of their aircraft. This has resulted in the need for new computer systems, data storage and data management systems being introduced, creating a very powerful mapping tool.

The full exploitation of this complex new mapping tool will take time to achieve but some early results are very encouraging. The quality of products produced will be dependent on a wide variety of parameters and influences, ranging from the calibration of the integrated system to the image measurement and data processing strategies. The IESSG at the University of Nottingham have an established relationship with Simmons Aerofilms Limited through research in integrated GPS and IMU measurements with traditional metric frame photography. This is continuing through this research into the potential and capability of the UltraCam D camera.

As this is a relatively new camera system only a limited number of papers are available (for example: Leberl et al., 2003;

* Corresponding author.

Kremer et al.,2004, Kröpfl et al., 2004) and therefore it is appropriate to present results here from the very early flight trials after the camera and system had been installed. This early flight was not a specific scientific trial for this particular project. However, it was flown over a small area containing a limited number of existing ground control points. This test area has been used in the past as a test area for traditional 9"x 9" metric camera photography. The data collected from the test site has enabled some limited analysis to take place.

1.2 Aims

The general aim of the research is to investigate the potential and capabilities of the Vexcel Ultra Cam D digital camera. Of particular interest at this early stage is the positional accuracy of the geographical information that can be extracted. This is initially being explored by analysing results from aerial triangulation. This normally forms the first stage of a photogrammetric activity and it is therefore appropriate that this is the starting point for our studies.

1.3 Methodology

As part of the early flight trials with the new camera a small test area was flown containing only a limited number of ground control points. Although it was not planned to undertake a rigorous scientific analysis from this flight it was felt part of the data collected could be used for preliminary photogrammetric analysis. The control distribution within the block of images is not ideal but there is sufficient to perform an aerial triangulation and start to appreciate the capabilities of the camera. A more scientific trial is being planned for the future. The blocks of photography and control distribution are shown in Figures 6 and 7. This paper presents some of the results obtained to date and further analysis is still being undertaken.

2. TECHNOLOGY

2.1 Vexcel UltraCam D Digital Camera

The Vexcel UltraCam D is an airborne multi-lens digital camera, Figure 1 shows the camera installed in the Simmons aircraft.

Figure 1. The Simmons Vexcel UltraCam D digital camera (Copyright Simmons Aerofilms Ltd)

The camera has multiple lenses as shown in Figure 2. that enable it to take simultaneously panchromatic, colour and colour infrared images, see Figure 3.

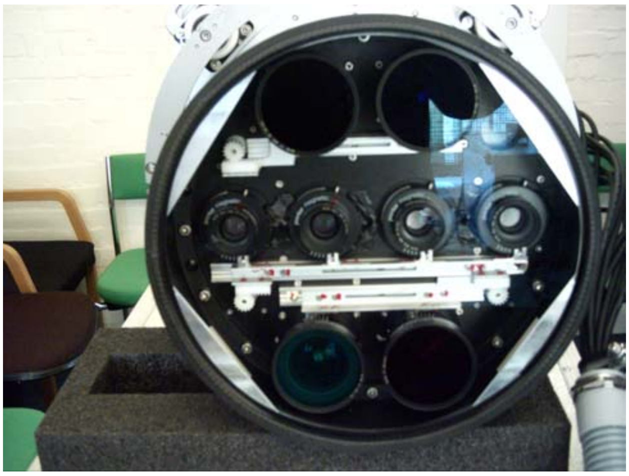

Figure 2. Multiple lens cones; 4 panchromatic across the centre and 4 larger colour cones (Copyright Simmons Aerofilms Ltd)

The single panchromatic image is produced from a merging of nine images as shown in Figure 4.

Camera details:

- Panchromatic, RGB and CIR imagery captured on a single pass
- 11500 pixels perpendicular to the flight direction
- 7500 pixels along the flight direction
- Focal length = 101.400mm
- CCD array sensor size =103.5 x 67.5mm
- CCD pixel size = 9 µm

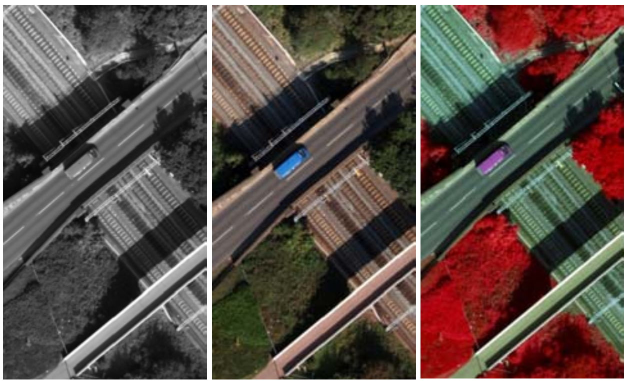

Figure 3. Panchromatic, colour and colour infrared images (Copyright Simmons Aerofilms Ltd)

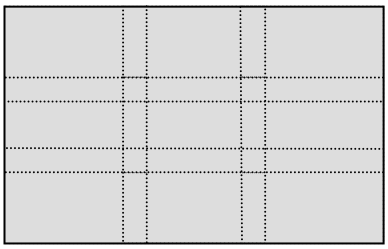

Figure 4. Schematic diagram of the formation of a single panchromatic image from 9 smaller images

2.2 Image Processing

The images are captured onto a 1.5 TB RAID on the aircraft then transferred at the airfield on to a four terabyte server see Figure 5. The first stage of image processing is undertaken by seven workstations linked with a high speed fibre network. The data is backed up on to an LT02 Ultrium tape drive and transferred to the offices at Potters Bar in London where the Simmons data archive is kept. Investigations are taking place into using high speed digital links between locations to save the use of tapes.

Figure 5. Four terabyte server at the airfield (Copyright Simmons Aerofilms Ltd)

2.3 GPS and IMU

The direct measurement of position and attitude is produced by an Applanix POS 510 GPS/IMU system using the post processing software, POSPac (4.02). The specification provided by the manufacturer for the GPS/IMU system is given in Table 1.

Position (m)	0.05 – 0.30
Velocity (m/s)	0.005
Roll & Pitch (deg)	0.005 (1/200th)
True Heading (deg)	0.008 (1/125th)

Table 1. Specification of the Applanix system for direct measurement of position and attitude

This system provides the potential for in-flight control for aerial triangulation, enabling a reduced amount of ground control to be used, or direct geo-referencing of individual images.

3. TEST SITE

3.1 Location

The test site is located at Milton Keynes, UK.

3.2 Aerial Triangulation Tests

As discussed above the images and data collected were from an early 'general performance' test flight and not specifically for a scientific test. So the amount and distribution of ground control points (GCPs) is not ideal and the GPS base station used was at Northampton some 30km from the test flight. This is a long baseline for high quality kinematic GPS, however, the results do start to give useful information about the potential of the system. There is also considerable interest in the use of long baselines between the base station and the aircraft.

The choice of flying height was based on typical flying heights for traditional 9"x9" metric frame photography, see Table 2.

Flying height (m)	Grd pixel size (m)	Coverage (m)	UltraCam Imagery nominal scale (f=101.4 mm)	Metric frame photography nominal scale (f=153mm)
1500	0.13	999 x 1531	1:15300	1:10000
760	0.07	505 x 776	1:7500	1:5000

Table 2. Flight characteristics

In all aerial triangulation computations 49 automatic tie point measurements were used in each overlap.

3.2.1 Aerial triangulation software: The software used was the Leica LPS software, ORIMA and the in-house IESSG software called 3db. Although relatively new to the IESSG, ORIMA was used for all aerial triangulation computations, except 3db was used to calibrate the misalignment between the IMU and camera.

3.3 Results and Discussion

The tests were divided into three groups, but only groups 1 and 2 have been under analysis so far:

1. aerial triangulation based only on ground control;
2. aerial triangulation based on ground control and in-flight GPS and IMU measurements;
3. direct georeferencing.

Figure 6 shows the 18 image block taken from a nominal flying height of 1500m and Figure 7 shows the 30 image block taken at a nominal flying height of 760m. The block at the lower flying height covers part of the higher flown block area. This block has four corner control points which each lie on only one image.

To enable some comparison to take place with a frame camera, results from a 24 photograph frame camera block taken at 880m flying height over the same test area have been included, see Figure 8.

In all cases automatic tie point measurements have been performed using ORIMA.

3.3.1 Aerial triangulation with ground control only: Results from a block of 18 images with a flying height of 1500m: Table 3 gives the results from various block configurations based on the number of strips and number of GCP used. The results are very good when considering the the flying height. Tie point RMSE values are reasonably consistent where as there is some variation in the RMSE of the residual for the GCPs. When the number of control points is small the influence of an individual point becomes more significant. As can be seen there is a small RMSE in Z for the two strips of 12 GCP solution and the Z RMSE for the tie points standard deviations is probably showing the effects of the relatively small airbase (base to height ratio, 0.27). Table 4 shows small image coordinate RMSE values. The values are becoming smaller as the solution is constrained less by the ground control. Overall, the tie point RMSE and the image coordinate RMSE values show a stable geometry.

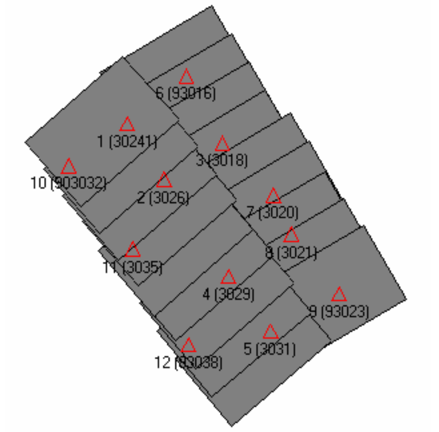

Figure 6. Block of 18 images taken at 1500m flying height showing the distribution of ground control

No of Strip /GCP	**Tie points RMSE (m) of standard deviations**			**Ground control points RMSE (m) of residuals**		
	X	**Y**	**Z**	**X**	**Y**	**Z**
Two /12	0.076	0.067	0.271	0.145	0.077	0.029
Two /4	0.063	0.058	0.271	0.071	0.067	0.004
One* /7	0.082	0.068	0.260	0.048	0.049	0.019
One* /4	0.083	0.071	0.313	0.036	0.040	0.020

Table 3. Tie and ground control point analysis, results from aerial triangulation using ground control points only, flying height 1500m (* left hand strip in Figure 6)

No of Strip /GCP	**Images coordinates RMSE (μm) of residuals**	
	x	**y**
Two /12	2.62	2.42
Two /4	1.77	1.88
One /7	1.91	1.66
One /4	1.63	1.31

Table 4. Image coordinate analysis, results from aerial triangulation using ground control points only, flying height 1500m

Results from a block of 30 images with a flying height of 760m: This block had limited analysis potential as the four corner control points appear on only one image, so only one configuration is considered, see Table 5 and 6. Bearing in mind the control limitations and the image scale the results show good tie point and GCP RMSE values as well as consistent image coordinate RMSE values when compared with the 'better' controlled 1500m flying height block.

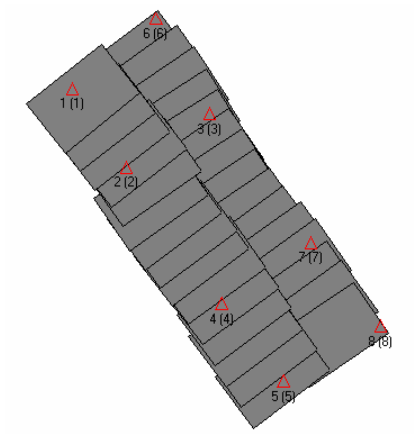

Figure 7. Block of 30 images taken at 760m flying height showing the distribution of ground control

No of Strip /GCP	**Tie points RMSE (m) of standard deviations**			**Ground control points RMSE (m) of residuals**		
	X	**Y**	**Z**	**X**	**Y**	**Z**
Two /8	0.041	0.039	0.155	0.066	0.052	0.050

Table 5. Tie and ground control point analysis, results from aerial triangulation using ground control points only, flying height 760m (distribution of control points not suitable for other image configurations)

No of Strip /GCP	**Images coordinates RMSE (μm) of residuals**	
	x	**y**
Two /8	2.78	2.53

Table 6. Image coordinate analysis, results from aerial triangulation using ground control points only, flying height 760m

3.3.2 Aerial triangulation including in-flight GPS and IMU: Selected blocks were re-triangulated with in-flight GPS and IMU measurements included. The results are given in Tables 7, 8, 9 and 10 which can be compared with Tables 3, 4, 5 and 6. The results show no improvement over the original GCP only solutions. This might be the expected effect from the long baseline that was used to compute the in-flight GPS values (30km). With a shorter baseline that would normally be used an improved solution might be expected. In addition, it does show the strong solution produced by the imagery and ground control. Note the results with no ground control which have been added to show the consistency produced. Table 7 and 8 show results from a block of 18 images with a flying height of 1500m.

No of Strip /GCP	Tie points RMSE (m) of standard deviations			Ground control points RMSE (m) of residuals		
	X	Y	Z	X	Y	Z
Two /12	0.124	0.107	0.388	0.150	0.114	0.044
Two /4	0.125	0.109	0.357	0.107	0.110	0.045
Two /0	0.121	0.112	0.276			

Table 7. Tie and ground control point analysis, results from aerial triangulation using ground control points/GPS/IMU, flying height 1500m

No of Strip /GCP	Images coordinates RMSE (μm) of residuals	
	x	y
Two /12	2.75	3.00
Two /4	2.01	2.31
Two /0	2.01	1.89

Table 8. Image coordinate analysis, results from aerial triangulation using ground control points/GPS/IMU, flying height 1500m

Table 9 and 10 show results from a block of 30 images with a flying height of 760m.

No of Strip /GCP	Tie points RMSE (m) of standard deviations			Ground control points RMSE (m) of residuals		
	X	Y	Z	X	Y	Z
Two /8	0.035	0.051	0.151	0.116	0.071	0.130
Two /0	0.065	0.063	0.138			

Table 9. Tie and ground control point analysis, results from aerial triangulation using ground control points/GPS/IMU, flying height 760m (distribution of control points not suitable for other image configurations)

No of Strip /GCP	Images coordinates RMSE (μm) of residuals	
	x	y
Two /8	2.84	3.18
One /0	2.61	2.85

Table 10. Image coordinate analysis, results from aerial triangulation using ground control points/GPS/IMU, flying height 760m

3.3.3 Aerial triangulation with scanned standard frame camera photography and ground control only: Results from a traditional (nominally 154mm principal distance), scanned (15μm resolution), metric camera block of 3 strips of 8 photographs (see Figure 8), are given in Tables 11 and 12. These are shown to give some comparison with the results in Tables 5 and 6. Interestingly the image residuals are smaller but the RMSE values for both tie points and GCPs are almost all slightly larger in the digital camera. This is possibly showing a slightly stronger geometry in the frame camera but better image quality of the digital camera. Further analysis is still required on this type of comparison.

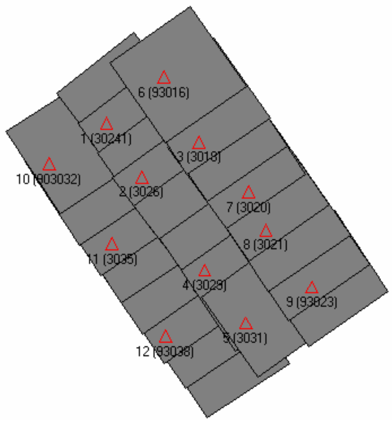

Figure 8. Block of 24 frame camera photographs taken at 880m flying height showing the distribution of ground control

No of Strip /GCP	Tie points RMSE (m) of standard deviations			Ground control points RMSE (m) of residuals		
	X	Y	Z	X	Y	Z
Two /12	0.029	0.028	0.055	0.044	0.059	0.030

Table 11. Tie and ground control point analysis, results from aerial triangulation using scanned frame camera photography and ground control points only, flying height 880m

No of Strip /GCP	Images coordinates RMSE (µm) of residuals	
	x	**y**
Two /12	3.70	3.90

Table 12. Image coordinate analysis, results from aerial triangulation using scanned frame camera photography and ground control points only, flying height 880m

4. CONCLUSIONS

The Vexcel UltraCam D digital camera has been successfully installed and made operational. Some good results have been produced from an informal data set. Image coordinate residuals show consistency with many RMSE values in the 2-3µm range. The analysis of the data from this flight is still taking place although scientific trials are necessary and being planned before the full capabilities of the camera can be determined.

4.1 References and/or Selected Bibliography

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