RADIOMETRIC AND GEOMETRIC QUALITY ASPECTS OF THE LARGE FORMAT AERAIL CAMERA ULTRACAM XP

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ABSTRACT:

UltraCamXp is the new flagship camera product which introduced in 2008 at the ISPRS Conference and Exhibition in Beijing by Vexcel Imaging (a Microsoft Company). This paper will give a technical overview about the advantages and concept of the camera. The focus is set on a large scale project which was carried out in late 2008 near Graz, Austria. Radiometric and geometric aspects of this flight mission are presented in this paper.

1. INTRODUCTION

UltraCamXp was introduced at the ISPRS Conference and Exhibition in Beijing in August 2008. The large format camera is based on the development of the UltraCamX sensor. The most important improvement can be seen in the larger image format of 17310 pixels cross track and 11310 pixels along track. Thus UltraCamXp is able to capture a frame image of 195 million pixels.

1.1 Sensor Unit (SU)

The basic design of the UltraCamXp is similar to the previous models UltraCamX and UltraCamD (Leberl, 2003). It consists of 4 panchromatic heads, covering 9 CCDs and 4 multi spectral heads covering 4 CCDs.
The sensor head is equipped with the new 6 µm CCD product FTF6040 developed by DALSA.

Figure 1 - Sensor Unit and storage component of UltraCamXp

The radiometric bandwidth of the CCD sensors is up to 13bit, converted via a 14 bit ADC component and stored within 16bit digital files. The optical lens system is produced by LINOS/Rodenstock with a focal length of 100 mm for the panchromatic channel and a focal length of 33 mm for multi spectral cones.

1.2 Technical Equipment

The image data is stored on two separate data units redundantly. Each data unit has a capacity of 4.2 TB, which is equivalent to 6600 images. The data units can be exchanged during flight which allows unlimited image collection. The highest possible frame rate is 1 frame per 2 seconds which means a data transfer rate of about 2.5 Gbits per second. A fast data download from the data units is managed via the docking station.

The complete UltraCamXp package comes with the sensor unit, onboard storage and data capture system, two data units and the operator interface panel. A docking station and the software for distributed post processing are included in the package. The complete setup can be seen in Figure 2.

Figure 2 - Complete technical equipment for the UltraCam Xp

1.3 Technical Camera Parameters

The most important parameters of the UltraCamXp camera system are listed below:

- Large image format of 17310 pixels cross track and 11310 pixels along track enabled by new 6 µm CCD sensors (the DALSA FTF 6040 M CCD sensor product)
- Physical image size of 104 mm by 68 mm
- Proven optical system with 100 mm focal length for the panchromatic camera heads and 33 mm for the multi spectral camera heads
- Image storage capacity of 6600 frames for one single data storage unit
- Instant data download from the airplane by removable data storage units
- Fast data transfer to the post processing system by the new docking station

1.4 Postprocessing Software

The camera is operated in the air by the Camera Operating System (COS), an intuitive and easy to handle software. The Post Processing Software Office Processing Center (OPC) handles the processing to Lvl02 and further to Lvl03 images. This software is currently being replaced by the UltraMap Platform, a framework which allows distributed processing of collected image data. The main functionality of the post processing remains similar to the OPC software. A major improvement besides the distributed processing is the effective Dragonfly visualization engine. This technology offers a fast visualization of large image data sets such as photo missions with several thousand frames and TeraBytes of digital data. This viewer is implemented based on the Microsoft Seadragon technology and allows fast access to multi resolution image data. Additionally, views can be changed to index maps, footprint views or heat maps, to show the degree of overlaps of an image block and other QC relevant color coded information. A sample display of a complete production flight can be seen in Figure 3.

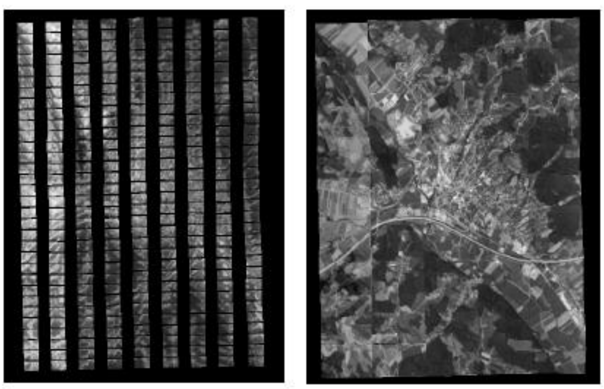

Figure 3 - Screenshot of Dragonfly viewer

With the UltraMapAT Vexcel Imaging offers a complete aerotriangulation software component. This tool is optional and includes automated tie point collection, a guided interactive control point measurement and a final bundle adjustment based on the well known BINGO software product (Kruck, 1984).

2. LARGE SCALE PRODUCTION FLIGHT - LEIBNITZ

A large scale photo mission was used to show the large scale capability of UltraCamXp. At a flying height of 500 m above ground level a GSD of 3 cm was achieved. The stereo overlap of images in flight direction was 60%. In addition to the 3 cm GSD flights, a 9 cm mission and a 18 cm mission were flown at 1500 m H_{agl} and 2800 m H_{agl} respectively (cf. Table 1).

Leibnitz is a city in the south of Graz, Austria. The testflight was performed with an UltraCamXp camera on the 8th of October, 2008, a bright and sunny day. Details to the three photo missions can be found in
Table 1.

	PM1	PM2	PM3
HAGL	500m	1500m	2800m
FOL	60%	80%	80%
SOL	60%	70%	90%
GSD	3cm	9cm	18cm

Table 1 - Overview of the three photo missions in Leibnitz

The overlaps in and across flight direction were more than 60%, rising up to 90% with the flying height. Altogether 163 images were recorded for the complete project. An overview of the project area is shown in
Figure 4.

Figure 4 - Overview of the project area Leibnitz in the south of Graz, Austria.

3. ULTRACAM XP QUALITY ASPECTS

3.1 Radiometry

The large scale photo mission was used to investigate the radiometric performance of UltraCamXp. The weather conditions were quite good (sunny, nearly no clouds) and the flying time was during noon (11.30am – 1.30pm).

UltrCamXp simultaneously collects light from five different spectral bands. The spectral sensitivity of red, green, blue and near infrared and the panchromatic channel are listed below in Table 2.

Channel	From (nm)	To (nm)
PAN	410	690
RED	580	700
GREEN	480	630
BLUE	410	570
CIR	690	1000

Table 2 - spectral sensitivity of all channels in the UltraCamXp

In Figure 5 a subarea of frame 117 is shown. The red line shows were the histograms have been calculated for PAN, Red, Green, Blue and Near Infrared have been computed. The blue window shows a zoom and histogram stretched view of a shadow area to prove that there is valuable information still available.

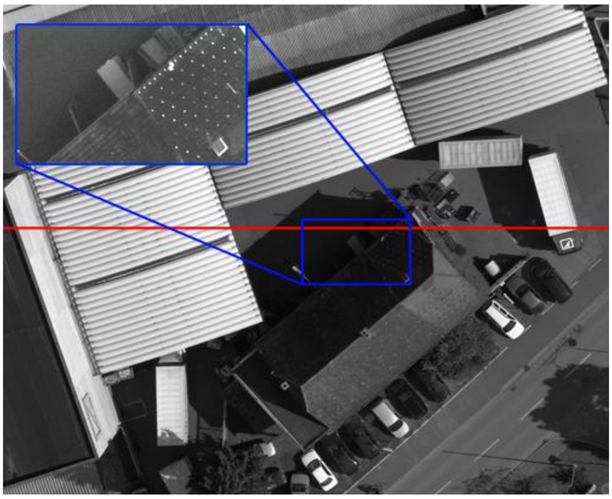

Figure 5 - subarea of Frame 117, red line indicates cross-section plot

The cross-section for the panchromatic channel in Figure 6 shows that the values in the bright areas of the image can raise up to above 5000 DN, in this case exactly 5382DN. And also in darker, shadow areas of the image there is still information available.

The RGB-cross-section (

Figure 7) along the red line of the subarea in Figure 5 show that the red and green channel are at an equal level (in bright areas up to 3500 DN) and the blue channel is generally lower in bright areas. The red channel has its maximum at 3586 DN, green at 3672 DN and blue at 2624 DN.

It was of interest how much the radiometric bandwidth of images from different flying heights correspond one to each other. For that investigation the same area and cross-section on the ground was identified in images of the different flying heights and the intensity levels along these cross-sections were investigated. Frames 14 at GSD 18 cm, frame 42 at GSD 9 cm and frame 117 at GSD 3 cm were used for this analysis.

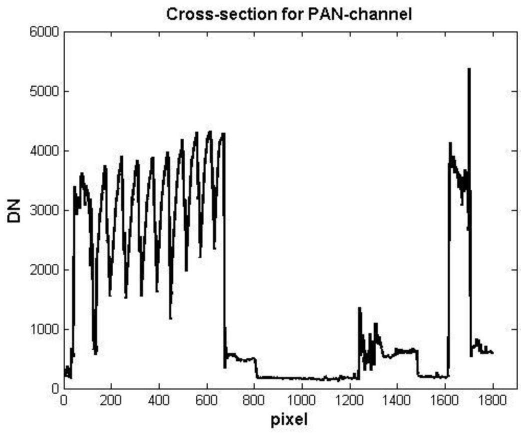

Figure 6 – Cross-section of the PAN-channel of frame 117

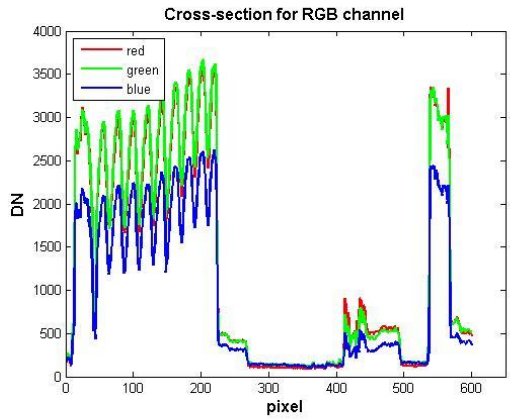

Figure 7 – Cross-section of red, green and blue channel of frame 117

As illustrated in Figure 8 one can observe the correspondence of the radiometric response in the three different photos. Maximum DNs of the entire frames and the cross sections are given below. DNs represent a bandwidth of 11 to 13 bit.

	MaxFrame	MaxCrossSection
Frame 14 - PM3		
PAN	4748	4542
R	3482	3346
G	3224	3162
B	2706	2584
CIR	3606	3334
Frame 42 - PM2		
PAN	5422	4092
R	3332	3040
G	3460	3246
B	3098	2324
CIR	3766	3312
Frame 117 - PM1		
PAN	6818	5382
R	7776	3586
G	7946	3672
B	6220	2624
CIR	7906	3660

Table 3 - Maximum radiometric response from three altitudes

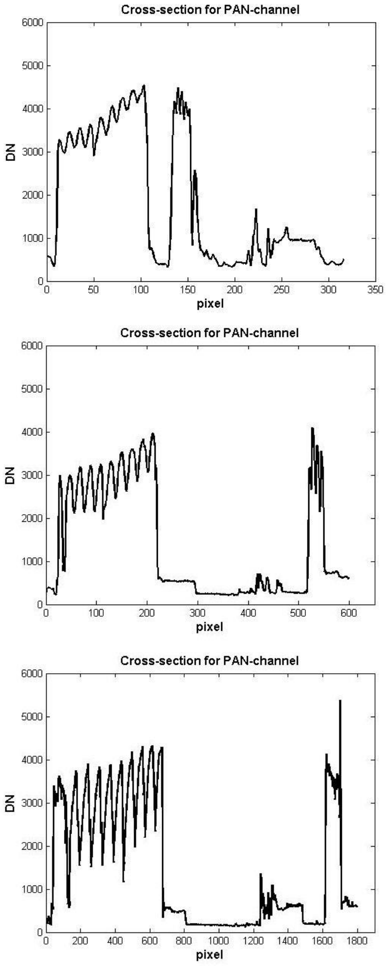

Figure 8 - Radiometric response of the panchromatic channel from three images from the same object area and different GSD

3.2 Geometry

The geometric performance of the digital camera system is illustrated by means of a complete aerial triangulation. The large scale flight consists of 99 images taken from an altitude of 500 m above ground level. The base length at 60% endlap was set at 135 m. The speed over ground was 60 m/sec (117 kn). The frame interval of 2.25 sec as well as the forward motion compensation (FMC) of 6 pixels at 3 msec could be achieved by UltraCamXp. The flight was processed and triangulated and did show high quality results after the least squares bundle adjustment. The sigma_x,y from image measurements was achieved at 0.7/0.8 µm (~ 1/7 Pixel) without self calibration parameters. RMS control point residuals were computed at a 2.5 cm for x/y as well as for z (= 0.05 o/oo of the flying height).
A slightly better result could be achieved when introducing additional self calibration parameters into the adjustment. Figure 9 shows the remaining image residuals at a magnitude of about ½ micrometer at the maximum.
The tree different photo missions at different flight levels did produce comparable results. Thus the RMS residuals of the photo measurements were in the range between 0.6 µm and 1.1 µm for x and y.

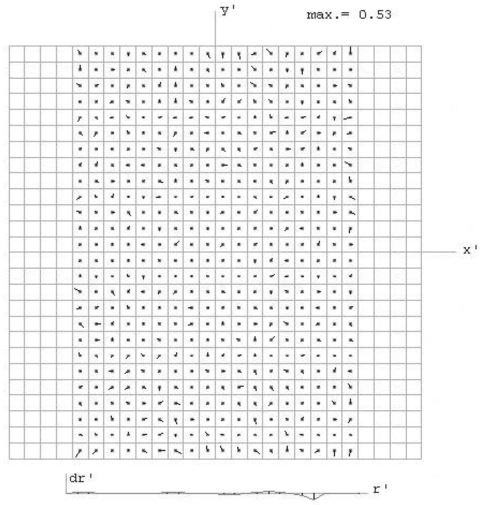

Figure 9 - Remaining image residuals less than 0.53 µm after the least squares adjustment including additional self calibration parameters

4. CONCLUSION

In this contribution we show an overview on the technical specifications and the performance of the UltraCamXp large format digital aerial camera system. In addition, the software products available for this camera are introduced shortly. To show the quality of the camera a flight project in Leibnitz, near Graz is presented. The radiometric quality and geometric accuracy is presented in this paper.

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