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UltraCam, A Brand for Continuous Developments

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ABSTRACT

UltraCam is the name of the Microsoft/Vexcel Imaging camera family which was introduced into the market in May 2003 by the first digital aerial camera product UltraCam D. This digital frame camera did show a very unique design and offered an image format of almost 90 MegaPixels. Since the last eight years Vexcel Imaging was able to continuously develop and enhance the camera product, the software to operate the camera and to process images as well as the photogrammetric production software. In May 2011 the new flagship product, the UltraCam Eagle – a 260 MegaPixel digital aerial framing camera was presented.

INTRODUCTION

The design concept of the UltraCam family is based on a multi camera head layout. UltraCam D was the first product of that kind and was introduced in 2003. Four camera heads contribute to the large panchromatic image and additional four camera heads take the multispectral spectrum including red, green, blue and near infrared. Based on that design Vexcel Imaging was able to launch UltraCam X in 2006, UltraCam Xp in 2008, UltraCam XpWA in 2009 and the UltraCam Eagle in 2011. In addition to the eight cone concept a four cone camera concept was developed and UltraCam L / Lp were launched in 2008 and 2009.

In line with modern industry technology a major contribution to the product comes from software which is responsible for the operation of the UltraCam in the air and for the end to end digital workflow. Within this workflow the image post-processing plays a significant role and enables the user to compute the final frame image.
Major milestones in the UltraCam software development did enhance the entire product and thus the concept of “Software leveraged hardware” was consequently implemented. The advantages of this philosophy are manifold and obvious. Flexibility to make use of high quality components from the information technology industry and the flexibility to continuously improve the entire workflow and the product shall be mentioned among many others.

Along the development path of the UltraCam sensor family we have focused on several improvements and product attributes which should be beneficial to the camera and to the photogrammetric workflow. It may be worthwhile to discuss this and to identify the magnitude of the added value.

THE ULTRACAM SENSOR FAMILY

The first UltraCam sensor product – the UltraCam D – was presented in 2003 and did show a specific design. Eight camera heads together (four for panchromatic image content and four for multispectral sensing) build the sensor head. All cones are looking nadir. The unique way of assembling image content from four panchromatic focal planes into one image coordinate system was already implemented into this sensor (cf. Fig.1). In order to enable large scale photo missions the specific trigger delay – the so called syntopic imaging concept – was implemented.

A derivative of this concept was then implemented into the UltraCam L /Lp sensor head and consist of two cones for the panchromatic channel and two cones for the multispectral channels (RGB and NIR). UltraCam Lp was launched in 2009 and the specific geometric properties of this 90 Megapixel camera are well described in (Wiechert, Gruber, 2009). Figure 2 illustrates the two camera design concepts. UltraCamX on the left has eight independent camera heads and UltraCam Lp on the right has 4 camera heads. It is notable that the two panchromatic sensor heads of UltraCam Lp are equipped each with one 48 Megapixel CCD sensor array.
The Software improvements- namely the introduction of thermal conditions and material properties and the introduction of the "Monolithic Stitching" (cf. Ladstädter et al, 2010) were implemented on a regular software release cycle and were made available to the user community. This ability to improve the performance of a product by no exchange of parts at the customer site is very well accepted benefit of the "Software Leveraged Hardware" design concept.

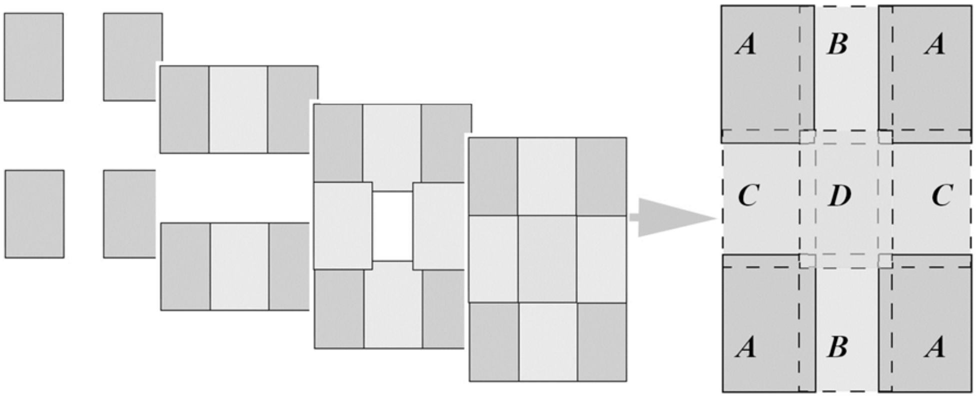

Figure 1: UltraCam four cone camera concept adding image content from four cones and 9 CCD sensor arrays into the large format panchromatic image. This concept was implemented in UltraCam D, X, Xp, XpWA and the Eagle.

MAJOR STEPS OF DEVELOPEMENT

The design of the UltraCam camera product does not only consist of the layout of the different optical cones and the way how these cones contribute to the final production image. Thus the entire weight of the equipment in the air, the level of power consumption and the ease of operation was improved over the last years. Improvements were possible by introducing a new concept of data transfer technology when image content was stored during the flight mission on the set of digital disk drives (HDDs) and when the download process could be simplified by exchangeable data units. Figure 3 shows the first concept of data storage for the UltraCam D (left) and the new data unit of the UltraCam X and UltraCam Xp. The next important step towards integration and ease of operation was performed when solid state memory modules became available at reasonable cost and satisfying performance. The UltraCam L/ Lp was the first Vexcel Imaging camera product which is equipped with such storage media and – based on the minimization of computer boards – offers a fully integrated system with one single component for the aerial operation. The UltraCam Eagle was designed based on the experiences from UltraCamLp. Figure 4 shows the two camera systems, UltraCam Lp on the left and UltraCam Eagle on the right.
The overall weight of the on board equipment could be reduced to 75 kg for the UltraCam Eagle and only 55 kg for the UltraCam Lp and – based on the integration of computer and storage components – consist of one single module, namely the sensor head itself. Power consumption was reduced significantly to 350 W (UltraCam Eagle) and 220 W (UltraCam Lp).

Figure 2: Sensor head of UlraCam X (left) and UltraCam Lp (right). UltraCam X has is equipped with 8 independent camera heads, UltraCam Lp has 4 camera heads.

It is worthwhile to mention that the availability of new CCD sensor products from the CCD manufacturer Dalsa (Teledyne Dalsa) has triggered the development path of the UltraCam sensor head and Vexcel Imaging was able focus on specific requirements. Thus the decreasing pixel size starting at 9 µm in 2003 vs. 5.2 µm of 2011offered an increase of the digital image format at the same high radiometric quality level as derived from the first implementation. The physical size of the CCD sensor array – 36 mm by 24 mm did remain unchanged and offered optimal properties to read out fast and at a very similar level of signal quality. Some component had to be adapted in order to meet the requirements of the fine geometric resolution and larger content of information of the set of CCD sensor arrays. Thus the Vexcel proprietary development of the 2nd generation electronic component is now responsible to enable fast and high quality readout of the analog signal and to convert into digital at the 14 bit level for the UltraCam Eagle as well as for the UltraCam Lp. The design of the optical components was tuned with respect of the geometric resolution of the CCD sensor arrays. Thus the new QIOPTIQ / Linos / Vexcel HR lens systems for the UltraCam Eagle resolves 100 lp/mm, offer an optimized MTF and benefit from the retro-focus design, a design concept which was already implemented for the lens systems of UltraCam X and UltraCam Xp.

A comprehensive overview of parameters and system components for all sensor products is given in Table 1a and Table 1b.

Figure 3: UltraCam D (left), UltraCam X (Xp) compete equipment (middle) and UCX data unit (right).

Figure 4: Integrated Camera systems: UltraCam Lp (left) and UltraCam Eagle (right). Sensor heads, computing unit and storage unit are placed in the sensor unit.

	UCD	UCLp	UCX	UCXp	UCXpWa	UCE
Release Year	2003	2009	2006	2008	2009	2011
Image Size [Pixel]	11500 x 7500	11704 x 7920	14430 x 9420	17310 x 11310	17310 x 11310	20010 x 13080
MegaPixel	86	92	136	196	196	260
CCD [MPixel]	11	48/24	17	24	24	32
Pixel Size [µm]	9	6	7.2	6	6	5.2
Radiometric Accuracy [bit]	>12	>12	>12	>12	>12	>12
Time between frames [sec]	0.85	2.5	1.35	2.0	2.0	1.8
Electronic Architecture	1st generation	2nd generation	1st generation	1st generation	1st generation	2nd generation

Table 1a: Specification and performance parameters of UltraCam sensors.

	UCD	UCLp	UCX	UCXp	UCXpWa	UCE
Lens System	**Linos *)**	**Linos/Vexcel**	**Linos/Vexcel**	**Linos/Vexcel**	**Linos/Vexcel**	**Linos/Vexcel**
Resolution (Lp/mm)	60	80	80	80	80	100
Focal length Pan [mm]	105	70	100	100	70	80
Focal length Color [mm]	35	33	33	33	23	27
FOV [°] cross/along track	55/37	52/37	55/37	55/37	73/52	33/23
Data Storage	HDD	SSD**)	HDD	HDD	HDD	SSD**)
#Images per Data Unit	2500	2500	4700	6600	6600	3800

*) Some early UltraCamD sensors where equipped with Schneider Lenses
**) Integration of storage and computing components into sensor unit.

Table 1b: Specification and performance parameters of UltraCam sensors (ctd').

FRAME SIZE AND PRODUCTIVITY

The productivity in the air of a digital aerial camera system is mostly triggered from the frame size of the individual photo and the cross flight line image dimension in particular. Thus the increase of the image format was a major goal in the development strategy of the UltraCam sensor product family. Starting at 86 Megapixel and 11 500 Pixel cross track frame size with UltraCamD a 100 km by 100 km project area could be mapped at 20 cm GSD by about 10 000 images at 60 flight lines and 170 frames per line at the standard flight pattern of 60% endlap and 25% sidelap. The new generation UltraCam Eagle enables one to do the same project from 35 lines and 100 images per line (3500 images). The increase of productivity by comparing the cross track image formats is almost 75 % from UltraCam D to UltraCam Eagle. Figure 5 illustrates the increase of the footprint and the cross track frame size. Frame 200 of the UltraCam Eagle flight mission from June 28th 2011 is shown on the right and the footprint sizes of UltraCam D, UltraCam X and UltraCam Xp (from left to right) were as an example derived from that frame.
There is no question that the increase of ground resolution and the trend to a denser flight pattern have an impact on the way of doing aerial operation. So the same project area may be acquired at significantly higher ground resolution and higher overlap. Thus the number of flight lines and the number of images may then be larger but the benefit of the improved information content compensates for the bigger effort.

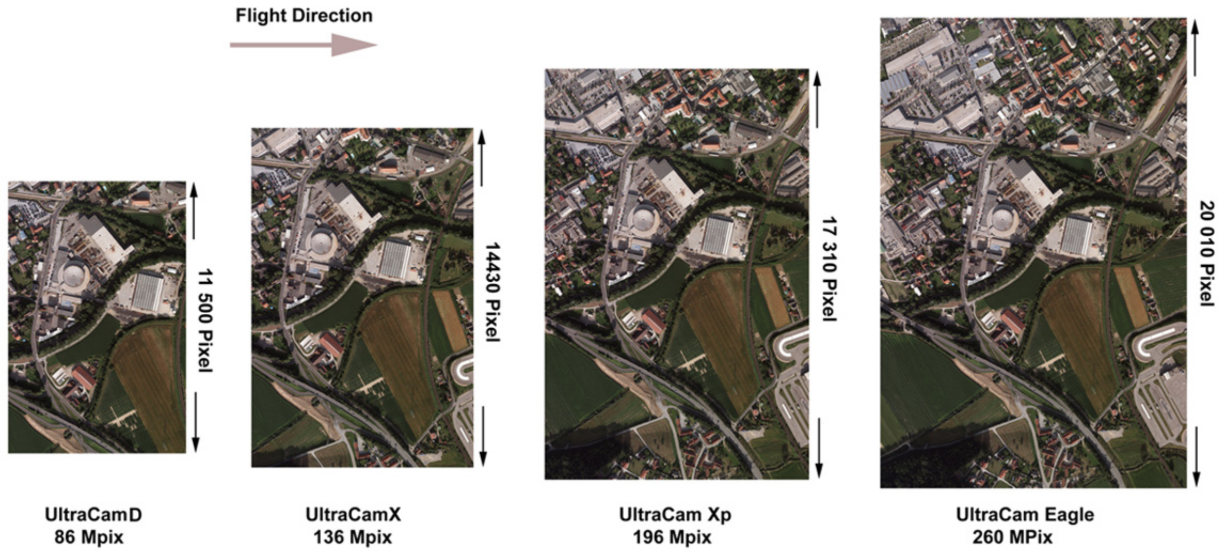

Figure 5: Illustration of the relative footprint size of UltraCam sensors from 86 MegaPixel to 260 MegaPixel based on frame 200 from the UltraCam Eagle flight mission on June 28th, 2011(right). The footprint size of the UltraCam Lp is slightly larger than that of the UltraCamD.

GEOMETRIC PERFORMANCE

The geometric performance of the UltraCam Sensor systems was subject of development and improvement even if the first results from the UltraCam D was already at a remarkable value of 0.2 Pixels (1.8 µm). Introducing an enhanced calibration and post processing workflow this high geometric quality could be maintained and even improved when the geometric resolution of the camera was significantly enhanced by the CCD sensor arrays. Thus the geometric quality of the UltraCam X was already at the 1 µm level (0.15 Pixel at 7.2 µm).

UltraCam Xp geometry performance was documented in (Gruber, Ladstädter, 2011) and show a magnitude of image residuals after least squares bundle adjustment of 0.8 µm which corresponds to 0.13 pixel. This result was achieved from the UltraMap AT workflow and embedded BINGO adjustment.
Results from UltraCam Eagle validation flights show a very comparable result and thus the relative accuracy in terms of fractions of a pixel was maintained at the same level of 0.13 of a pixel.

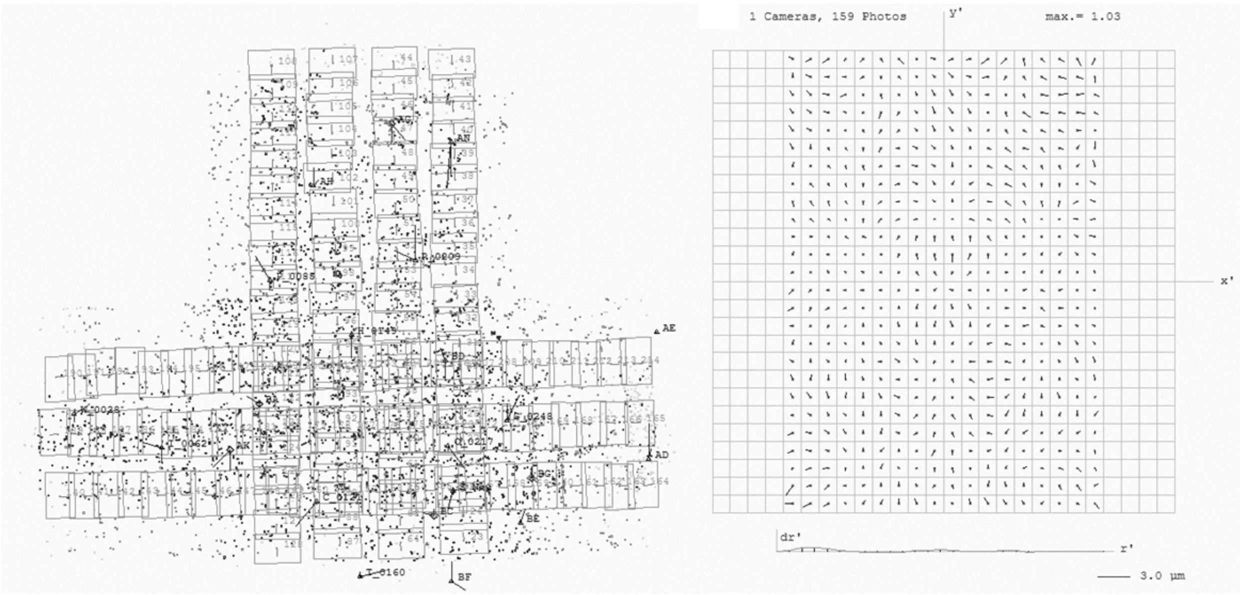

Figure 6: Least squares bundle adjustment result of the UltraCam Eagle (flight mission from June, 28th 2011).

RADIOMETRIC PERFORMANCE

The dynamic range of the UltraCam system is a combination of the performance of several components and could be kept at the high level of 12 bit since the beginning. Thus a close cooperation with the CCD sensor manufacturer Dalsa led to the high quality Microsoft/Vexcel OEM sensor products we use in our camera. Even if the physical size of the Pixels was reduced from 9 µm by 9 µm (UltraCam D) to 5.2 µm by 5.2 µm (UltraCam Eagle) we still achieve the same dynamic bandwidth (cf. Leberl et al., 2005). A special focus on the in house development of the sensor electronic boards led to an even better signal behavior for our latest camera system. Figure 7 exemplarily illustrates the dynamic range of an image by local histogram adaption. A bright roof as well as a dark shadow area does show the full radiometric resolution without saturation.
The subsequent steps of the UltraCam data processing chain are performed at significantly higher radiometric resolution. The analog to digital conversion is implemented at the 14 bit level and all digital image processing is implemented in 16 bit.

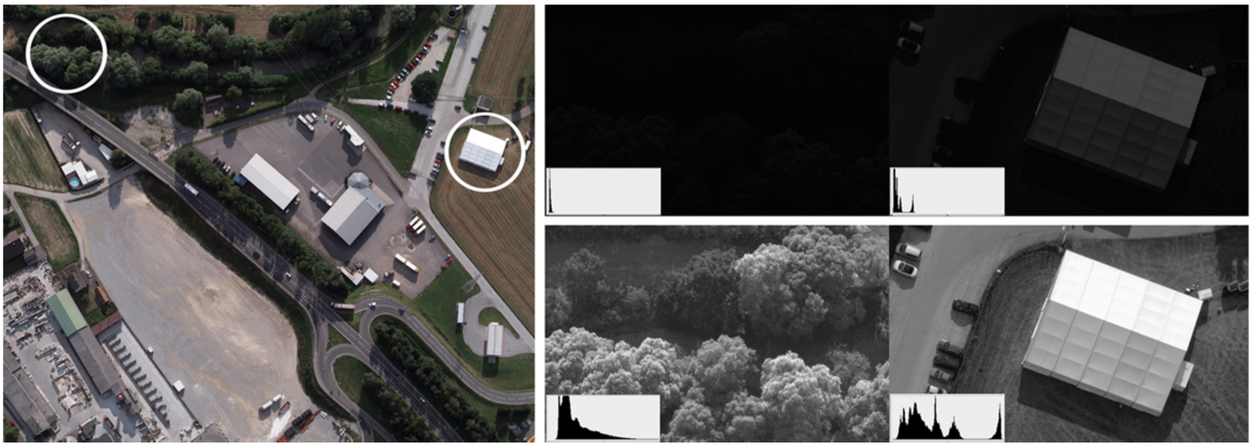

Figure 7: Radiometric bandwidth of 12 Bit shown at a high dynamic scene from UltraCam Eagle. The bright roof shows maximum value at 12416 DN(16). The Noise Level is at 3 DN(16) thus the system covers a dynamic range of 1: 4139 (= 12 bit or 72 dB).

CONCLUSIONS

The main goals of the UltraCam Sensor development have been mentioned. Beside productivity in the air and superior image quality the ease of operation was a prominent target of the product design and development. These goals could be achieved by integrating high end components from the information technology industry as soon as available and developing such elements which are unique for the camera product.

One important basis of this flexible and user oriented development path was the concept of the multi cone design and powerful software to process the digital image data and support an effective workflow. Thus the combined contribution of software and hardware components – the "Software Leveraged Hardware" may be identified to be the driving motto of the UltraCam digital camera product family.

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