ULTRACAM: THE NEW SUPER-LARGE FORMAT DIGITAL AERIAL CAMERA

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ABSTRACT

This paper introduces the new flagship of the digital aerial camera industry for remote sensing. Vexcel Imaging GmbH has developed and announced a new UltraCam camera. This camera defines a new bucket in the digital aerial camera market: the so called super-large format camera segment. This paper presents the camera design and technical parameter. In addition, features of the processing software UltraMap are described, which are required to process super-large images.

KEYWORDS: UltraCam, UltraMap, digital camera, aerial camera, remote sensing, digital photogrammetry

INTRODUCTION

Digital aerial cameras have basically replaced analog cameras for all kind of applications. Since the first digital cameras came to the market, a constant increase of frame size or more generic: an increase of the amount of pixel across the flight strip took place. That development was driven by the need of increased flight efficiency to minimize flight costs, minimize flying time and to minimize project risk.

The key parameter for the collection efficiency of a digital aerial camera is the number of pixel across flight strip. This directly impacts the number of flight lines required to map a certain area. The number of pixels along the flight line has no or only very little impact on the collection efficiency because this can always be offset by a fast frame rate and an automated processing workflow. Since years, cameras are segmented into buckets such as medium format or large format cameras. The new UltraCam opens a new bucket, the so called super-large format bucket. Figure 1 shows the segmentation of the current available digital aerial photogrammetric cameras.

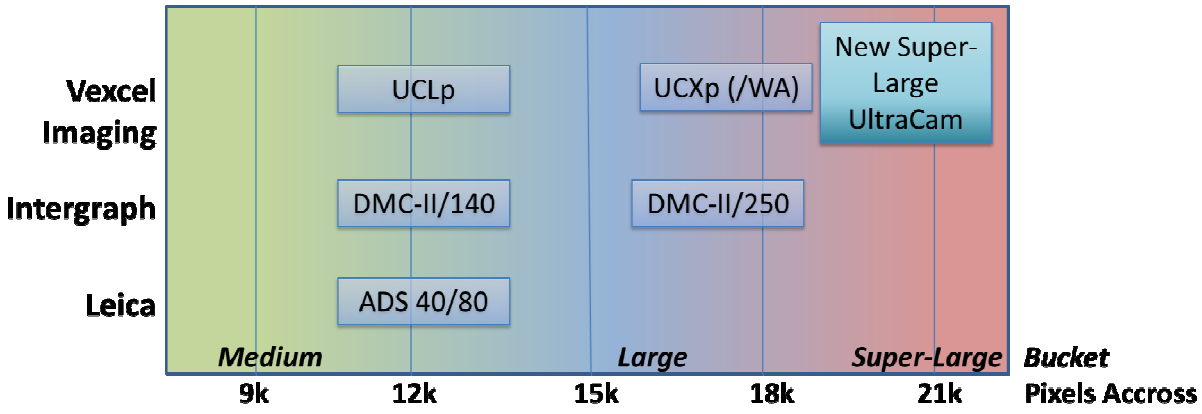

Figure 1. Photogrammetric digital aerial camera segmentation.

SUPER-LARGE FORMAT ULTRACAM

As already mentioned above, the key parameter for collection efficiency is the amount of pixels across the flight strip. The UltraCam series has always been an innovation driver of the industry. Figure 2 shows the frame size development of the UltraCam camera series since 2004. It ranges from UltraCamD (2004), to UltraCamX (2006), to UltraCamXp and UltraCam Xp Wide Angle (2008 and 20009) to the most recent model, the new super-large format UltraCam (2011).

Figure 2. UltraCam frame size (UltraCamD, UltraCamX, UltraCamXp, new super-large UltraCam).

Figure 3 compares the pixel across of various digital sensor systems for stereo acquisition to determine collection efficiency. Comparison is done based on the published technical camera parameters.

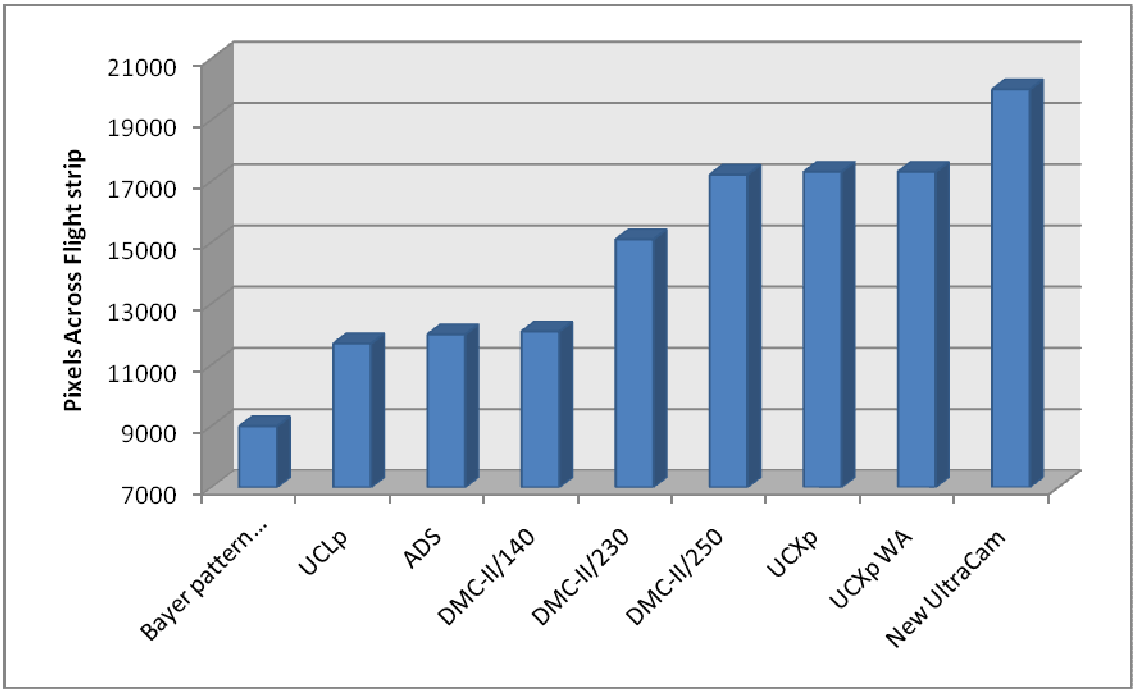

Figure 3. Collection efficiency comparison based on pixel across flight strip.

With a frame size of 20,000 pixels across the flight strip @ full stereo capability, the new super-large UltraCam defines again the standard of the aerial camera industry. The camera has new lenses, two different lab exchangeable lens systems, new CCDs, new filters, new electronics for a fast frame rate of < 1.80 seconds, a new storage system and a new camera flexible modular housing concept.

The new UltraCam is a radical new camera system; each component has been rigorously reviewed and newly developed to the extent of today's technological limits, however it is based on the well proven camera design of the former UltraCam models such as the UltraCamX or UltraCamXp. The PAN channel is stitched together by Monolithic Stitching from nine overlapping sub-images. The nine sub-images are exposed by syntopic exposure which results in a parallax free image.

Key parameters of the new super-large UltraCam are listed in Table 1 and Figure 4 shows a sketch of the new UltraCam.

Due to the high integration, all components are integrated into the sensor head and no additional storage or computer unit is required. With this, the new super-large UltraCam follows the new architecture which has already been introduced with the UltraCamL in 2008.

Figure 4. Sketch of the new super-large UltraCam.

Table 1. Key parameters of the new super-large format UltraCam.

Super-Large UltraCam – Key Parameter		
Parameter	**Value**	**Comment**
Frame Size	20,000 x 12,900 pixels across x along flight strip	New super-large format footprint.
Focal length – lens system 1	PAN: 80 mm R, G, B, NIR: 27 mm	Newly developed, Vexcel Imaging specific digital high resolution lens system. Optimized for 5 µm CCDs and remote sensing.
Focal length – lens system 2	PAN: 210 mm R, G, B, NIR: 70 mm	Newly developed, Vexcel Imaging specific digital high resolution tele lens system. Optimized for 5 µm CCDs and remote sensing.
Lens configuration	Two lens configurations. Exchangeable by a specifically trained end user expert	New: two exchangeable lens system configurations are available to support lower altitude engineering applications as well as large high altitude ortho projects.
Max. frame rate	< 1.8 seconds	New Vexcel Imaging specific camera electronic based on silent board technology. Fast frame rate allows high flight speed and high forward overlap.
CCD pixel size	5,2 µm	New Vexcel Imaging specific CCD development by DALSA based on the latest available CCD technology. Optimized for remote sensing.

CCD signal/noise ratio	72 dB	New CCD technology and use of nine smaller CCDs for PAN allow better image dynamic compared to the use of monolithic large CCDs.
CCD image dynamic	16,000 grey values (14 bit/pixel)	New filter to reduce vignetting and optimize aperture setting for high MTF values
Workflow image dynamic	16 bit/pixel workflow	
Channels	High resolution PAN Lower resolution R, G, B, NIR	
Pan-Sharpening ratio	1:3	Pan-sharpen ratio supports classification applications.
Accuracy	Sub-pixel accuracy (better 15% of pixel size)	Camera supports engineering application accuracy with one inch GSD or even higher resolutions..
Shutter	Prontor for Vexcel	Vexcel Imaging specific shutter, developed by Prontor. Optimized for remote sensing.
Storage system	Solid State Storage > 3900 images per data unit	New in-flight exchangeable storage system, based on solid state devices.
Weight	< 75 kg	New camera housing concept, electronic and computer reduce weight significantly.
Power Consumption	350 watts @ 24-28 V DC	New electronic and computer reduce power consumption significantly.
Camera Housing	Highly integrated, modular	New innovative flexible modular camera housing concept. Customer can either stack to a one senor head system or split the camera into two units (sensor and storage),
Operator Display	Touch Display	New innovative user interface to configure and operate the camera. Features touch screen technology. Allows in-flight control of each captured image.
Project parameters	Example: 10 cm GSD	Flight height: 1,570m Max. speed: 284 kts @ 80% frontlap Max. frontlap: 90% @ 140 kts
GPS/INS/FMS	Embedded POSTrack OEM solution as an option	New OEM POSTrack system as an option fully integrated in the sensor head. That minimizes cabling and connectors. Other systems are supported by external interface.
Mount	UltraMount GSM 3000	New interface between camera and mount with the embedded POSTrack system.
Image processing	UltraMap	New automated workflow to process super-large images fast.
Ortho processing	GXL Aerial	New automated workflow to process super-large ortho images fast supports large ortho projects.

Another key parameter for the collection efficiency of a camera is image dynamic or radiometric dynamic. The higher the image dynamic of an aerial camera is, the better the camera can handle different illumination conditions. The capability to handle lower illumination conditions extends the flying hours per day and also allows flying under cloud coverage. That leads to more flight hours per day and to more flight days per year. Image dynamic also directly impacts image quality and measurement quality. The higher the image dynamic is, the more details are visible e.g. in the shadow. That leads to more and more robust tie points during AT or photogrammetric measurement.

The use of nine newly developed smaller CCDs for the PAN channel of the new UltraCam ensures best image dynamic, superior to the dynamic of monolithic large CCDs. Also, monolithic large CCDs require multiple readouts to obtain a somehow acceptable frame rate. These multiple readouts split monolithic large CCDs into several non-overlapping tiles. So, the radiometry of a large CCD is not at all monolithic. The smaller CCDs of the UltraCam have higher signal to noise ratios which leads to higher image dynamic. Radiometric, the big footprint of the UltraCam is stitched together out of only nine overlapping sub-images by Monolithic Radiometric stitching implemented into UltraMap.

The new UltraCam features a b/h ratio of 0.34, which is a suitable value. Due the rectangular aspect ratio of the UltraCam and the fast frame rate, collection efficiency and geometric accuracy by b/h ratio are well balanced. The nine sub-images of the PAN channel are stitched together by Monolithic Geometry implemented into UltraMap with sub-pixel accuracy. Values of 0.8 µm to 1.0 µm are constantly achieved by UltraCams and with Monolithic Stitching also independent from the image content.

Processing of super large format images require a tailored workflow. UltraMap features a highly automated workflow and features such as automated distributed processing, automated load balancing, automated level 0 to level 2 and level 2 to level 3 processing enable the end user to process quickly and to deliver high quality results fast.

ULTRAMAP

The amount of data collected by digital cameras is huge. The new super-large format UltraCam image size is around 832 Mega Byte per capture. UltraMap is the processing software for all UltraCam cameras. It extends the workflow into a full photogrammetric workflow by a seamless integration of aero triangulation and bundle adjustment functionality into the existing image processing workflow. UltraMap is designed to handle all kind of projects ranging from projects with a few hundred images up to projects with ten thousands of images and it is optimized for UltraCam images. For this, it introduces a new, revolutionary technology and concept of image handling, a direct spin off from the latest available Microsoft technology.

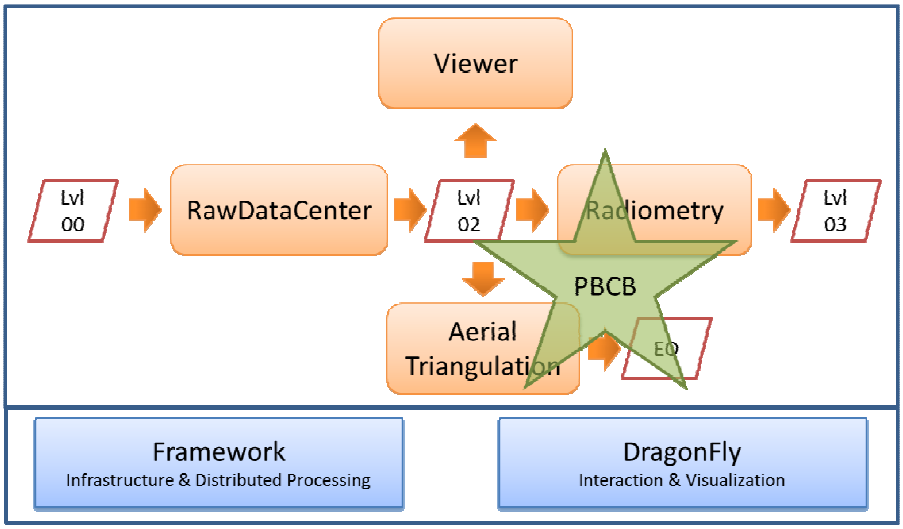

Figure 5. UltraMap overview.

UltraMap offers all the features to process super-large format images efficiently and to deliver high quality results in time. Key is the workflow oriented innovative workflow featuring:

- Automated verified fast download of image data into the processing system
- Automated distributed processing level 0 to level 2 featuring Monolithic Geometry
- Automated distributed processing level 2 to level 3 featuring Monolithic Radiometry
- Automated load balancing
- Embedded aerotriangulation with automated tie point collection
- Automated blunder removal during bundle adjustment
- Automated project based color balancing (PBCB)
- Model-based radiometric correction such as hotspot, atmospheric effects, and haze
- Dragon fly based viewer
- Full 16 bit workflow with multi-camera support

GXL AERIAL

As an extension to the workflow, GXL Aerial provides an automated workflow to process huge amount of UltraCam images to ortho mosaics. This workflow also fully supports the new super-large UltraCam.

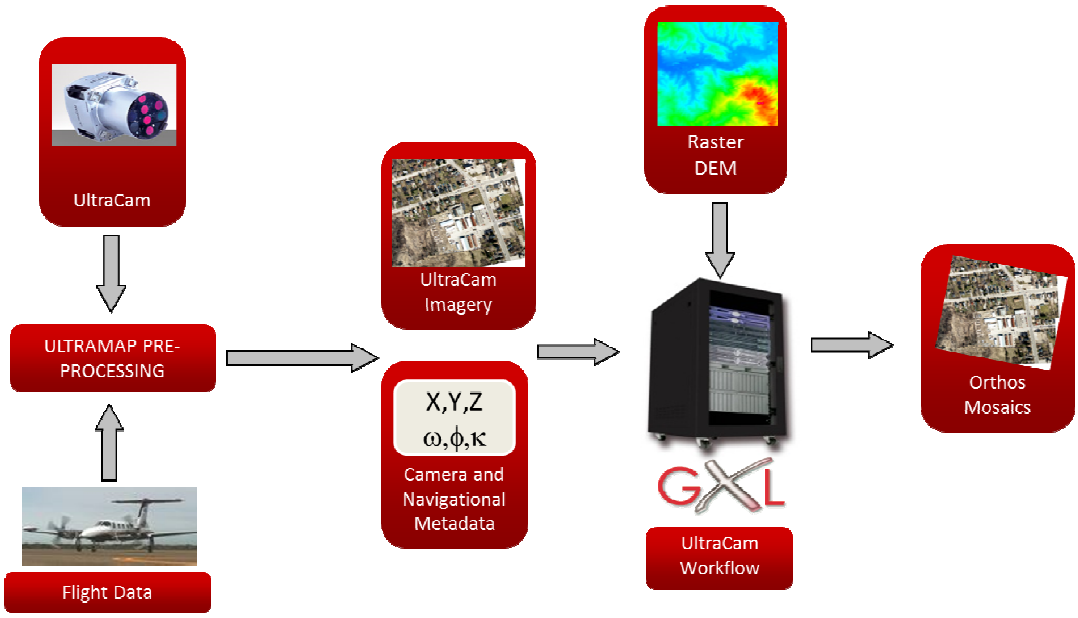

Figure 6. GXL Aerial overview.

GXL Aerial (Figure 6) extends UltraMap processing with multi-core, distributed, GPU-based orthorectification and auto-mosaicking. It allows to quickly process and preview results for custom editing and final inspection before mosaic creation. The extended workflow connects to UltraMap and integrates easily into the existing business processes thanks to flexible, modular workflows:

- Extends UltraMap functionality with ortho and mosaic such as
    - UltraMap Level 3 data ingest
    - UltraMap AT ingest
    - High-speed orthorectification
    - Automated seamline selection
    - Automatic mosaic generation
    - Automated tiling, reprojection and pyramiding.

- Quickly process and inspect results for custom editing before mosaic creationing
- Process thousands of images per day using multi-core & GPUs
- Distributed, flexible, automated GPU-enabled processing
- Throughput aligned with UltraCam collection capacity and UltraMap throughput

Three product lines match customer needs with respect to budget and business needs (Table 2):

Table 2. GXL Aerial and UltraMap packaging.

Processing Solution	Processing Capability/throughput	UltraMap HW/SW	GXL Aerial HW/SW
Field Solution "GXL Field"	100's Orthos / day	4 Core UltraMap and UltraMap/AT	Single Quad Core and single GPU Geomatica GXL
Desktop Solution "GXL Standard"	2,000 Orthos / day	20 Core UltraMap and UltraMap/AT	Single Quad Core and 2 GPU Geomatica GXL
Rack Solution "GXL Advanced"	>5,000 Orthos / day	40 Core UltraMap and UltraMap/AT	Dual Quad Core and 4 GPUs Geomatica GXL

REFERENCES

Gruber, M., 2007: *UltraCamX, the new digital aerial camera system by Microsoft Photogrammetry*, Proceedings of the Photogrammetric Week 2007, Stuttgart, DE

Gruber, M. & Wiechert, A., 2009: *New digital aerial cameras by Vexcel Imaging / Microsoft*, Proceedings of the Remote Sensing and Photogrammetry Society (RSPSoc) Annual Conference 2009, 8-11. 9. 2009, Leicester, UK.

Ladstaedter et al, 2010: *Monolithic Stitching: One Sensor Geometry For Multiple Sensor Cameras*, Proceedings of the American Society for Photogrammetry & Remote Sensing, 26-30 April, 2010, San Diego, CA

Leberl, F. et al. 2003: *The UltraCam Large Format Aerial Digital Camera System*, Proceedings of the American Society for Photogrammetry & Remote Sensing, 5-9 May, 2003, Anchorage, AL

Mansholt, U., Ladstädter, R. (2008): Geometric analysis of Vexcel Imaging UltraCamX test flights, Proceedings of the XXI ISPRS Congress, 3-11 July 2008, Bejing, China.