UltraCamX, the new Digital Aerial Camera System by Microsoft Photogrammetry

MICHAEL GRUBER, Graz

ABSTRACT

UltraCamX is the new digital large format aerial camera developed by Vexcel Imaging GmbH, Graz, Austria and is now available from Microsoft Photogrammetry. This article presents a short technical overview on the camera system and shows the results from several flight missions. Finally a view words about the transition from Vexcel Imaging GmbH to Microsoft Photogrammetry under the ownership of Microsoft Corp., Redmond, US are given.

Key Words: Digital photogrammetry, aerial cameras, large format framing cameras.

1. INTRODUCTION

Vexcel Imaging GmbH, situated in Graz, Austria was known as the manufacturer of photogrammetric devices. The first product was the precision film scanner UltraScan5000. In May 2003 the digital large format camera system UltraCamD was presented and – three years later – the new large format digital aerial camera system, the UltraCamX was introduced to the international mapping market at the ASPRS 06 in Reno, Nevada.
The new camera was developed on top of the experience and success of three years of contribution to the digital sensor market and the digital photogrammetric source image acquisition. Reviewing the time since the ISPRS2000 when the first digital large format aerial cameras have been presented, we see a rather poor performance during the first 3 or 4 years after 2000. Only in 2004 the number of digital large format sensors in operation exceeded 50 units and therefore digital cameras did start to play a role in the worldwide photogrammetric production.

2. ULTRACAM X, THE LARGEST DIGITAL FRAME CAMERA

UltraCamX is the successor of the UltraCamD camera system and exploits the most valuable developments of the industry in the fields of sensor technology, data storage technology and data transfer technology as well as Vexcel's in-house experience and know-how.
The most considerable advantages of UltraCam X are

- large image format of 14430 pixels cross track and 9420 pixels along track
- excellent 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 4700 frames for one single data storage unit
- almost unlimited image harvest due to exchangeable data storage units
- instant data download from the airplane by removable data storage units
- fast data transfer to the post processing system by the new docking station

The camera consists of the sensor unit, the onboard storage and data capture system, the operators interface panel and two removable data storage units. Software to operate the camera and process the image data after the flight mission completes the system.

Fig. 1: UltraCam X digital aerial camera system with the Sensor Unit (right) and the airborne Computing Unit including two removable Data Units (left).

2.1. The UltraCam X Sensor Head

The basic photogrammetric concept of the UltraCamX sensor head does not differ from the older UltraCamD concept. It consists of eight independent camera cones, 4 of them contributing to the large format panchromatic image, 4 contributing to the multi spectral image. The sensor head of the UltraCamX is equipped with 13 FTF5033 high performance CCD sensor units, each producing 16 mega pixels of image information at a radiometric bandwidth of more than 12 bit.
The transition to 7.2 µm CCD sensors caused a redesign of the optical system which is able to resolve the 70 lp/mm of the CCD pixel grid. In cooperation with LINOS/Rodenstock such high performance optical system with the focal length of 100 mm for the panchromatic cones and the focal length of 33 mm for the multi spectral cones was developed. This set of two lenses supports the pan sharpening ratio of 1:3.

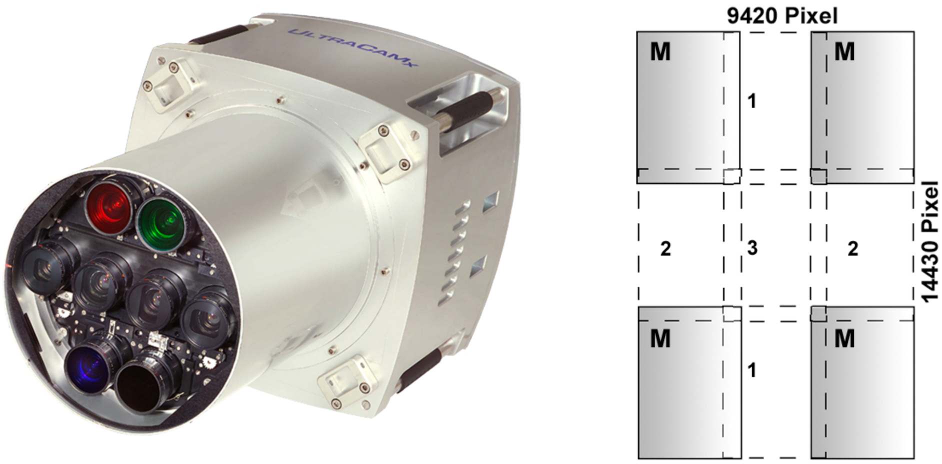


Fig. 2: The UltraCamX sensor head (left) consists of 8 camera heads, 4 of them contributing to the large format panchromatic image. These 4 heads are equipped with 9 CCD sensors in their 4 focal planes. The focal plane of the so called Master Cone (M) carries 4 CCDs (right).

The image format of 14430 pixels cross track and 9420 pixels in flight direction contributes to productivity in the air. At a 25 % side overlap between strips the UltraCamX covers more than one mile or 1650 m at 6 inch pixel size.

Technical Data UCX Sensor Unit	
Panchromatic Channel	
Multi cone multi sensor concept	4 camera heads
Image size in pixel (cross track/along track)	14430 * 9420 pixel
Physical pixel size	7.2 micron
Physical image format (cross track/along track)	103.9 mm * 67.8 mm
Focal length	100 mm
Lens aperture	f = 1/5.6
Angle of view (cross track/along track)	55° / 37°
Multispectral Channel	
Four channels (Red, Green, Blue, Near Infrared)	4 camera heads
Image size in pixel (cross track/along track)	4992 * 3328 pixel
Physical pixel size	7.2 micron
Physical image format (cross track/along track)	34.7 mm * 23.9 mm
Focal length	33 mm
Lens aperture	f = 1/ 4
General	
Shutter speed options	1/500 sec – 1/32 sec
Forward motion compensation	TDI controlled, 50 pixels
Frame rate per second	1 frame in 1.35 sec
A/DC bandwidth	14 bit (16384 levles)
Radiometric resolution	> 12 bit /channel

Tab. 1: Technical Data and Specifications of the UltraCamX Senor Unit

2.2. The UltraCam X storage system

The new data storage system of the UltraCamX improves the end to end workflow of the aerial mission and meliorates the working conditions of the aerial crew. The system contains two independent data units for redundant image capture. The data units are able to capture up to 4700 images of 136 mega pixels each and – most valuable for large scale missions – can be replaced by spare units within a few minutes. Thus one can increase the entire number of images for one single mission by a factor of two or three and enjoys practically unlimited image storage capacity on board. Disconnecting the data units from the camera system after the completion of a flight mission and shipping the raw data to the office is then an easy play.

The downloading of the image data is supported by a docking station, which allows the complete data transfer of 4000 images within 8 hours through four parallel data transfer channels. A 24 hour cycle of flying, copying and QC can be achieved.

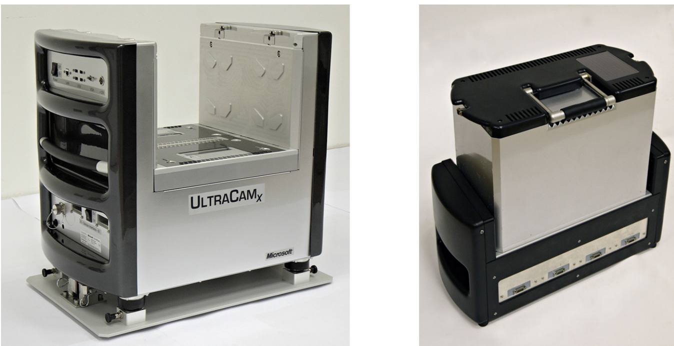


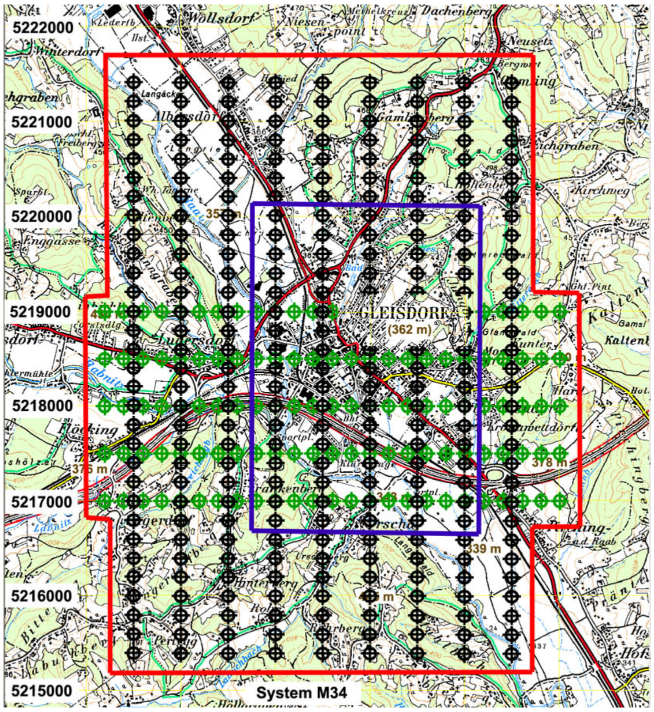
Fig. 3: UltraCamX on board computing unit (left) and Data Unit attached to the Docking Station (right). The download of image data to the post processing station is supported by four parallel data streams.

3. GEOMETRIC ACCURACY AT THE 1 MICROMETER LEVEL

Geometric quality is still the main issue for mapping cameras. After decades of experience with analog film cameras the digital sensors have to prove that such geometric quality is achievable. UltraCamX has been put onto the proof bench since the first flight and did show a remarkable geometric quality. One measure of geometric quality is the sigma_o value of an aerial triangulation project. This value reflects the quality level of image coordinate measurements and can be achieved at the 1 micrometer level.

But comparing the geometric performance of mapping cameras does mean more than just comparing the sigma_o value. One may draw the attention to the base/height ratio of the camera, arguing that analog film cameras are equipped with a square image format and therefore have a better base/height ration than digital cameras with a rectangular image format. This does not cover the entire potential of digital cameras. Much more of importance is the ability to accurately and automatically measure image coordinates of features. This is basically supported by the superior radiometric quality of images from digital cameras vs. images from scanned film and the superior geometric stability of the CCD sensors vs. film. Automatic tie point matching by means of digital image correlation proofs this impressively.

Routine flights with UltraCamX during the last 9 months over a well known area with ground truth did proof the geometric performance of UltraCamX. The automatic tie point matching was done using INPHO's well known aerial triangulation software packages Match AT. A cross check and additional self calibration options were applied by BINGO.



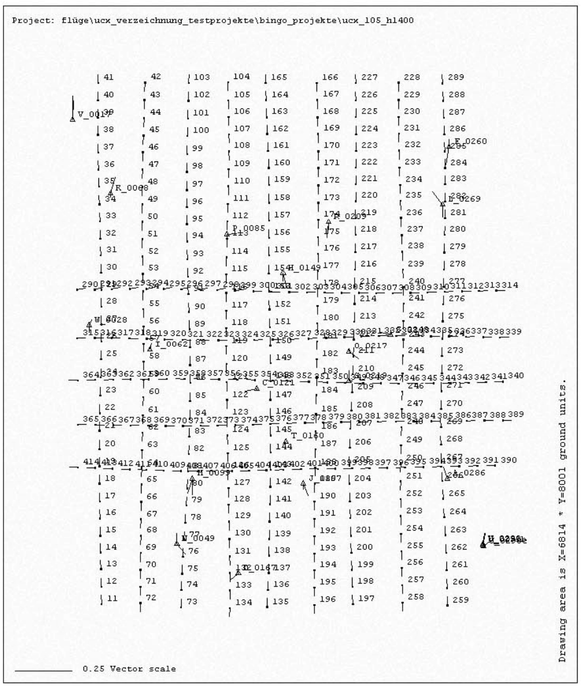


Fig. 4: Test area near Graz, Austria. Flight plan with 14 flight lines and result of the AAT after an UltraCamX photo mission.

Sensor	GSD (m)	HAGL (m)	Sigma_o (µm)	#images	#points	#pts/img	rmse z (m)
UCX1a	0.09	1250	1.50	127	3134	184	0.053
UCX1b	0.13	1800	1.45	92	2310	198	0.070
UCX2	0.08	1150	1.39	76	2822	238	0.049
UCX3a	0.10	1400	1.17	404	3575	104	0.044
UCX5	0.10	1400	0.73	199	13099	323	0.041
UCX7	0.10	1400	0.94	403	13156	330	0.040

Tab. 2: Results from UltraCamX aerial missions. The sigma_o value lies between ±0.73 and ±1.50. The variation of the image coordinate measurement is in the range of ±0.6 µm to ±1.6 µm. The vertical accuracy is at the level of 0.03 o/oo of the flying height.

3.1. Improving accuracy by means of auto calibration

Modern aerial triangulation methods exploit the specific advantages of the well known bundle adjustment technology. It is widely known and understood, that this method does expect measurements which do not contain systematic errors or blunders. In the case of systematic image errors automatic self calibration offers the proper tool to improve the result.

When automatic self calibration is applied, one expects that systematic image errors are stable and do not change during the flight mission. This stability is a clear advantage of the digital camera over the film camera and has been already documented. In the case of UltraCam an additional process of stabilization is introduced into the post processing workflow based on the physical model of the camera hardware and a temperature dependent behavior. After this step the information from the actual aerial triangulation project can be used to compute and apply remaining image distortion parameters.

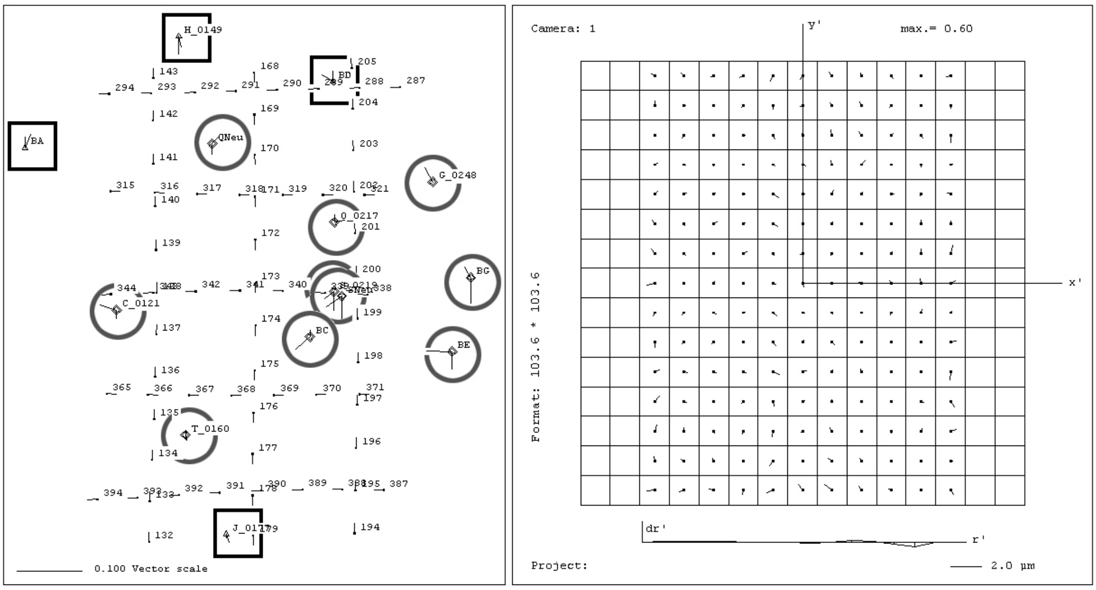


Fig. 5: AT Results showing 8 flight lines, 4 GCPs and 10 check points.The vertical residuals of the check points are in the range of a few centimeters (left). The remaining image residuals are presented on the right and show small residuals (< 0.6 µm). Radial and tangential distortions after the auto calibration do not exceed 1.6 µm.

4. RADIOMETRIC QUALITY AND MULTI SPECTRAL CAPABILITY

UltraCamX exploits the radiometric quality of the high performance CCD sensor FTF5033 manufactured by DALSA. Not much less then 13 bit of radiometric information can be extracted via the 14 bit analog/digital converter. Such broad bandwidth allows resolve dark and bright areas in one and the same scene like from a city area on a bright sunny day with dark shadows in the streets and almost white roofs or other bright objects. The performance in dark image regions shows the full potential of the sensor and its sensibility. Only ± 6 DN @ 16 bit (= 0.4 DN @ 12 bit) of noise could be detected in shadows.

Figure 6 shows frame 1090 from a flight mission over the city of Graz, Austria on March 27th 2007, a clear sunny day. At a flying height of 900 m above ground level a ground sampling distance (GSD) of 6.5 cm was achieved. Two sub areas of the panchromatic camera head containing very bright objects (umbrellas and welded roofs) as well as dark shadows were analyzed by computing the histogram. Levels of intensity from 350 DN to 7800 DN @ 16 bit could be detected, image areas were not saturated. Such huge dynamic range of 7450 DN corresponds to almost 77 dB or 12.9 bit.

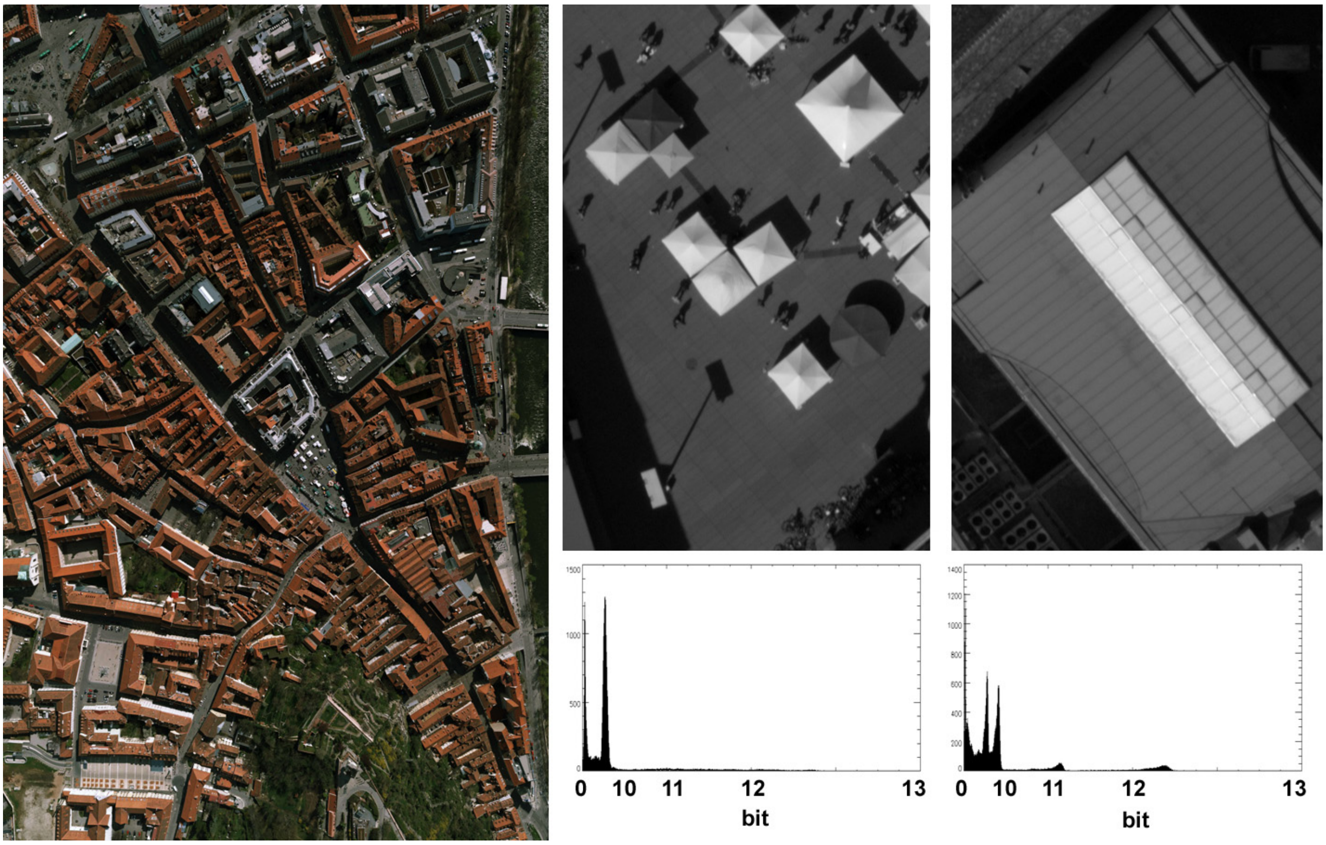


Fig. 6: Frame 1090 of a UltraCamX on flight mission over the city of Graz. Two details of the image show a radiometric bandwith of almost 13 bit. The darkest pixels are at a level of 350 DN and the brightest pixels are at a level of 7800 DN in a 16 bit representation.

The multi spectral channels of UltraCamX offer true color (red green and blue) as well as near infrared bands and therefore supports the multi spectral classification.

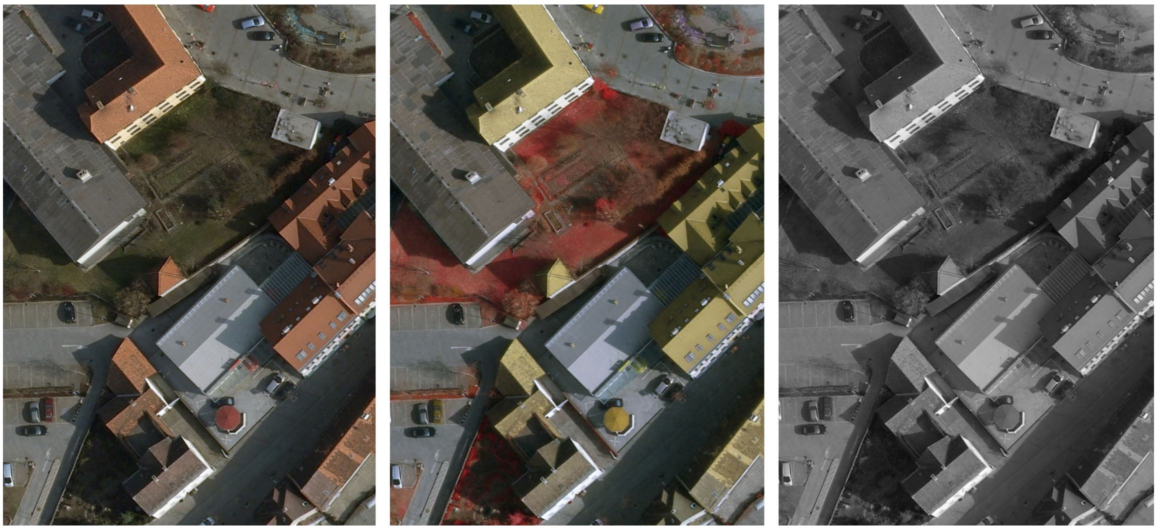


Fig. 7: Frame 154 of a flight mission in early 2007 (22-Feb-07). The vegetation between buildings and sealed surfaces can be detected by examining the CIR image.

5. MICROSOFT PHOTOGRAMMETRY

The acquisition of Vexcel Corp., Boulder, Colorado and Vexcel Imaging GmbH, Graz Austria, by Microsoft Corp., Redmond, Washington did raise questions, expectations and guesses when it was published about one year ago. There is no doubt that this acquisition is in line with and for supporting the Microsoft "Virtual Earth" Program. The target of this program is to model the human habitat of the world, thus a few thousand cities and their neighborhoods as well as rural areas between cities need to be acquired. Photogrammetry is the prime technology to do this job and UltraCamX is the preferred sensor.

5.1. Aerial Missions

Aerial photo missions are carried out at a large scale (GSD at 6 inch) at endlaps of 80% and sidelaps of 60%. This huge amount of highly redundant image data supports the automatic process of aerial triangulation, digital elevation modeling and feature extraction. Redundancy does also support the robustness of the process and the automatic detection of blunders, mismatches and out layers. Another important advantage of the high overlaps can be recognized in the rigorous reduction of occlusions, a most helpful side effect when working in dense build up areas of city centers.

5.2. Best visuals for non-expert users

Since long years geo data have been produced from experts and were presented to experts. Depending on the scale a specific kind of signature had to be used to make maps readable, details visible and content interpretable. The user had to be educated and trained to read such maps and to match abstract data and real world objects.
Microsoft's Virtual Earth initiative is designed to overcome this exclusivity. Not maps but photorealistic three dimensional representations of the real world build the interface between data and user and thus no longer only experts are able to interact with these data but everybody can enjoy.

Fig. 8: 3d model of Philadelphia, automatically computed from UltraCam images at high overlap. The photo texture of the 3d scene was also extracted from UltraCam Images.

5.3. A 22 Petabyte Database

The entire world needs to be digitized. Such challenging project has been launched by Microsoft almost two years ago. One may now ask the question, how many pixels and 3-d objects may be needed in order to fulfill this mission. A few key numbers can be given:
Taking into consideration a land surface of 140 000 000 sqkm the entire world can be covered by one ortho image of 6.2 PetaByte at 15 cm resolution. Adding geometry and texture of build up areas – the cities of the world – a total of 22 PetaByte of data is expected.
The number of aerial images taken over metropolitan areas only may exceed 20 000 000.

6. CONCLUSIONS

The digital aerial camera UltraCam X, developed and manufactured by Vexcel Imaging GmbH, Graz, Austria, was presented at the ASPRS in May 2006. During this event Microsoft Corp. and Vexcel Corp. announced the closing of the acquisition of Vexcel Corp. and Vexcel Imaging Austria by Microsoft.
The new camera has already made it's way into the mapping market and did show its huge potential for the photogrammetric application. Geometric accuracy and radiometric quality as well as the smooth digital workflow are outstanding advantages of the entire system.
The Virtual Earth Initiative is the new challenge for UltraCamX. Flying at high overlap the camera is used to collect enormous volumes of images which are then introduced into a fully automated production line were at its end three dimensional digital city models are worldwide available via the Microsoft Live Search platform.

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