

4 System Design, Intended Use and Expected Accuracy

This section provides a summary of the Vexcel design and system calibration for the family of UltraCam systems, a description of the intended use of the systems, and the accuracy that can be expected from the systems. The UltraCam camera family is the large format digital aerial mapping camera product series of Vexcel, all with the camera sensor head based on Vexcel's multi cone design concept. This concept was initially presented in 2003 together with the introduction of the UltraCamD camera system.

4.1 Basic Design

The basic design concept behind UltraCam cameras is a sensor head consisting of eight independent camera cones, four of them contributing to the large format panchromatic image and four contributing to the multi-spectral image (See Figure 1).

The sensor head of the UltraCam is equipped with 13 CCD sensor arrays, manufactured by DALSA Corp. (the FTF 4027M at 9 μm pixel size for UltraCamD, the FTF 5033M at 7.2 μm pixel size for UltraCamX, and FTF 6040M at 6 μm pixel size for both the UltraCamXp and Xp WA). All of these sensors provide a radiometric bandwidth of more than 12 bits.

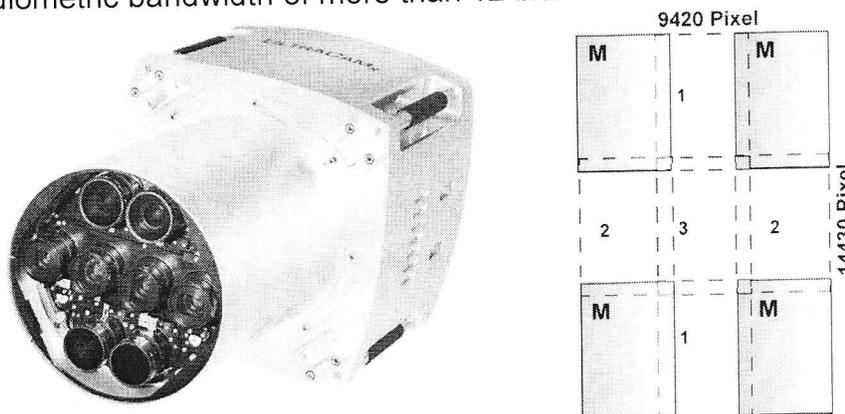


Figure 1: The UltraCam Sensor Unit and the concept of the four cones contributing to the large format panchromatic image.

These UltraCam systems have lenses with a focal length of 100 mm for the panchromatic cones and 33 mm for the multi-spectral cones. This set of two lenses supports the pan sharpening ratio of 1:3.

The panchromatic sensor head of the UltraCam large format camera series has four individual camera heads (i.e., camera cones). These cones have a specific mechanical distance from the camera center which needs to be compensated for during exposure in order to produce a consistent virtual image. This process is unique for the UltraCam digital aerial cameras and is known as "syntopic exposure". It exploits the movement of the aircraft in such way that the shutters of the cones are delayed so they don't open at the same time (synchronic) but at the same position (syntopic).

4.2 Radiometric Properties

The radiometric bandwidth of the UltraCam is based on the dynamic range of the CCD sensor arrays (> 12 bit or >72 dB). The analog signal is converted into a digital signal by the 14 bit ADC and all of the image data are stored at a bandwidth of 16 bits.

The band separation of the UltraCam large format cameras is based on volume filters for the red, green and blue color channels. The four channels of visible light (pan, red, green and blue) are also equipped with Infrared cut off filters and the infrared channel is equipped with a 690nm IR Filter. The spectral signatures of the panchromatic, infrared, red, green, and blue are graphically shown in Figures 2a-d.

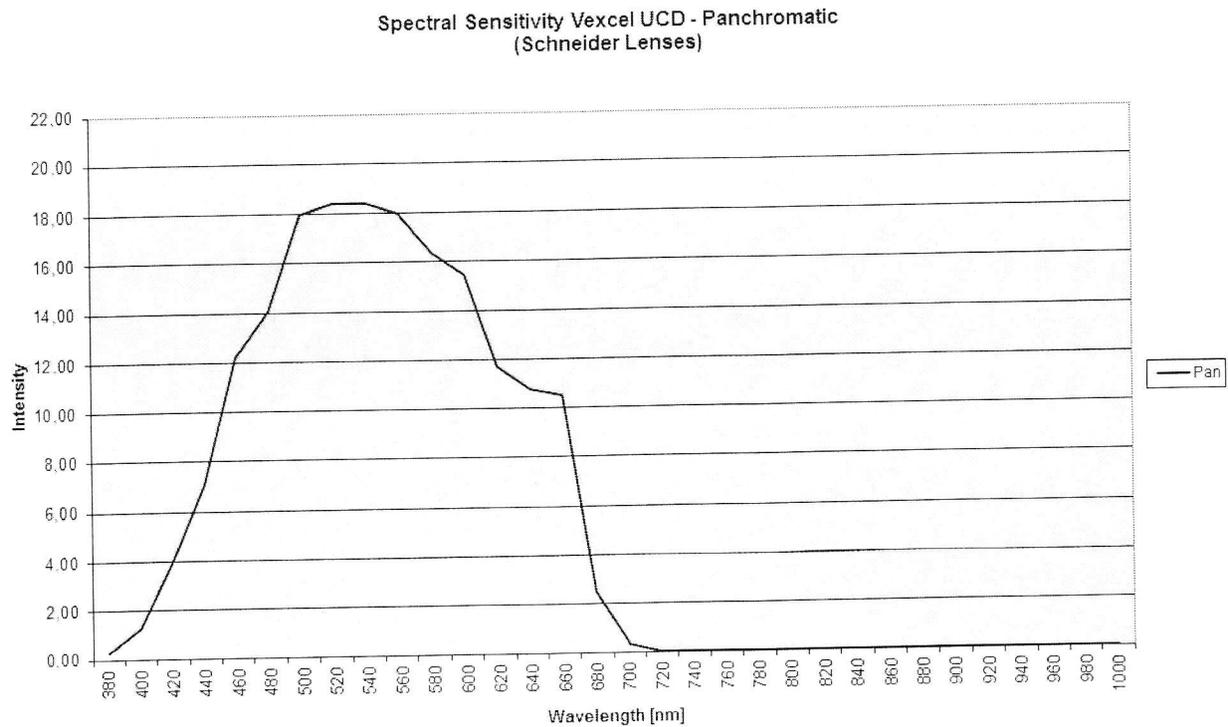


Figure 2a: UltraCam D Panchromatic Spectral Sensitivity

Spektral Sensitivity Vexcel UCD - Multispectral (Schneider Lenses)

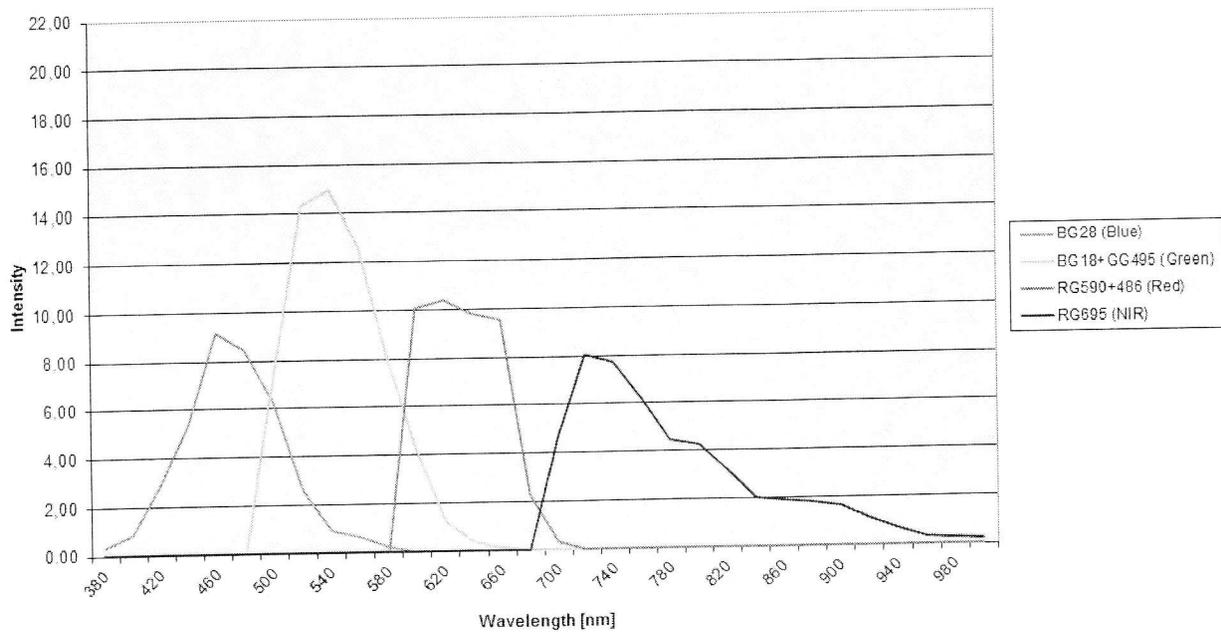


Figure 2b: UltraCam D 4-band Spectral Sensitivity

UltraCam image data are collected at a 12+ bit level (analog signal), converted to digital at a 14 bit level (14 bit ADC), and stored without compression at a 16 bit level (the so-called raw data). There is no compression performed from the Level-0 (raw) through the Level-2 (initial image, 16-bit, temporary TIF) processes.

At Level-3 (final image, user-selected manipulations applied such as pan sharpening or number of bits/pixel) there is an option for the user to select JPEG compression or uncompressed TIF. Conversion to 8-bit from 16-bit data is accomplished using gradation curves.

4.3 Geometric Calibration

The routine calibration of the UltraCamD sensor head took place in the calibration laboratory at the Münzgrabenstrasse facility, consisting of a three dimensional calibration target with 367 circular marks (See Figure 3). These marks are surveyed to an accuracy of about +/- 0.1 mm in X, Y and +/- 0.2 mm in Z and show a well defined circular pattern. The dimensional size of the entire structure is 8.4m by 2.5m at the rear wall and 2.4m in depth. Rear wall, ceiling and floor carry 70 metal bars with 280 marks; four additional vertical bars in the center of the structure carry 16 marks; 98 marks are mounted at the rear wall. The mean distance between marks is about 30cm.

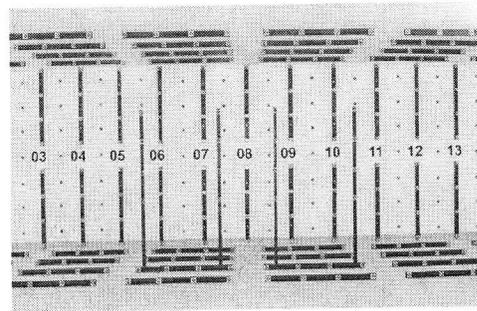
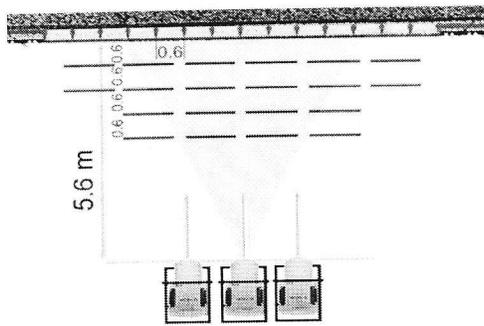
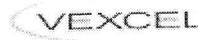


Figure 3: New Camera Calibration Laboratory
Layout of the Lab (left) and Photo of the 3D Targets (right)

The data capture of 84 images is taken from three different camera stations in such way that the camera is tilted and rotated. Software is used to compute subpixel accurate image positions of each mark in each image of the entire set of images. This results into a dense and complete coverage of coordinate measurements over the entire the image format. A single calibration dataset consists of almost 90,000 measured image points.

The unknown camera parameters are computed using the commercially available photogrammetric bundle adjustment called BINGO which was modified to accommodate the multicone design of the UltraCam sensor head. It was critical to have the ability to estimate the positions of the multiple CCD sensor arrays in the one virtual focal plane of a camera head. The radiometric calibration of the UltraCam sensor head is done by taking a set of images and then automatically processing these images in order to detect defective pixels, lens vignetting, and pixel based offset and gain values for each CCD sensor element. During the radiometric calibration the shutter response time is also measured and stored for each individual shutter.

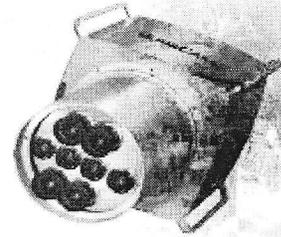
The result of the laboratory calibration is documented in the delivered camera calibration report. The calibration parameters relevant to the post processing of the imagery are stored in the camera calibration dataset.



UltraCam D, Serial Number UCD-SU-1-0030

Calibration Report

Short Version



ULTRACAM_D
Large Format Digital Area Camera

Camera:	UltraCam D, SN: UCD-SU-1-0030
Manufacturer:	Vexcel Imaging GmbH, A-8010 Graz, Austria
Date of Calibration:	Sep-06-2005
Date of Report:	Oct-27-2005
Camera Revision:	1.0
Revision of Report:	1.0

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Visual Imaging GmbH, Metrophotogramm 11, A-8010-GRAZ, www.vexcel.com

4.4 Intended Use

According to Vexcel, the UltraCamD digital aerial cameras have been designed for any type of aerial monoscopic or stereoscopic photogrammetric application. It can support high and low altitude missions while collecting four-band multispectral (red, green, blue, and infra red) and panchromatic imagery simultaneously.

For large scale mapping, the fast cycle rates and the special exposure concept of syntopic exposure control allows the system to collect down to a ground pixel size of 3 cm or 1.2 inches.

For medium and small scale mapping, flight altitudes up to 15,000 feet in nonpressurized aircraft are supported since the HDDs are sealed.

4.5 Expected Accuracy

The expected accuracy values presented in the following tables were provided by Vexcel. These accuracies were derived on the basis of a small orthophoto project area consisting of a single mosaicked orthophoto from four images, two from each of two strips of imagery covering the area of interest.

UltraCam Models D

Resolution (GSD)	CE95 Accuracy					
	With GPS/IMU			Without GPS/IMU		
	Number of Control Points			Number of Control Points		
	0	1	4	0	1	4
1 Meter	N/A	N/A	N/A	N/A	N/A	N/A
12-inch (30cm)	11"	11"	10"	N/A	N/A	10"
6-inch (15cm)	5.5"	5.5"	5.0"	N/A	N/A	5"
3-inch (7.5cm)	4"	4"	3"	N/A		3"
Highest advertised resolution: 1.2-inch (3 cm)	N/A	N/A	N/A	N/A	N/A	1"

6 USGS Team Findings

The quality program in use at Vexcel covers every step of the manufacturing process. Vexcel enjoys a very close relationship with their primary supplier, WILD Austria, in nearby Völkermarkt. The Quality Program at WILD is very thorough. The close working relationship between Vexcel and WILD allows for physical collaboration between engineers and assemblers and thus gives Vexcel the ability to monitor quality and performance at the subsystem level during assembly and testing.

System engineering processes, including configuration control and management, in use at Vexcel follow standard industry practices, as do manufacturing engineering, testing, and quality monitoring processes.

Geometric calibration of the Vexcel UltraCamD is performed in-house at Vexcel in Graz, using multiple images taken in a control-point chamber (room). The distortion coefficients from this calibration are then further refined using aerial imagery over a survey-controlled test range. These final results are delivered with each UltraCamD sold. This calibration process generates calibration parameters that are very precise and virtually eliminates systematic distortions within the system.

Radiometric calibration for the UltraCamD is limited to defective pixel identification and correction, normalization, and aperture correction. These measures control the qualitative radiometry of the imagery produced. The UltraCamD has not been designed to deliver spectral measurements in reflectance units, but rather to produce four-band color images ready for imaging applications and requirements.

Vexcel strongly recommends annual factory servicing of the UltraCamD and provides a Service Plan including this. During annual servicing, the calibration of the system is verified using the methods above. Vexcel's incentives to purchasers to enroll in the service plan, which will provide verification of performance, went a long way to ensure data quality. Vexcel's service and support operations were found to be excellent.

The Team was presented with overviews of the Vexcel software that is used to process the UltraCamD output into photography that can then be processed into products using standard softcopy photogrammetric software. The Vexcel software is produced using good software engineering processes.

Vexcel has thoroughly tested and verified the technical performance of the UltraCamD systems, including test flights under harsh environmental extremes. Each system is flown and verified before delivery.

The Team has found the Vexcel UltraCamD System to be designed, manufactured, tested, and supported to the level required to reliably meet the performance claims of the manufacturer when operated within manufacturer's intended operational parameters. These systems, when operated properly by a conscientious and technically qualified operator, are capable of meeting the accuracy claims given by Vexcel for digital aerial data.

Appendix A: UltraCam Technical Specs (All Models)

A.1: UltraCam -D through -XpWA System Specifications

System	System Nomenclature	UltraCamD	UltraCamX	UltraCamXp	UltraCamXp WA
	Number of Lens Cones	8			
	Number of Sensor Chips/Lines	13			
	On-board Storage (GB/TB)	4.2 TB	4.2 TB	4.2 TB	4.2 TB
	On-board Storage (images)	15,000	9,500	6,600	6,600
	Image Storage Redundancy (Y/N)	Y			
	Power Consumption (Watts)	850 W			
	Camera Temperature Range (°C)	0°C to +45°C			
	Computer Temperature Range (°C)	0°C to +45°C			
	Humidity Range	95% @ no condensation			
	Mount Type	GSM 3000, T-AS, PAV30, PAV 80			
	Output Pixel Size(s)	9um x 9um	7.2um x 7.2um	6um x 6um	
	Fwd Motion Comp (FMC) Type	TDI controlled			
	Maximum FMC Correction (pixels)	50 pixel			
	Recommended Forward Overlap (%)	as per project definition			
	Recommended Side Overlap (%)	as per project definition			

Size & Weight	Camera Size/Weight	45 x 45 x 60 cm / 55kg
	Processing System Size/Weight	50 x 36 x 65 cm / 65kg
	Storage System Size/Weight	40 x 30 x 20 cm / 16 kg
	Mount Weight	depends on configuration
	Total System Weight	147kg

Controls	Exposure Control Options	Time & Aperture
	Light Metering Type	Manual settings
	Shutter Type	Prontor Magnetic 0 – Vexcel
	Shutter Speed Range	1/500 to 1/32
	ISO Range	N/A
	Exposure Compensation	N/A

A.2: UltraCam -D through -XpWA Panchromatic Specifications

UltraCam Model		UltraCamD	UltraCamX	UltraCamXp	UltraCamXpWA
Sensor	Sensor Type	Full Frame CCD			
	Sensor Nomenclature	Dalsa FTF 4027M	Dalsa FTF5033M	Dalsa FTF6040-M	
	Total Pixels (MP)	11 MP	17 MP	24 MP	24 MP
	Along Track Pixels	2672	3328	4008	
	Cross Track Pixels	4008	4992	6051	
	Aspect Ratio	3:2			
	Pixel Size (mm)	0.009	0.0072	0.006	
	Fill Factor (%)	90%			
	Radiometric Resolution (bits)	12+ bit			
	Dynamic Range	>72 db			
	Max Exposure Rate (images/sec)	0.5			
Lens	Lens Manufacturer	Linor Rodenstock			
	Lens Nomenclature	Linor Vexcel Apo-Sironar Digital HR 5.6/105 mm			Linor Vexcel Apo-Sironar Digital HR 5.6/70 mm
	Focal Length (mm)	100 mm			70 mm
	Aperture Range (f-stop)	1/5.6 - 1/22			
	Along Track FOV (deg)	13.7°			19.5°
	Cross Track FOV (deg)	20.5°			29.2°
Spectral Response	Panchromatic	410 – 690 nm			
Virtual Image	Total Pixels (MP)	82	130	196	196
	Along Track Pixels	7500	9420	11310	
	Cross Track Pixels	11500	14430	17310	
	Aspect Ratio	3:2			
	Pixel Size (mm)	0.009	0.0072	0.006	
	Along Track FOV (deg)	37°			51.7°
	Cross Track FOV (deg)	55°			77.6°
	Radiometric Resolution (bits)	12+ bit			
Dynamic Range	>72 db				

A.3: UltraCam -D through -XpWA Multispectral Specifications

	UltraCam Model	UltraCamD	UltraCamX	UltraCamXp	UltraCamXpWA
Sensor	Sensor Type	Full Frame CCD			
	Sensor Nomenclature	Dalsa FTF 4027M	Dalsa FTF5033M	Dalsa FTF6040-M	
	Total Pixels (MP)	11 MP	17 MP	24 MP	
	Along Track Pixels	2672	3328	4008	
	Cross Track Pixels	4008	4992	6051	
	Aspect Ratio	3:2			
	Pixel Size (mm)	0.009	0.0072	0.006	
	Fill Factor (%)	90%			
	Radiometric Resolution (bits)	12+ bit			
	Dynamic Range	72+ db			
	Max Exposure Rate (images/sec)	0.5			
	Lens	Lens Type	Linor Rodenstock		
Lens Nomenclature		Linor Vexcel Apo-Sironar Digital HR 4/33 mm			Linor Vexcel Apo-Sironar Digital HR 4/23 mm
Focal Length (mm)		33 mm			23 mm
Aperture Range (f-stop)		1/4.0			
Along Track FOV (deg)		40°			55.2°
Cross Track FOV (deg)		60°			82.8°
Spectral Response	Blue	410 - 540 nm			
	Green	480 - 630 nm			
	Red	580 - 700 nm			
	NIR	690 - 1000 nm			
Virtual Image	Total Pixels (MP)	82	130	196	196
	Along Track Pixels	7500	9420	11310	
	Cross Track Pixels	11500	14430	17310	
	Aspect Ratio	3:2			
	Pixel Size (mm)	0.009	0.0072	0.006	
	Along Track FOV (deg)	37°			51.7°
	Cross Track FOV (deg)	55°			77.6°
	Radiometric Resolution (bits)	12+ bit			
Dynamic Range	>72 db				