MEDIUM FORMAT DIGITAL CAMERAS - A EUROSDR PROJECT

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ABSTRACT: More medium format airborne camera systems are in operation globally than the well recognised large format digital imaging systems. EuroSDR has initiated a digital medium format project to investigate the market, the geometric and radiometric potentials as well as current trends and future developments. After a categorisation of small and medium format systems an in depth comparison to large format cameras is given. Beside the apparent differences in size and system cost, the special problems such as differences in the interior orientation, the minimum GSD and the photogrammetric workflow are addressed. Medium format cameras require geometric and radiometric calibration. Medium format cameras have established their own markets and application domains, such as strip mapping and the joint operation with a laser scanner. A market overview compares five different camera systems. A description of current trends and future developments concludes the paper.

1. INTRODUCTION

Beside the well known large format digital photogrammetric cameras such as the DMC or UltraCAM-D, professional digital medium format cameras are widely used to acquire digital airborne images. Medium format digital systems are used for a wide range of applications. Some of the applications are unique to medium format and in other applications medium format cameras compete against large format cameras. For instance, medium format camera systems have developed special markets for joint applications with laser scanners and corridor mapping, and they are very competitive for small-area large-scale mapping projects, rapid response applications for disaster monitoring, and for image acquisition for 3D-city models. The market for medium format cameras is rapidly increasing; however available medium format systems differ greatly in terms of performance, reliability, accuracy and price. In order to get a status report on the current situation and an insight into the geometric and radiometric properties, EuroSDR [1] has initiated a project on medium format digital cameras.

1.1 Objectives of this paper

The main objective of this paper is to inform about the first phase of the 2-year project, which was completed in April 2008. Thereby an extensive report describing the currently used professional medium format systems has been prepared. Furthermore, the paper will cover the following points:

- Categorisation of digital medium format camera systems
- Medium format cameras versus large format cameras
- Geometric properties and calibration
- Radiometric properties and radiometric workflow
- Application analysis
- Documentation medium format cameras / systems
- Current trends and future developments

Last but not least, this paper will list open problems which need to be solved.

[1] http://www.eurosdr.net/

2. CATEGORISATION OF DIGITAL MEDIUM FORMAT CAMERA SYSTEMS

At first a categorisation and a separation between small format, medium format and large format cameras has to be made. In the literature several surveys dedicated to medium format cameras can be found, e.g. Cramer, 2004, Petrie & Walter, 2007, GIM International, 2008. Beside the technical aspects of the digital medium camera itself, the focus of the EuroSDR survey will be on professional medium camera systems.
Figure 1 gives a categorisation of small and medium format camera systems that not only takes the camera itself into account but also other important issues for airborne camera systems.

	Small format		Medium format	
Components	Low-cost	Amateur	Semi-Pro	Pro
Digital Video- / Consumer camera < 12 MP	X	X		
High end digital SLR Camera, (12 bit, 16 MP) or better		X	X	
Industrial digital camera, (12 – 16 bit, (22) – 39 MP			x	X
GPS / L1 DGPS	X	x		
RTK - GPS			X	X
Simple GPS- flight management system	X	X	x	
Professional flight management system			X	X
Stabilized platform				X
GPS - INS (x,y,z < 0.1 m ω,φ,κ < 0.01°)				X
System Price [€]	<5.000	<25.000	<50.000	>250.000

Figure 1: Comparison of small and medium format camera systems

The different components of the airborne imaging systems strongly influence the quality of the images, the efficiency of the airborne and photogrammetric workflow and the reliability of the system. With respect to the EuroSDR project the characteristics of state-of-the-art professional medium format digital cameras for airborne applications are:

- Single lens - single focal frame - single shutter

- Large image footprint (39 MP)
- Ruggedised metric design – fully calibrated systems
- Short exposure interval (2 – 3 sec.)
- Compact systems suitable for small single-engine aircraft
- RGB or CIR by changing lens filter (limitations in CIR)

3. COMPARISON TO LARGE FORMAT CAMERAS

Compared to large format mapping camera medium format cameras have some distinct technological differences, which are compiled in
Table 1.

	Medium format	Large Format
	Technology	
Camera	Single head	Multiple heads
Image Size	Max. 39 MegaPixel	Max. 136 MegaPixel
Colour	Either RGB or (CIR)	Separate heads, (Pan, R, G, B, NIR) image fusion
Lenses	Interchangeable	Fixed
	Airborne system	
FMC	Only mechanically	TDI
System cost	Low	Expensive
System weight	Light	Heavy
Energy consumption	Low	High

Table 1: Main differences between medium and large format digital camera systems

Beside the technological differences the vertical range of manufacture of digital medium format cameras and large format cameras is quite different. While in large format cameras all components are developed, optimised and tested for airborne applications, medium format camera systems including the processing software are often a composition of several off-the-shelf products for professional photographers combined with special features for the airborne environment.

One of the main advantages of medium format cameras is the lower system price and the possibility to fly with small and cheap aircraft. The overall cost and the effort for an aerial survey and subsequent ortho photo production are related to many factors of the photogrammetric workflow. The comparison of the different processing steps reveals that the major advantage of medium format cameras are the lower costs for the aerial survey and the easier and faster postprocessing of the images of the single head cameras. Assuming an automatic tie point matching and a precise GPS/INS the cost of aerotriangulation is not very much higher for medium format cameras because this is normally a highly automated procedure. Due to the smaller ground coverage of an image more ground control points may be necessary. Nowadays the photogrammetric block does not necessarily rely solely on ground control points, but even for an integrated sensor orientation and quality assurance a certain number of ground control points are necessary, depending upon the number of images taken. The refinement of the seamlines between adjacent images is one of the manual and labour intensive step in digital ortho photo generation. Due to the relatively large number of medium format images, more manual labour is necessary for the generation of a seamless ortho photo mosaic. Together all of the factors lead to a lower cost reduction per area, compared to large format cameras, making medium format cameras less competitive for large area surveys.

A big advantages of medium format cameras are interchangeable lenses with focal lengths of 35 mm to 210 mm. Different lenses allows missions to be flown at different altitudes to either maintain the desired resolution or maintain a predefined strip width during joint flights with others sensors, e.g. laserscanning. Also with interchangeable lenses the stereo / DEM capabilities may be changed as well as occlusions in narrow streets etc. during ortho photo production. However lenses with a long focal length generally cause several special problems in terms of their interior orientation and calibration.

3.1 Geometric Potential

The achievable geometric potential of a digital camera is related to the "metric" properties of the camera, which stands for a determinable and stable interior orientation.

3.1.1 Interior Orientation

The determination of the interior orientation of CCD-colour sensors based on the Bayer-pattern is related to some general sources of error due to longitudinal and transversal chromatic aberration, Cronk et al., 2006. However these errors are relatively small and only applicable for close range applications at the highest precision.

However the airborne environment imposes special requirements on the camera system. To survive the shock and vibrations experienced in the airborne mapping environment a rigid camera body and a fixed lens mount is necessary for a stable interior orientation. Large format cameras generally operate with a fixed lens aperture. On medium format cameras the lens aperture is generally set by the amount of light available and the requirements of the shutter speed to minimise image movements. The lens aperture changes the interior orientation to a small extent. Also the work with interchangeable lenses requires a new (on the job) calibration every time the new lens is mounted. Even with a ruggedised design and special locking mechanism of the lens mount, some parameters of the interior orientation (especially the focal length) may change in the airborne environment due to changes in the air pressure when flying at higher altitudes. This is of special relevance for direct georeferencing, because the errors in the interior orientation are directly visible in the accuracy of the object coordinates. Therefore a simultaneous on the job calibration in terms of an integrated sensor orientation should be done.

3.2 Minimum GSD of medium format cameras

Customers are demanding higher and higher ground resolution. The highest possible ground resolution (GSD) for aerial surveys with standard endlap (60 %) depends on several factors such as the image exposure interval of the camera Δt and blur due to image motion. The exposure interval is related to the endlap p (in percent), the velocity of the aircraft over ground (v_g), the GSD and the number of pixels (n_{pix}) of the CCD-Sensor in flight direction:

$$\Delta t = \frac{b}{v_g} = \frac{GSD * n_{pix}}{v_g} (1 - \frac{p}{100}) \qquad (1)$$

The minimum exposure interval of the digital medium format cameras is somewhere between 2 – 3 s.

Figure 2 provides an overview which minimum GSD for a photogrammetric aerial survey with an endlap of 60 % applies at what speed over ground.

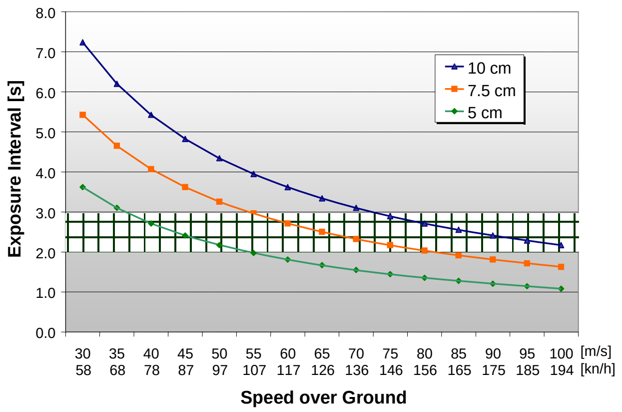

Figure 2: Exposure interval of medium format cameras related to GSD and ground speed

3.3 Image motion

Airborne images are acquired from moving platforms such as aircrafts or helicopters. The movement of the sensors during the exposure influences the quality and the sharpness of the acquired imagery. For analogue airborne cameras this image motion is taken care by forward motion compensation (FMC). For large frame digital airborne sensors the translation effect of the FMC is solved digitally by moving the charges on the matrix area itself (time delayed integration, TDI). Additional rotational movements are compensated from the stabilised mount. For medium format sensors an active mount is typically not available – exemptions are the DSS and cameras which are used as a sub-system e.g. in combination with laser scanners mounted on a common platform which is then stabilised. Also TDI is not available for the medium format digital sensors due to the Bayer pattern of the CCD-chip. The image motion u is related to the aircraft velocity over ground v_g, the exposure time t_e, the focal length c, the flying height above ground h_g and the size of the pixel s_p see formula 2.

$$u \approx \frac{u_{th}}{2} = \frac{1}{2} * v_g * t_e * s_p * \frac{c}{h_g} = \frac{1}{2} * \frac{v_g * t_e * s_p}{GSD} \qquad (2)$$

where only 50% of the theoretical image motion u_{th} is valid in the images. For digital imagery the smear due to image motion should not exceed 0.5 pixel. Since aircraft velocity and GSD are typically given by default for a certain project, exposure time is the only variable to minimise effects of image motion, if suitable light conditions are available. Exposure time on the other hand is coupled with lens aperture and the sensitivity of the digital sensor given by the ISO value. However a higher sensitivity (ISO number) is always associated with higher image noise levels. The aperture is also a limiting factor, because a wide aperture may cause or enhance vignetting and optical aberrations. To sum up: the image motion limits the GSD of medium format cameras and the short exposure interval necessary limits the flying operation times under poor lightning conditions when compared to large format cameras.

4. GEOMETRIC AND RADIOMETRC CALIBRATION

The calibration of digital cameras includes geometric and radiometric issues. From the viewpoint of a photogrammetrist, geometric issues are the more important. For large format cameras detailed tests within the frame of OEEPE and EuroSDR were conducted, e.g. Cramer, 2007. The special geometric problems of multi head cameras are discussed quite extensively in the literature, e.g., Jakobsen, 2007. Research in the calibration of large format cameras systems is an ongoing process with the aim to develop a calibration procedure of the whole camera system and its subsystems, including GPS/INS, radiometric and geometric issues and the whole photogrammetric processing chain, EuroDAC² (2008).

4.1 Geometric calibration

Due to the compactness and the low weight of medium format cameras, laboratory calibration of the interior is relatively easy to obtain. As mentioned in section 3.1.1 the interior orientation of medium format cameras may change under airborne conditions. Therefore the geometric calibration of the medium format camera system should be done in four different levels:

1. Laboratory calibration with a 2-D or 3-D test field.
2. In flight calibration over a calibration range.
3. Simultaneous in flight calibration on the job to adjust for project specific circumstances
4. Long term camera stability analysis to determine the necessary calibration intervals.

4.2 Radiometric accuracy and calibration

An increasingly important task is the "radiometric accuracy" and the radiometric calibration of aerial cameras. The first goal of such a radiometric calibration is to eliminate the influence of the optics and the sensor and make sure that the resulting images will have the same sensitivity throughout the image. The radiometric calibration is also split in two main parts. The first part of the radiometric camera calibration is done by the manufacturer to eliminate radiometric dysfunctions of the sensor such as:

- Defect pixels
- Dark Signal Non Uniformity (DSNU)
- Individual sensitivity of each single CCD pixel
- Vignetting (partly)
- Influence of aperture (partly)

However, the manufacturer radiometric calibration effort differs between medium format cameras. White balance calibration procedure or more general the Look-Up-Table (LUT) generation is the second step. For each project the user performs this type of calibration individually. After post processing the user can set the white balance for the project using some example images which cover the typical surface,. With suitable software the user can also minimise remaining vignetting and lens aperture effects which may occur at low f-stops. Radiometric problems of the medium format cameras are related to several issues.

- The radiometric postprocessing of the raw imagery, which come in a black box raw format is generally done in a software environment primarily developed for non photogrammetric users, but for professional photographers. Therefore issues such as radiometric linearity, atmospheric correction etc. are not a primary issue.
- There is no single standard algorithm for converting data from a Bayer filter or Foveon sensor into RGB format.
- the color infrared option causes longitudinal chromatic aberrations. Due to the strong sensitivity of the CCD-chip in the IR-light the resulting image is more or less a reddish coloured IR-image, Grenzdörffer, 2006
- In the postprocessing of the raw images after the flight the images may be corrected and manipulated with respect to:
  - a colour balancing due to the atmospheric conditions
  - general visual expectations of the users (e.g. grass has to be green)
  - vignetting and influence of aperture
  - histogram enhancements for 16 bit → 8 bit conversion
  - image sharpening and noise reduction.
  - the degree of the radiometric postprocessing and the resulting colors are solely subject to the visual impression of the interpreter, and
  - proposed radiometric corrections steps (e.g. Honkavaara & Merkelin, 2007) and quality measures are difficult to obtain.

5. STANDARDISATION

Standardisation for aerial cameras and the photogrammetric processing chain is taking place at several levels, from ISO down to national initiatives. However most of the standardisation effort is related to large format cameras, thus sometimes neglecting and more or less excluding medium format cameras. In other instances the standardisation is very general and in general not of great practical use.

In Germany the standard series DIN 18740 – Photogrammetric Products (Part 1 – 4) covers especially large format cameras, Reulke et al., 2007, DIN 2007. Part 4, finalised in Sept. 2007 deals with the requirements for digital aerial cameras and digital aerial photographs. Focus is given to digital aerial cameras, aerial survey flights and the digital aerial photograph. For digital aerial cameras the standardisation provides quality measures on: general requirements of the camera and its components, camera calibration (geometry and radiometry) and requirements of sensors for positioning and attitude determination. The geometric quality related to the image product has to be documented in a manufacturer certificate, in which the camera system and its subsystems have to be geometrically and radiometrically calibrated. The validity of geometrical calibration at the time of flight has to be proven by validation test (less than one year ago) or new calibration (less than two years ago), DIN 2007.

Due to the fact that digital aerial systems are more than just cameras and the final quality is not only related to the sensor standards should not only focus on the certification of the cameras itself but include the whole end-to-end processing chain. Based on these facts the USGS has formulated a different approach. Individual cameras are not the subject of certification, but a “type certification”, Stensaas, 2007. With this approach it should be ensured that the sensors are designed, built and tested to reliably deliver data with a high quality. However this is only true if the operating company operates and maintains the system properly. Currently the DSS 439 is the only medium format camera system certified by the USGS.

6. APPLICATION DOMAINS

From an application standpoint, it is safe to say that medium format digital cameras are not their large format cousins, but rather a niche market solution for specific project types. The largest proportion of medium format cameras are used as a sub-system of integrated airborne data acquisition platforms consisting of laser scanners (LIDAR) combined with imaging

Exclusive market of medium format ↔ Competitive market to large format

Laserscanning & Camera
- Mapping & Orthophotos
- True Orthophotos
- 3D-City Models

Strip Mapping
- Linear-based mapping projects
- Pipeline surveys
- Hydro corridors
- Transportation routes

Rapid Response Imaging
- Rapid mobilisation for disaster management
- Time-dependent image acquisition
- Homeland Security digital imaging

Agriculture and Forestry
- Species identification
- Timber value assessment
- Disease control and monitoring
- Precision Farming

GIS and Urban applications
- Urban and regional planning
- Urban Hot-Spot Monitoring
- 3D-Models (Nadir + Oblique)

Remote Sensing
- Environmental research
- Coastal zone monitoring
- Colour-Infrared imaging

component and GPS/inertial sensors for direct platform orientation. Such integrated airborne systems are operated by many airborne companies. A special requirement for joint laser surveys is an extremely high light sensitivity and a fast shutter speed, Artés, 2004. Another more or less exclusive market for medium format cameras are mapping small, irregular shaped areas, strip mapping, transmission line corridors or pipeline contracts, which do not always require the ground coverage produced with a large format camera. A direct georeferencing capability with GPS/INS is in these instances a tremendous advantage because it allows for a greater degree of freedom in the aerial survey, such as a strip map coverage where a single line imagery can be utilised without the need for a second flight line, and small blocks can be easily georeferenced to produce orthophoto mosaics. Direct georeferencing enables “hot spot” monitoring of small places of interest with single images (ortho photos). These capabilities are also important for disaster response surveys which require quick data turnaround. The following overview addresses more or less exclusive application domains of medium format and competitive applications to large format cameras.

For smaller aerial survey/remote sensing organisations, the medium-format alternative is changing the face of the industry, as an affordable technology that can deliver increased performance, a marked reduction in operating costs, and most importantly a digital product when it is most needed.

7. MEDIUM FORMAT CAMERA SYSTEMS

The following detailed description and comparison includes five different digital medium format camera systems. The camera systems compared are: Applanix DSS 439, DigiCAM-H39, Leica RCD105, Rollei AIC and DiMAC. While all five camera systems use the same 39 MegaPixel CCD-Chip, the systems differ greatly in many features, such as:

- The possibility of dual or multi sensor head configuration
- Optics and shutter speed
- CIR option (special optics)
- Min. exposure interval
- External or internal data storage
- Mount adapters for existing camera mounts
- The availability of a FMC
- Optional elements such as GPS/INS etc.
- Image processing and radiometric calibration software
- ….

The largest suppliers of medium format cameras are the Applanix DSS and the Rollei AIC camera. The DigiCAM for IGI is a smaller player along with the DIMAC system. The Leica RCD105 is a very new product in the market and specialised for the joint use with ALS 50 of Leica Geosystems, thus replacing the NexVue camera of Spectrum Mapping, LLC. As many of the medium format cameras are used together with a LIDAR-system, four suppliers of the cameras have been integrated with airborne LIDAR systems.

7.1.1 Applanix DSS – 439

The Applanix Digital Sensor Systems (DSS) consist of completely integrated medium-sized digital camera, the Applanix POS/AV 410 GPS/inertial system and a flight-management system software for generating orthomosaics, Applanix, 2008. POS AV provides the exterior orientation parameters in both real-time and post-mission mode. An active azimuth mount control automatically removes the aircraft drift angles based on real-time POS/AV navigation data. The active mount allows for flights in a rough environment and the generation of systematic block pattern. Although primarily used to generate high-resolution colour and colour infrared digital ortho-photos/mosaics by direct georeferencing and an existing DEM, the system also supports full stereo imagery for DEM extraction and visualisation. GSD ranges from 3.3 cm to 1.0 m, depending on platform and using 40 mm or 60 mm lenses. The DSS system can be flown in small, single engine aircrafts, ultra-light aircrafts or helicopters, Applanix, 2008.

7.1.2 Rollei AIC

The Aerial Industrial Camera (AIC) series from RolleiMetric is designed for aerial and industrial purposes, Rollei, 2008. The 22MP or 39MP digital backs from PhaseOne are rigidly fixed to the aluminium camera body. Everything is optimised for photogrammetric use, with interchangeable lenses and stabilised bayonet. The focal lengths of the medium format lenses range from 35 mm to 150 mm. The maximum shutter speed is 1/1,000 second, enabling a minimum GSD of 5 – 10 cm, depending upon the speed of the aircraft. Filter change allows acquisition of images in RGB, NIR and CIR. For the 39 MP sensor the pro lenses, especially designed for digital-camera sensors and small pixel size, are necessary. The camera control is done either by a PC or a PDA. Interfaces with IMU/GPS systems and flight management systems are given. The image data of the camera may be stored on board by a 8 GB CF-memory card, holding up to 200 images or transferred via firewire to a PC. The new AIC xN architecture allows joint fitting of up to eight standard AICs in one frame, using electronic boards for accurate synchronisation. All AIC's are in full communication with each other. Depending on desired overlap, the footprint may cover up to 13,000 x 10,000 pixels.

7.1.3 DigiCAM-H39

The DigiCAM from IGI is a very compact camera weighting 1.7 kg (without lens). The system combines modified professional digital cameras (Hasselblad) with a graphical user interface for real-time preview together with the CCNS/AEROcontrol. The Camera settings are adjusted on an 8" TFT monitor. The CCNS4 triggers the system. Determination of exterior orientation parameters is done using the AEROcontrol GPS/IMU system. Along with the camera, each of the two 100 GB storage units onboard can store up to 1,800 raw images and be exchanged during flight to extend storage capacity. Standard units may be replaced for high-altitude flights by flash memory units with 1,150 image capacity. The focal lengths of the available lenses range from 28 mm to 300 mm. The modular design enables a quick change from RGB mode to CIR. The maximum exposure interval is 1.9 s, IGI, 2008. Two DigiCAMs can be coupled either to increase image size or allow for faster flying speed. The IGI mount hosts up to two synchronized cameras and the adapter fits into most common mounts.

7.1.4 DiMAC - (Digital Modular Aerial Camera)

The DiMAC system (Digital Modular Aerial Camera, produced by Aerophoto in Bergem, Luxembourg, uses single and multiple camera units. Each camera of the DiMAC system acquires one RGB or one near infrared image through one lens. The lens may be one of three focal lengths: 55mm, 80mm or 120mm. GSD ranges from 2 cm to 1 m. The camera cylindrical frame allows for combining up to four camera modules. If two cameras are placed here they create a RGB image of slightly less than twice 5,412 pixels (10,500 pixels) by 7,200 pixels. Two additional cameras may be placed in the vacant holes, resulting in an image of 10,500 by 14,400 pixels. Another configuration is formed by adding a near infrared camera in one camera mount covering the same area as the other one in the other camera mount, or by placing a 55-mm near infrared camera in camera mount 1 covering the same area as camera mount 2 and camera mount 3 together (Dimac, 2008).

7.1.5 Leica RCD105

The Leica RCD105 now offers a new medium format digital aerial camera system designed specifically for use with its ALS-series airborne LIDAR systems of Leica Geosystems. The RCD 105 is designed from the ground up as an airborne digital metric camera solution in compliance with all applicable airborne environmental specifications, including temperature, shock and vibrations. The CC105 Camera Controller is responsible for the operation and data storage. The image data is stored on two removable hard discs. Camera control is done via the operator terminal of the ALS 50. Radiometric calibration provided which balances the output of all pixels when uniformly illuminated. The lenses of 35, 60 or 100 mm focal length are optimised for both RGB and CIR. The CIR use requires filter/compensating optic to avoid chromatic aberrations, software and calibration. A single camera controller is capable of recording data from two camera heads, allowing simultaneous acquisition of RGB and CIR images. The RCD 105 is available the fastest frame interval of 1/4,000s, Dold & Flint, 2007.

8. CURRENT TRENDS AND OUTLOOK

The current trends in medium format digital cameras include:

1. A movement towards rapid processing with the aim of (near) online orthophoto generation, e.g. for disaster management, security applications etc. This is only possible with direct georeferencing and several prerequisites, such as precise online GPS/INS data, a constant interior orientation and a rigorous bore site alignment, and a high speed and high quality data management. Compared to digital large format cameras, single-head medium format cameras have two important advantages for rapid processing: Due to the single head, fewer time-consuming preprocessing steps are necessary before orthorectification. The smaller images also allow for faster processing of single orthophotos.
2. Multi camera head developments, which will provide a similar coverage of a standard digital large format camera, but for a much lower price. By their nature, multi-head cameras do not acquire vertical images but slightly oblique images. This may result in geometric and radiometric problems for example every camera of a multi-head has its own interior orientation and the relative orientation of the different cameras may change slightly. In digital large format cameras, a laborious process is necessary to generate a single merged image from the different single heads. With multi-head medium format cameras a less complex strategy is necessary, e.g. maintaining single image treatment.
3. Forward-motion compensation (FMC) will come, not by time delayed integration (TDI) but mechanically. Clients ask for larger and larger ground resolution. In order to get perfect images with a GSD of 3 – 5 cm, FMC has to be applied.
4. A trend towards a combination of oblique and vertical imagery acquisition, e.g. for texturing of 3D-city models. To fully exploit the information from the oblique perspective, a minimum of four images from all sides have to be acquired and managed. Oblique images are difficult to obtain with standard mapping cameras. Only single- or multihead middle-format camera(s) systems provide the necessary flexibility.
5. Compared to large format cameras the digital sensors of medium format cameras have undergone a strong and steady increase in resolution, from 6 Megapixels a few years ago to currently 39 Megapixel. New technologies will increase the number of pixels even further. Kodak, the supplier for the 39 Megapixel KAF-39000-CA Chip, which is currently in many medium format cameras introduced a new Colour Filter Array layout. This technology increases the overall sensitivity of the sensor, as more of the photons striking the sensor are collected and used to generate the final image. This provides an increase in the photographic speed of the sensor, which can be used to improve performance when imaging under low light, enable faster shutter speeds (to reduce motion blur when imaging moving subjects), or the design of smaller pixels (leading to higher resolutions in a given optical format) while retaining performance.

Nowadays digital medium format camera systems are mature airborne systems with high reliability. With the increasing demand of “near-online” digital aerial data these systems will become even more popular in the future.

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