PERFORMANCE OF MEDIUM FORMAT DIGITAL AERIAL SENSOR SYSTEMS

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ABSTRACT:

Dealing with digital airborne photogrammetric data acquisition today's main focus is quite often exclusively laid on the large format digital sensor systems like ADS40 (Leica Geosystems), DMC (ZI-Imaging) and UltracamD (Vexcel Austria) which are already used in practice now. Their advantages are well known, nonetheless, for smaller area projects the use of such large format systems might be ineffective. Hence, there still is a need for smaller cameras which can be used in a more flexible and cost effective way. This application is addressed within the paper, where the main focus is on the medium format sector, utilizing digital matrix arrays about 15 Megapixel. After some first remarks on classification of digital matrix cameras the requirements for usage of non-dedicated sensors in airborne photogrammetric environments are recalled. The second part of the paper concentrates on the demonstration of the potential of two exemplarily chosen medium format cameras, namely the DSS sensor system from Applanix/Emerge, the dIGIcam-K14 sensor system from IGI and the Kodak DCS Pro 14n. The DSS is based on a classical analogue medium format housing which is supplemented with a digital CCD camera back, whereas the last two are using a standard small format camera housing with CMOS matrix array. The performance of such systems is proven from the results of airborne tests.

1. INTRODUCTION

Within the last years the development and commercial introduction of high resolution digital airborne imaging sensors was one major topic in the photogrammetric community. In the meantime new sensors like ADS40 (Leica Geosystems), DMC (ZI-Imaging) and UltracamD (Vexcel Austria) are available and their potential is proven from first experimental tests and pilot projects in practice. Such systems will substitute the well known analogue large format cameras within the next decades, although the analogue image recording using the well-known photogrammetric large frame cameras will be in use for a several years. Nonetheless, the change to digital sensors is inevitable since only a limited number of traditional photogrammetric cameras is available from system manufacturers and no replacement of stocks will be done.

Beside the large format digital sensors mentioned above there is a need for smaller and more flexible digital sensor systems which are designed to address the requirements for a smaller format and - in contrary to the very high priced large format camera segment - medium or lower priced digital image acquisition. In combination with direct georeferencing based on integrated GPS/inertial components and with the availability of digital elevation models (i.e. from laser scanning (LIDAR)) such sensor platforms provide an ideal mapping tool for the fast collection of smaller areas and linear features.

The today's situation in this digital camera field is very viable and lots of different systems are already used in practical applications. Some of the systems are developed as individual items only, others are sold commercially. In order to illustrate the situation of smaller format airborne digital camera systems a short overview on the different systems is given in the following. The second part of the paper focuses on two individual medium format cameras which are presented in more detail. First test flight results are given to illustrate the performance of such systems.

In order to classify the different types of airborne digital frame sensors the pixel resolution of the resulting digital image is the most important criterion. The number of pixels in the digital image is not necessarily congruent with the size of the internally used digital matrix array, since some of the larger formats are realized combining several arrays. Following the classification given by Petrie (2003) one can divide three different system classes:

- Small-format cameras, generating images in the range up to 6 Megapixel (i.e. image formats up to 2000 x 3000 pixel typically by using one equal sized matrix array). Sometimes up to four of those arrays are combined to obtain full resolution colour imagery.
- Medium-format cameras with image formats around 15 Megapixel (i.e. image formats 4000 x 4000 pixel or better). The RGB and CIR images are typically realized using Bayer colour mosaic filter to interpolate the colour information.
- Large-format cameras having a format of at least 36 Megapixel (i.e. image formats up to 13500 x 8000 pixel). These image formats are realized by combination of several smaller format matrix arrays since the largest available single matrix arrays allow for the recording of 9.2k x 9.2k pixels and is used in aerial reconnaissance systems (Gorin et al 2002). In this context "smaller format" has to be treated relative since the matrix areas used for acquisition of sub-images are sized about 4k x 2.7k (UltraCamD) or 7k x 4k (DMC), which is closer to the medium sized category in the sense of the nomenclature given here.

2. DIGITAL MEDIUM FORMAT FRAME CAMERAS

Focussing on the medium format segment only two different groups have to be separated (Petrie, 2003):

The first one is based on traditional medium format analogue camera housings where the film cassette is replaced by a digital back only. Such medium format digital camera backs have been developed from different manufacturers like Creo Inc. (Leaf Valeo 22), Imacon (Ixpress), Kodak (DCS Pro Back), MegaVision (S4), PhaseOne (H25, H20), SinarBron Imaging (Sinarback 54, 44) to be used to modify the analogue cameras offered i.e. by Contax, Hasselblad, Linhof, Mamiya or Rollei. There matrix area typically varies from approx. 4000 x 4000 pixel to 5400 x 4100 pixel.

In contrary to this, the systems from the second group are originally designed as digital cameras, where the Redlake/Kodak MegaPlus camera series is one of the most popular representatives. Quite often those MegaPlus cameras are used as one sub-system of integrated airborne data acquisition platforms consisting of laser scanners (LIDAR) combined with imaging component and GPS/inertial sensors for direct platform orientation. This approach is highly effective, not only for classifying the returned laser pulses but even more for rapid production of orthoimages based on the height data obtained from laser scanning and the directly measured sensor orientations. Such integrated airborne systems are operated from many airborne companies. A good online link catalogue of world-wide laser scanning system users is given by www.airbornelasermapping.com (2004). Many of them are using medium format cameras supplementary to the laser height data.

Within the following figures two representatives of digital medium format sensors are given. The Contax 645 camera (Figure 1) is originally designed as classical medium format analogue camera which can be extended by different digital backs as mentioned above and therefore belongs to the first group of medium format segment digital sensors. Different to that the Kodak DCS Pro 14n camera (Figure 2) is based on a standard analogue small format photography housing, where a large format CMOS digital matrix array providing 13.9 million total pixel is replacing the analogue small format film. From the resulting sensor size of 24 x 36 mm (which exactly matches the standard small format analogue film (no focal length magnification effect)) these camera could also be assigned to the small format group. Nonetheless, from the number of pixel this camera is closer to the medium format sensor. Hence the Kodak DCS Pro 14n is treated as representative of this class segment here.

Figure 1: Contax 645 (© Kyocera 2004).

Figure 2: Kodak DCS Pro 14n (© Kodak 2004).

To resume, the use of medium format digital cameras might be a quite attractive alternative for certain applications which are more focused in smaller projects with reduced spatial extensions or lower resolution imagery utilizing higher flight heights, mainly for photointerpretation and classification purposes. Although the price for such medium format sensors is higher compared to the small format systems up to 6 Megapixel the number of images to cover a certain project area is significantly less which simplifies the later processing. And still, the financial budget is significantly lower compared to the very costly large format sensors. From this point of pricing the Kodak DCS Pro 14n is advantageous combining the classical small format film housing (consumer product) with a high resolution 13.8 Megapixel matrix in total which is almost in the 15 Megapixel medium format segment.

Some of those digital sensors are additionally combined with GPS/inertial components for direct exterior orientation measurements. Such combination with GPS/inertial components results in a significant price increase especially when using the very high-quality GPS/inertial products (i.e. Applanix POS/AV, IGI AEROcontrol). Such systems are more expensive than the camera body itself but the combination of both offers the possibility for the very fast production of geo-referenced products. It gives more flexibility, and the fast turn-around of geo-referenced products is highly desirable especially for digital imagery. Such integration is standard when using the digital camera as sub-system for integrated airborne data acquisition platforms, as mentioned above.

3. REQUIREMENTS FOR NON-DEDICATED AIRBORNE SENSORS

3.1 Influence of sensor format

Using digital frame cameras for airborne data acquisition the size of the matrix array in combination with the used optics (focal length, lenses) is of major importance. The dimension of the used matrix array taking into account the individual pixel size is relevant for the achieved base-to-height ratio $\vartheta = B/h_g$.

This value reflects the geometry during image recording and is one main factor for the resulting point accuracy in object space. From the well-known normal case equations the influence of base-to-height ratio for object point quality is obvious. From the following equation the influence on 3D object point accuracy $\sigma_X, \sigma_Y, \sigma_Z$ is given,

$$\sigma_Z = \frac{h_g}{c} \cdot \frac{h_g}{B} \cdot \sigma_{px} = m_b \cdot \frac{1}{B/h_g} \cdot \sigma_{px}$$

$$\sigma_X = \sqrt{\left(\frac{x'}{c} \cdot \sigma_Z\right)^2 + \left(m_b \cdot \sigma_{x'}\right)^2}$$

$$\sigma_Y = \sqrt{\left(\frac{y'}{c} \cdot \sigma_Z\right)^2 + \left(m_b \cdot \sigma_{y'}\right)^2}$$

where $\sigma_{px}, \sigma_{x'}, \sigma_{y'}$ reflect the accuracy of horizontal parallaxe and image coordinate measurements in x and y, respectively (Kraus, 1990). As it can be seen from the formulas, for high performance object point determination a large base-to-height ratio should be aspired. For analogue photogrammetric cameras values of 1.08 (super-wide-angle, focal length 8.5cm) or 0.61 (wide-angle, focal length 15cm) could be achieved assuming standard 60% forward overlap conditions. In principle, similar values are feasible for digital sensors. Since many of the digital sensors are using normal angle optics due to the virtual magnification of focal length caused by smaller format matrix arrays, this results in smaller ϑ values and less accurate object point accuracy. Additionally, if digital sensors with non-quadratic arrays are used for airborne imaging the orientation of the sensor relative to the aircrafts flight direction influences the base-to-height ratio. Since the base-to-height ratio is given by

$$\vartheta = \frac{B}{h_g} = \frac{s'}{c} \cdot \left(1 - \frac{p}{100}\right)$$

where s' depicts the sensors extension in flight direction and p is the forward overlap in percent, the linear dependency of ϑ and the sensors size is obvious. For example, if the dimension ratio of the sensor is 4:3 (i.e. 5400 x 4100 pix) the base-to-height values differ between 25% dependent on the sensor orientation. In order to obtain larger swath width quite often the larger sensor side is oriented perpendicular to flight direction which again influences the quality of photogrammetric point reconstruction. This is even valid for the large format digital sensors (UltracamD, DMC). The DIMAC system (DIMAC 2004) is different: Due to the modular design the orientation of individual cameras heads relative to aircraft flight direction can be chosen application dependent. If the image data are mainly used for orthoimage generation based on given DTM the influence of base-to-height ratio on geometric accuracy is not as relevant.

3.2 Influence of image motion

Since airborne images are recorded from moving platforms like aircrafts or helicopters the movement of the sensors during exposure is of certain influence of the quality/sharpness of the acquired imagery. This so-called image motion which results in certain image blur is well known from the classical airborne cameras. In order to fully exploit the theoretical resolution power of photogrammetric high performance films forward motion compensation is realized by physically moving the photo film during the image exposure. This movement is synchronized with the mean forward velocity of the aircraft. Additional rotational movements are compensated from the stabilized mount which is typically activated during data recording. Such full motion compensation (translation plus rotation component) not only allows for a significant jump in image quality but also in an extension of maximum exposure times which results in use of higher resolution films even under non optimal flight conditions. This increases the number of potential flight days. Although a full motion compensation is applied, not all sources of image movements are compensated: Reasons for remaining image blur are due to deviations from the assumed mean flight velocity, variation of terrain heights resulting in a non constant velocity-height ratio and remaining rotational influences due to the latency of the closed loop control of the active stabilized mount.

Generally this initial situation is also valid for digital airborne frame sensors. Two main differences have to be taken into account: At least for the small to medium format sensors an active mount is typically not available - this situation might be different if the cameras are used as sub-system in combination with laser scanners mounted on a common platform which is stabilized then. Hence the rotational components of image motion could not be compensated. The translation effect of forward motion compensation has to be solved digitally by moving the charges on the matrix area itself (so-called time delayed integration TDI), which is typically not available for the small to medium format digital sensors. In contrary to analogue film, where the film role is moved in the focal plane of the camera the digital matrix array is typically fixed in the camera housing.

For reasons of completeness one specific realization of forward motion compensation should be mentioned finally: Within the DIMAC sensor systems, consisting of up to four individual 4080 x 5440 medium format matrix arrays, each array in the individual camera heads is truly physically shifted during image recording based on a piezo controlled technique. This approach is identical to the film based solution. Since there are no fiducial marks in the digital camera available the movement of the matrix array has to be known very exactly otherwise the relation between pixel and image coordinates is not established.

As described above, the medium format digital sensors typically suffer from influences of non compensated image motion effects. This gives certain limitations on the realizable image scales and therefore restrictions on the application fields. The influence of image motion follows the given equation below: With the aircraft velocity v, the exposure time t, focal length c and flying height above ground h_g the image motion u is obtained from well-known formula

$$u \approx \frac{u_{th}}{2} = \frac{1}{2} \cdot v \cdot t \cdot \frac{c}{h_g} = \frac{1}{2} \cdot \frac{v \cdot t}{m_b}$$

where only 50% of the theoretically image motion u_{th} is valid in the images (Kraus, 1990). For analogue imagery the reciprocal of 1.5 times of the film resolving power is tolerable for image motion. For digital imagery the influence of motion blur should be well below one pixel. Since aircraft velocity and image scale are typically given by default for a certain project, exposure time is the only variable to minimize effects of image motion. Exposure time on the other hand is coupled with lens aperture and film sensitivity given by the ISO value. In digital cameras, this ISO number is variable over a certain interval which allows for a larger variation of exposure times, although higher ISO numbers quite often are associated with higher image noise.

4. MEDIUM FORMAT DIGITAL SENSORS IN AIRBORNE USE

4.1 Applanix/Emerge DSS

The Applanix/Emerge DSS is one representative of digital medium format sensor systems. The optical part is based on a MegaVision 4092 x 4077 pix CCD array digital back mounted at a Contax 645 medium format film camera housing (Figure 3). This housing is stabilized using an proprietary exoskeleton in order to maintain a more or less fixed interior camera geometry. The camera body itself is rigidly integrated with an Applanix POS/AV 410 GPS/inertial system providing full high performance exterior orientation elements for direct georeferencing. This gives the possibility for fast turn-around orthoimage generation. In order to obtain regular block structures (which simplifies the processing significantly) and active azimuth mount control is realized for the automatic removal of the aircraft crab angles based on real-time POS/AV navigation data. The drift correction accuracy is < 0.5deg (RMS).

Figure 3: DSS camera head with exoskeleton (© Applanix 2003).

The dimension of the used CCD matrix is 3.68 x 3.67 cm² (9 x 9 µm² individual pixel size) which is less compared to the size of medium format analogue films (typically between 4.5 x 6 cm² and 6 x 7 cm²). In combination with the two available lens systems of 55mm (standard) and 35mm focal length (optional) the resulting field of view is 37deg and 56deg. Comparing the field of view to the geometry of standard photogrammetric cameras (23 x 23 cm² format) these values correspond to a normal-angle (41deg, 30.5cm focal length) or medium-angle (57deg, 21.0cm focal length) image geometry, respectively. The same situation holds for the base-to-height ratio: With 60% forward overlap the ratio ϑ is 0.42 (35mm focal length) and 0.27 (55mm focal length). Again, both things show the effect of virtual focal length magnification which will influence the quality of object point accuracy. This is the reason why the main application field of the camera is seen in orthomosaicing followed by photointerpretation or classification (i.e. forestry, agriculture), or change detection and natural disaster monitoring and documentation and not in photogrammetric point determination. In order to illustrate the accuracy potential of the DSS digital sensor system the results of two different test flights should be recalled briefly. Both tests were done by the Emerge production division, where Applanix was responsible for data processing.

4.1.1 DSS Lakeland test

The Lakeland test flight, flown in December 2002, was mainly dedicated to evaluate the overall in-flight system calibration and the potential of photogrammetric point determination – although this is not the main application field of the DSS system. The details of the test and the data analysis are already given in Mostafa (2003). Only a short summary of the main results is following here. The flight itself consists of 6 flight strips with standard photogrammetric overlap conditions, i.e. 60% forward and 20% sidelap. Each strip consists of 10 or 11 images, resulting in a total number of 65 images for the block. Since the flight was done in a flying height of 2000m above ground using the standard 55mm lenses, the obtained image scale is about $m_b = 33000$ resulting in a ground sample distance of approximately 0.3m. The object coordinates of 33 independently determined ground points served as control or check information to estimate the quality of object point determination. Two different investigations were done to evaluate the absolute accuracy of object point determination. Within the first test the overall system calibration (i.e. in-site refinement of a priori boresight angles from lab calibration and control of camera calibration parameters) was performed in the test area itself. Using the exterior orientations after system calibration as fixed direct observations (so-called given EO) to obtain the object coordinates from model-wise forward intersection is one of the QC/QA features in the Z/I-Imaging ISAT software that was used in this specific case. Based on the given EO parameters after calibration the accuracy (RMS) of object point determination is about 20-25cm for horizontal and 80cm for vertical component, which is in one pixel range for horizontal and close to 3 pixel in vertical direction. The maximum deviations (absolute values) are in the range of 0.55m, 0.80m, 1.90m for east, north, vertical component respectively. This situation changes when using the given EO parameters (with certain accuracy) as input data for an integrated sensor orientation (GPS/inertial assisted AT). Such approach allows for compensation on small effects in EO quality or system parameters and results in a better object point accuracy. The RMS values are considerably smaller indicating a higher accuracy in object space. The accuracy increase is about 30% compared to the solution based on the fixed given EO parameters. The maximum absolute deviations are smaller and reach 0.56m, 0.46m, 1.33m for X-, Y-, Z-components. Still the vertical component is significantly worse in comparison to the horizontal component. This is due to the already mentioned worse base-to-height ratio resulting in less accurate object height determination.

4.1.2 DSS NASA Stennis Space Centre test

Within the second test briefly cited the quality of the obtained final orthomosaic was evaluated. Since the orthomosaic is the final chain in the overall processing flow all different error sources during processing are controlled which is different from the first presented test where only the performance of object point determination was estimated. There seems to be a clear trend in North-America to perform such final product quality assessment from independent institutions. In this context the NASA offers their Stennis Space Center (SSC) facilities for such system evaluation. This test was done in January 2003, flown by Emerge production division. Again a 0.3m GSD was obtained. The final orthomosaic processing was done using the given NED digital elevation model. For the processing no additional ground control was used. The result then was submitted to NASA SSC, where the absolute accuracy performance was evaluated, by comparing the point coordinates measured in the rectified orthomosaic to their given reference values. The results of this test are shown in the Figure 4. The quality (RMS) about 0.32m is within one pixel, the additional circles indicate the radii of object point quality within 90% (CE90) and 95% (CE95) error radius probabilities. The values are 0.48m, and 0.55m for CE90 and CE95.

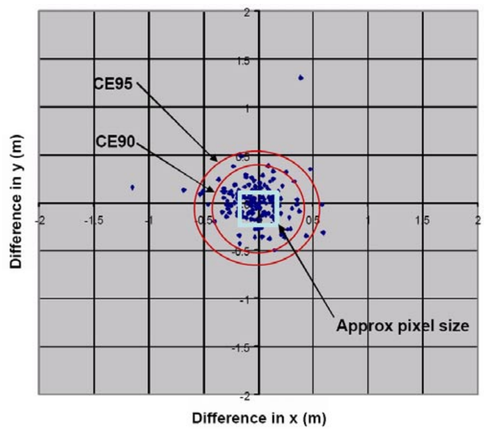

Figure 4: Performance of orthogeneration of DSS imagery from SSC test (© Applanix 2003).

4.2 KODAK DCS Pro 14n system

The second camera system being introduced in more details within this paper is the already mentioned Kodak DCS Pro 14n, which is a camera system available on market since June 2003. In contrary to most other digital cameras this camera model uses a CMOS sensor. From Blanc (2001) the performance of todays CMOS active pixel sensors is close or even better than their CCD equivalents. Just recently (March 2004) a slightly modified version, the Kodak DCS Pro SLR/n was made available, where the ISO range was upgraded compared to the predecessor model DCS Pro 14n. Nonetheless, version updating is possible by replacing the CMOS matrix sensor and the analogue electronics part. The main technical specs of the DCS Pro 14n are given in Table 1. More detailed technical specifications can be seen from the manufacturers WWW site at www.kodak.com (2004).

Besides the discussed topics of base-to-height ratio and image motion effects, the maximum feasible image frame rate is of concern for use of digital sensors in airborne environment. In this case the DCS Pro 14n allows for the internal buffering of approx. 20 full resolution images with an maximum image recording rate of 1.7 frames / sec as given in the specification sheets. If the image data are stored external (CompactFlash card or computer hard disc) the maximum frame rate is highly dependent on the used hardware. Dependent on the available equipment frame rates from 0.6 - 5 sec / frame are documented.

Since now, only few of those cameras are tested in airborne photogrammetric environments. To the authors knowledge tests were already done from IGI Germany (with a modified version of DCS Pro 14n), the Mexican photogrammetric company GeoSistemas Aéreos (GeoSisA) and GeoTechnologies consultancy at Bath Spa University College (Petrie 2004). Experiences from the first two system installations are covered in more details in the following.

DCS Pro 14n at GeoSistemas Aéreos (GeoSisA) The Mexican flight company GeoSistemas Aéreos (GeoSisA) is using the Kodak DCS Pro 14n since September 2003 mainly for production of large area coloured orthoimage mosaics. Since that time different projects with several thousand sqkm are already flown. As an example a production project to survey for clandestine garbage dumps in three of the biggest municipalities in Mexico (Tijuana, Rosarito and Puerto Penasco) should be mentioned. The Tijuana-Rosarito block covered an area of 65km by 40km with 21 lines (60% forward overlap and 30% sidelap) and 75 to 50 photographs per line (as function of the longitude) making a total of 1057 exposures for the complete block. The blocks were flown at an average of almost 4000m above ground, with some variations dependent on differences in terrain height. At this flight level, each photograph covered almost 4000m wide and 3000m forward. Based on the used AF Nikkor 35mm f/2D lens the obtained image scale is 1:110000. The flight was designed in order to obtain a ground sample distance (GSD) of 80cm, but in high contrast areas spatial resolution was higher. In order to keep the use of the system as flexible as possible an outside platform was designed, which can be placed outside any available airplane and command from the inside of the aircrafts cabin in order to be able to control tilt, bank, and drift angle to maintain the camera levelled and aligned. This installation is shown in Figure 5. The reliability of the system in this operational mission was very high. The whole job was done in less than 6 days. Using the base information data from Mexican mapping agency (i.e. topographic map 1:50000, existing small scale orthomosaic map 1:75000 and DTM) an accuracy of 8m is obtained from AT. This accuracy is in the range of several pixels only, caused by the lower quality of input data used for orientation, but fully agrees with the required accuracy demands. From another project with 60cm GSD (flying height 3000m) an orthomosaic accuracy of 2m (RMS) was proven based on check point data from 1:1000 base map and field topography.

CMOS sensor	13.89 million total pixel (4560 x 3048 pix) 13.50 million recorded pixel (4500 x 3000 pix)
Format size	36 mm x 24 mm (full format), no focal length magnification
Sensitivity	Pro 14n ISO 80 – 400 (full resolution) Pro SLR/n ISO 6 – 1600
Bit depth	12 bit / colour
Frame rate	Burst rate 1.7 frames / s Burst depth ~20 frames (full res., 512 Mb RAM)

Table 1: Kodak DCS Pro 14n technical specifications.

Figure 5: DCS Pro 14n in outside platform installation (© GeoSisA 2004).

From their practical experiences with digital medium format images obtained from Kodak DCS Pro 14n GeoSisA proved that the coloured mosaics have more semantic information and resolution than high-resolution satellite imagery (i.e. Ikonos and Quick Bird). The mosaics are delivered to the clients in less time than the satellite image (even when the satellite image has been already taken) and less expensive, especially when the clients need is to cover an area considerably less than the minimum size image offered by the satellite provider. Besides that the stereo capability of digital airborne images supports the clients within the photointerpretation process. Working stereo is possible from satellite images also, but considerably more expensive since an additional scene is necessary.

4.3 IGI dIGIcam-K14 system

The new dIGIcam series sensor systems of IGI has been combined with the IGI LiteMapper (LiDAR Terrain Mapping System) as imaging sub-component of an airborne laser scanning platform. The dIGIcam-K14 is based on the Kodak DCS Pro 14n and has been improved for airborne operations with a proprietary external housing and fixed focus lens. Also, the dIGIcam benefits of the fully integration to the IGI CCNS guidance and sensor management and AEROcontrol integrated

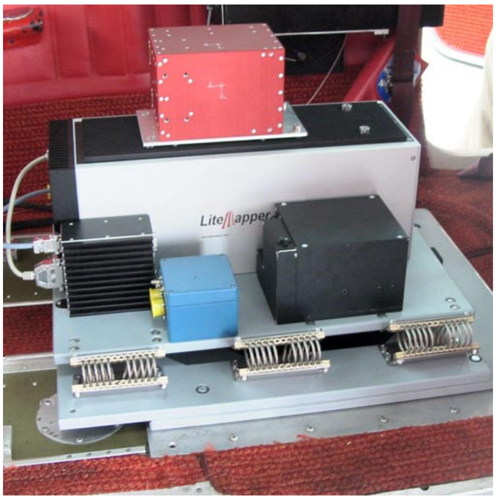

Figure 6: DigiCam-K14 with LiteMapper system installation (© IGI 2004).

GPS/inertial system. The camera is rigidly fixed on one common platform with the LiteMapper laser scanner and the AEROcontrol-IId for providing the direct georeferencing data for laser scanner and camera in parallel. The high performance of the AEROcontrol-IId was already proven several times and could be seen for example from Cramer (2003). The LiteMapper system was officially presented during the last Photogrammetric Week 2003 in Stuttgart/Germany. Details on the system parameters are given at www.igi-systems.com (2004). The airborne system installation is depicted in Figure 6. The modified DCS Pro 14n is fixed in the dark box in the right. In order to adjust the field of view of camera and laser the camera is mounted in that way that the small sensor side is pointing across flight direction, which also has advantages for photogrammetric point determination since larger base lengths are possible. On top of the LiteMapper laser scanner the IMU-IId is clearly visible. Within this specific system installation, all components were mounted on a non-stabilized platform fixed to the aircraft body via spiral springs for passive damping of aircraft vibrations.

Although the modified Kodak DCS Pro 14n as sub-part of the laser scanner platform is originally not designed for photogrammetric point determination a test was done by Institute for Photogrammetry (ifp) in mid of April 2004, where the whole system was flown in the photogrammetric test area Vaihingen/Enz (close to Stuttgart/Germany) in order to estimate the photogrammetric performance of the camera in combination with self-calibration techniques. Besides the large number of signalised ground control points special resolution targets are provided within the test area to evaluate the geometric and radiometric resolution of the sensor. During the mission two different image blocks using 28mm optics with standard overlaps were flown at 700m (8 flight lines east-west with 21 images each) and 400m above ground (4 flight lines north-south with 8 images each) resulting in image scales of 1:25000 and 1:15000 respectively. The corresponding ground sample distances are 20cm and 12cm.

During the time of writing only very first results are available for the Vaihingen/Enz test showing an accuracy in the range of 1 pixel which is very sufficient for this initial evaluation. A detailed analysis of test flight results including the topics like in flight camera calibration and image resolution will be given during the conference.

5. SUMMARY

As it could be shown in the paper, medium format digital sensors have their right to exist and could be used in several applications. The big advantages of such airborne sensors are their high flexibility and relatively low costs of operation. If certain photogrammetric pre-necessities are fulfilled (i.e. stable interior camera geometry as most important fact and the requirements already mentioned in Section 3) these sensors can even be used for photogrammetric point determination and stereo processing. Nonetheless, their main application will be in the field of photointerpretation and fast orthoimage generation based on existing DTM for smaller areas. Application tasks are monitoring of land use changes, disaster and risk assessment, forestry and others like real estate search and promotion or tourism. Certainly, such medium format systems will not replace the professional large format digital cameras, which are inevitable for highest photogrammetric demands and large area projects, but they might be of increasing interest for such groups of users, which are more interested in multispectral analysis and interpretation of more locally oriented projects. From this future application a closer look on the radiometric quality of those sensor systems seems to be necessary and will be done. Especially the FOVEON X3 (FOVEON 2004) technology seems to be an alternative to supplement the inherent need for colour interpolation when using traditional Bayer pattern.

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