'Photogrammetric Week '99' D. Fritsch & R. Spiller, Eds., Wichmann Verlag, Heidelberg, 1999.

Applications and market for digital airborne cameras

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ABSTRACT

The advances in sensor technology allow digital cameras to be used more and more also for aerial photography applications, but they will not meet all requirements of the aerial mapping cameras in use today in the foreseeable future. The launching of high-resolution earth observation satellites and new commercial fields of application both in photogrammetry and remote sensing will alter the market for aerial imagery significantly. In the beginning digital airborne cameras will be used in these new applications and in addition in big application areas of the analog aerial mapping cameras respectively satellite photos. This paper describes fields of application and market demands for future digital airborne cameras.

1. INTRODUCTION

Carl Zeiss in Oberkochen has developed and produced RMK series aerial mapping cameras for more than 40 years. Since April 1, 1999, this Carl Zeiss tradition is being continued by the Z/I-Imaging GmbH Oberkochen. Aerial mapping cameras like the RMK-TOP have been used successfully for decades all over the world. In recent years they have evolved from purely airborne cameras into complex system solutions through the compensation of aircraft motions, photoflight management with GPS navigation, and the use of measurement methods for the precise determination of the exterior orientation. 230 mm film with different specifications is still being used in a wide field of applications for image taking and image storage.
In photogrammetric plotting, however, the digital technology in the form of digital plotter stations has supplanted analytic plotters in many areas in recent years. Ever more jobs are defined by digital end products in GIS applications. Digital cameras are already being used successfully in many fields of application, e. g. professional photography, even though they cannot match the resolution of comparable analog films. Also in aerial photography, professional digital cameras are being used successfully for special applications. The advances in sensor technology and new applications in airborne remote sensing ensure that airborne cameras are at the threshold of the digital age. To lay the basis for the definition of future digital airborne cameras, their market demands are investigated in the following.

2. PHOTOGRAMMETRIC PROCESS CHAIN

Aerial photogrammetry is a mature work process that has developed over many decades. This process extends from taking the photo in the aircraft to the end product (Figure 1). The individual procedural steps are determined by the requirements of the respective application. Most aerial photos are made for cartographic purposes, while a smaller part is taken for pure remote sensing applications. In all applications the real demand originator is not the aerial photo but a salable end product e.g. a thematic map. This end product will increasingly be required in digital form within a GIS application. The use of digital airborne cameras opens up the possibility to establish end to end digital process chains.
Since the applications are the demand originator, they define the end product in this process chain, but do not specify the components or the flow of a process. The end product for many aerial photo applications today is digital information. Therefore a completely digital process promises many benefits. However, the desired information can be the result of various alternative processes. A digital airborne camera as a component of a genuinely digital photogrammetric process therefore

always competes with other measuring methods such as geodesy, GPS, satellite images, aerial mapping cameras as well as radar or laser scanners.

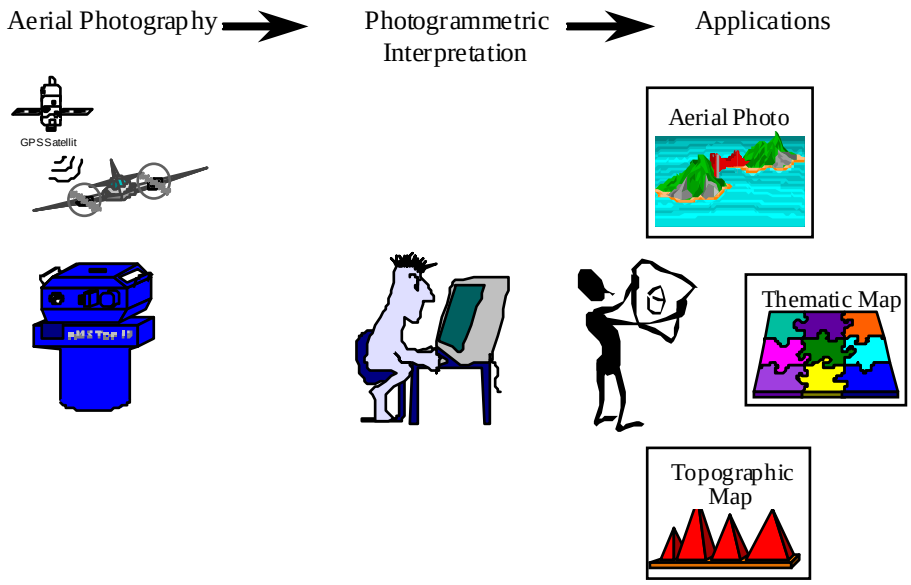

Figure 1: Photogrammetric Process Chain.

To establish a market for digital airborne cameras, they have to offer a clear competitive edge for a series of differing processes. For assessing the performance potential, the whole process from the sensor to data transfer, data processing, and up to archiving has to be considered. For each application an investigation is required why digital sensors should be used for taking the photo instead of 230 mm aerial film. An analysis of the technical capabilities of digital imaging sensors in the photogrammetric workflow allows the benefits for the overall process to be assigned to 4 groups (Table 1).

cost saving	**time saving**
• no film • no film development • better automation • additional Photoflight days	• less interrupts • no film development • no scanning
higher quality	**new applications**
• better radiometric resolution • reproducible color • radiometric accuracy • spatial accuracy • in-flight image control	• new kind of information, multispectral • quick results within a short time • multimedia

Table 1: Advantages in change from analog to digital technology.

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3. AIRBORNE REMOTE SENSING MARKET

Process analysis and the technical capabilities of digital cameras - advantages and disadvantages - show that the development of a new digital airborne camera involves much more than just the substitution of a piece of silicon for analog film. The photogrammetric resolution of 230 mm aerial film cannot be matched complete by silicon chips in the foreseeable future. Digital airborne cameras will therefore not supplant aerial mapping cameras in the near future. Before substitution can take place, all procedural steps from taking the photo and plotting it to archiving must be able to process the expected data volumes economically. The market segments for digital airborne cameras and aerial mapping cameras will therefore differ at the beginning. Of course there will be a common overlap area. For defining a digital airborne camera, these market segments will be identified more precisely.

3.1. Market Forecast

The aerial image market as demand originator for airborne cameras is a part of the GIS market. The future development of the GIS market has been investigated and illustrated in various market studies (e.g. CEO 1995, Dataquest 1996, EIA 1994, Frost & Sullivan 1996, OTA 1994). Depending on the task, the market delimitation and the reporting period, the absolute results of these market studies differ significantly. There is agreement, however, in forecasting significant growth in the period from 1995 to 2005 (Figure 2). More interesting than the absolute numbers are the changes in the market segments National Security and Civil Administration on one side and Commercial Applications on the other side. A major trend seems to be that the public sectors will stagnate or shrink and a clear growth impetus will only come from new commercial applications. This area will grow by approx. 500% in the reporting period and only from this area will initiatives for new uses of digital airborne cameras come.

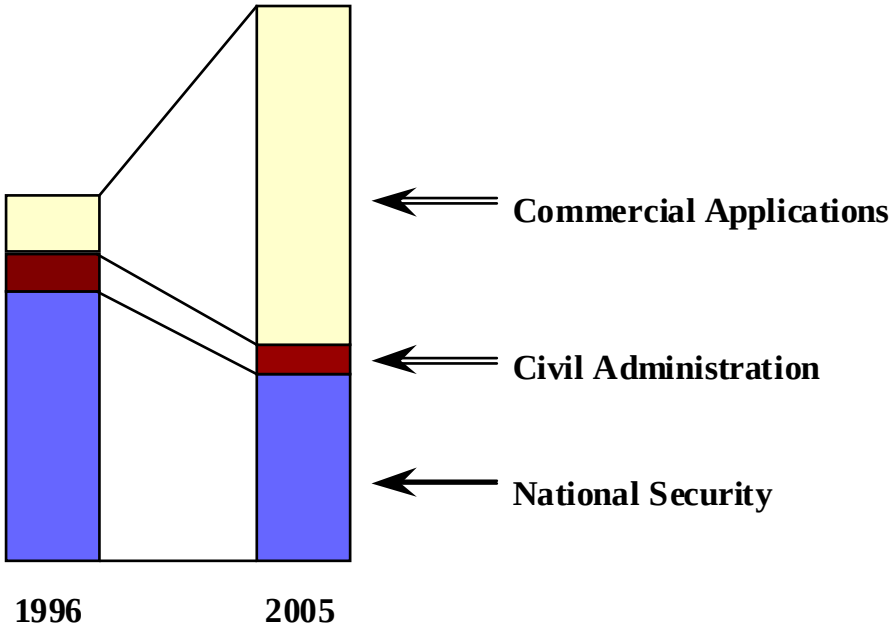

Figure 2: World GIS - Market Forecast.

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3.2. Future Airborne Applications

For the conception of new airborne camera systems, the opportunities resulting from these changes in the GIS market have to be considered. The demand in classical aerial imaging applications such as cartography will stagnate and perhaps even shrink in the coming years, while a market segment for new commercial applications will develop (Table 2). In part this involves applications from the field of remote sensing, which benefit from the expanded spectral capabilities of digital imaging sensors. As can be seen from this survey, these commercial applications have some quite different requirements than map production by means of analog aerial imagery.

Application	Description
Mapping	City and county governments, cartographic departments, remote sensing companies; photo scale 1:5.000 - 1:50.000
Construction	overground + underground building, facility management, supply lines, small events; photo scale 1:3.000 - 1:7.000
Infrastructure	route planning and monitoring of pipelines, railways, streets, corridor applications; photo scale 1:3.000 - 1:7.000
Telecommuncation	3D-models of the city buildings
Agriculture	monitor crop yield, soil, stress, and impacts of pests and disease
Forestry	monitor tree yield, tree trimming, fire
Insurance	high resolution data in a very short time e.g. height resolution 0,1 m for flood monitoring
Disaster Management	quick reaction within hours

Table 2: Future Applications of Airborne Imagery.

3.3. Satellite Competition

Another important market aspect is the future competition between airborne image sensors and high-resolution earth observation satellites. Currently some satellite projects are being implemented which should achieve a panchromatic ground resolution of 1 m and a multispectral ground resolution of 3 m (Table 3). Although the first two attempts to launch commercial, high-resolution satellites failed, the first high-resolution satellite images should be commercially available before long. These satellite images aim clearly at the growth market of the new commercial applications.
As a rule, airborne cameras are today used for photo scales of approx. 1:2,000 to 1:50,000. However, the distribution within this scale range is not homogeneous. Most aerial imagery by far is taken at scales of 1:5,000 to 1:15,000. For small-scale mapping at photo scales < 1:25,000, competition can be expected between new high resolution satellite imagery and aerial imagery. Some of the aerial imagery market will be lost to this satellites. However, for digital airborne cameras this results in a market chance for supplementing digital satellite images.

- Satellites have a limited resolution
- Satellites cannot gather image data in several locations simultaneously
- Satellites cannot always photograph the ground at the desired time and location and because of the cloud cover.

program	satellite	launch date	status / resolution
			ground resolution > 5 m
India	IRS-1C IRS-1D	1995 29. Sept. 97	6m pan 6m pan
France	Spot 4	24. März 98	10m pan
			ground resolution < 5 m
Earth Watch	Early Bird Quick Bird	24. Dez.97 1999	failed planned 1m pan
Space Imaging	Ikonos1 Ikonos2	27. April 99 1999	Failed planned 1m pan
Orb Image	Orb View3 Orb View4	1999 2000	planned planned
Spot Image	Spot 5	2002	planned
NASDA Japan	ALOS	2003	planned

Table 3: Overview of some high resolution earth observation satellites.

For these reasons the airborne remote sensing sector will grow significantly to complement the satellites (Figure 3). Space Imaging recently began to operate a photographic aircraft with a digital airborne camera to supplement the IKONOS imagery in the submeter resolution range.

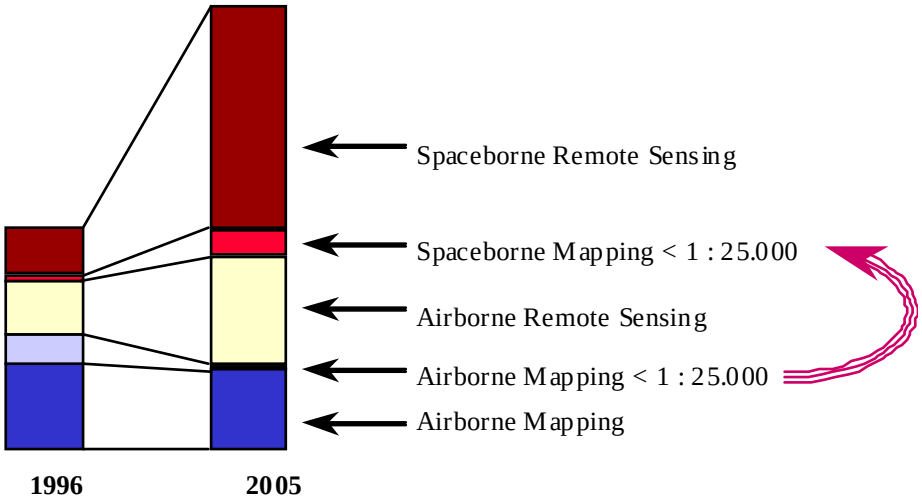

Figure 3: Image Market Forecast.

3.4. Image Market

In the future, three fundamentally different image data sources have to be reckoned with in the photogrammetric image market:

- High-resolution earth observation satellites
- Digital airborne cameras
- High-resolution analog aerial mapping cameras

This competition and new technical capabilities make for drastic changes in the availability and the price of image data in the coming years. Satellite image data are already being collected in photo data bases and sold as required through e-commerce over the Internet. Not only the pure image data but finished products are also offered. In addition to orthophotos there are complete information

packages containing image data with evaluations as well as weather information e.g. for use in agriculture. For the image market it is therefore possible to identify the following trends:

Image Market Trends:

- Shift from "Performance Enhancement" to "Affordability Improvement"
- New methods for distribution; e.g. direct sales via the Internet
- New services for the consumer market; e.g. satellite images on CD-ROM
- Low-cost geo-coded image data
- Preprocessing of image data is a challenge for photoflight companies
- Image data will become a commodity

These trends in the image market have different effects on aerial imagery applications. New thematic applications will arise in the field of remote sensing because of the enhanced possibilities of digital color images. The demand for low-cost color orthophotos will also rise because of the satellite images and the new distribution channels offered by the Internet. Classical photogrammetric applications such as stereoplotting of aerial photography and the production of terrain models will shrink because of the competition with other measuring methods such as laser scanning and other space-borne image data sources.

4. MARKET NEEDS AIRBORNE DIGITAL CAMERAS

This analysis of the image market indicates the demands digital airborne cameras will have to meet. To complement high-resolution satellite images, a ground resolution of better than 1.0 m and multispectral features of approx. 450 to 900 nm are required. Advantages over the satellites result from a higher ground resolution, higher accuracy in georeferencing, and faster availability in case of partial cloud cover and independently of the satellite orbiting times.
A special competition will arise between aerial mapping cameras and digital airborne cameras. Both system are being used in planes under comparable conditions. Compared with the aerial mapping camera, the digital airborne camera offers

- higher radiometric resolution
- reproducible color information
- cost savings for film
- cost savings for film processing
- cost savings for scanning
- immediate availability of the image data

The essential criterion in a performance comparison between aerial mapping cameras and digital airborne cameras is the geometric resolution. In this field, no digital airborne camera can match an aerial mapping camera in the foreseeable future. For the comparison between aerial mapping cameras and digital airborne cameras, the following approaches make sense.

- Corresponds to 230 mm film scanned with 7.0 µm ==> 32,800 pixels
- Corresponds to 230 mm film scanned with 14.0 µm ==> 16,400 pixels
- Ground resolution 0.2 m and FOV 2.km ==> 10,000 pixels

230 mm aerial film can be digitized with the help of a state-of-the-art photogrammetric precision scanner such as the SCAI with a pixel size of 7 µm for digital plotting. This resolution would

correspond to a sensor a transverse resolution of with 32,800 pixels. An uncompressed color image with 12bit information depth requires approx. 4.5 gigabytes of memory space and a complete roll of aerial film requires 2.7 terabytes. The yearly taking performance of a modern aerial mapping camera such as the RMK-TOP is some 20,000 photos. This taking performance would result in approx. 90 terabytes of image data at a resolution of 7 µm. These data apply not only to the taking process but to the whole process chain. . However, money can be made with a digital airborne camera only if the data volumes involved can be processed economically. Although the data processing technology is soaring, a yearly taking performance of 90 terabytes per camera will not be easy to process in the near future.
These numbers imply that the time not yet ripe for supplanting aerial mapping cameras. The question of the pixel numbers required of a digital airborne camera cannot be answered by comparing frame formats and pixel sizes only. When flying along linear objects such as roads, utility lines or coastlines, the 230 mm film format of an aerial mapping camera is not fully used. In spatially limited applications the data volume and the image quantities are also limited. In these applications it is in part possible to use digital cameras economically already today. The definition of the most economic digital resolution therefore depends on the application.

5. CONCLUSION

New applications and new image data sources will impact the market for aerial imagery significantly in the coming years. These changes as well as advances in the sensor and computer fields will soon make the use of digital airborne cameras economical. They will most likely complement the currently used aerial mapping cameras rather than supplant them completly. Before the 230 mm film technology can be replaced by digital sensors, some major tasks will have to be solved in the sensor resolution and data processing fields. This development can be seen in the medium to long term.

6. REFERENCES

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