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RMK TOP AERIAL SURVEY CAMERA SYSTEM

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1. INTRODUCTION

The RMK TOP aerial survey camera system was launched two years ago.
The development of this system was preceded by a comprehensive analysis of aerial photography, which demonstrated that it would be possible to improve the camera performance by implementing the following measures:

- strict adherence to the specified geometric overlap in the survey area,
- retention of the optimum image quality achievable in the prevailing flight conditions,
- integration of the camera control into a photoflight management system.

2. GEOMETRIC OVERLAP

At first glance, the adherence to a preselected geometric overlap in the survey area does not appear to be any special challenge for the camera designer.

During mission planning

- the boundaries of the area are defined,
- the optimum arrangement of flight strips is determined and
- the longitudinal and transverse overlap is specified.

It is then primarily the task of photoflight navigation to ensure that these requirements are met during the mission. Until now, this has mainly been achieved by visual navigation. In large-scale photography and in photoflights over undeveloped terrain in particular, this method makes exacting demands on the navigator.
GPS, however, now is the first hardware available to provide the necessary accuracies even in large-scale photos. It enables precise triggering of exposures at precomputed stations (pin-point photography), permitting, for example, 1 map sheet to be covered by 1 model.

The only area which is normally taken care of by the camera control system is the overlap control. In this process, the current ground speed and altitude above the ground are used to control the exposure sequence in a run in such a way that the successive exposures display the preselected overlap. Apart from 'pin-point photography', overlap control will continue to play an important role in the future, especially in the event of major height differences in the terrain which influence the overlap. Overlap control was also the first method of camera control, which dates back to the twenties and has made a decisive contribution towards the cost-effective surveying of large areas.

A variety of suitable instruments is available for the different applications, with the NA automatic navigation meter at the top of the range.
As a result, there does not seem to be any immediate need for instrument innovation in this field. It is true that the inherent drawback of standard rotating-disk shutters is their inability to be triggered at any required time, but only when the continuously rotating disks are in the shutter open position. Needless to say, this access time, which is particularly critical at low speeds, i.e. with long exposure times, and may last as long as 1 second, impairs the overlap of the exposures. If, however, the exposure time is selected to ensure that the image motion does not exceed 25 μm - as is necessary for photos without image motion compensation - the displacement of the photo center will remain below 2.5 mm. This corresponds to an overlap error of approx. 1 % and is therefore acceptable.

3. OPTIMUM IMAGE QUALITY

In photogrammetry, exacting demands are made on both metric accuracy and resolution. Camera lenses and film emulsions have been continuously improved in both these respects. In practical use, however, these improvements have only had a partial effect, as image quality - especially as far as resolution is concerned - is considerably influenced by the external photoflight conditions such as

- atmospheric conditions
- forward motion of the aircraft and
- angular motion of the aircraft.

3.1 Overlap control and FMC

The introduction of **Forward Motion Compensation (FMC)** was a first, crucial step towards a marked improvement in image quality. In particular, the extensive use of high-resolution, but low-speed film types was only made possible by FMC in the first place. However, since this permits the use of longer exposure times even at a higher relative speed (v/h = ground speed to flying height above ground), the access time of conventional rotating-disk shutters previously mentioned may have an extremely adverse effect on the overlap. The maximum image motion that can be compensated by the camera control system may lead to a displacement of more than 60 mm of the photo center from its correct position, i.e. the overlap deviates by more than 25 % from the preselected amount. This results in a severe restriction in the choice of the exposure time and thus in the use of FMC in general.

As an essential component of a camera featuring FMC, an **entirely new shutter** has therefore been developed, which ensures a short, constant access time of only 50 ms, no matter what exposure time is used. This means that the selected exposure time no longer influences the overlap accuracy. This, of course, also applies to the accuracy of 'pin-point photography'. If the camera is triggered by a GPS receiver, for example, even the delay of 50 ms can be taken into account, which permits the specified moment of exposure to be met within a few milliseconds. Moreover, the actual moment when the shutter is open can be recorded with an accuracy of 50 μs for high-precision GPS measurements. This signal is also used for the exposure of the fiducial marks on the frames.

3.2 Automatic exposure control and pulsed shutter

Due to the new shutter design, the overlap no longer needs to be taken into account in the selection of the exposure time. Automatic exposure control can therefore be based on the principle of 'image quality priority'. This means that the aperture and exposure time are set in such a way that optimum image quality is achieved in the prevailing photoflight conditions. The admissible ranges for the aperture and exposure time can be defined by the user at the T-TL terminal in three priority levels depending on the mission requirements and current flight conditions.

Generally speaking, it is recommended to use

- the optimum aperture of the lens, if possible, and
- the shortest possible exposure time.

The system uses these criteria and the specified priority levels to select the best combination of aperture and exposure time for the conditions involved.

3.3 T-AS stabilized suspension mount

In spite of FMC, the use of long exposure times is considerably limited by image motion caused by the random angular movements of the aircraft. A gyro-stabilized suspension mount can reduce these influences to approx. 3 % of the original amount and at the same time keep the vertical alignment of the camera to within approx. 0.5°.

Photogrammetrische Woche 1991
Schriftenreihe, Heft 15, 1991
Institut für Photogrammetrie

For high-precision GPS measurements, the eccentricities of the antenna and the camera projection center need to be taken into account. The current position of the suspension mount can therefore be recorded for each exposure. Assuming proper levelling of the camera, the angle values recorded indicate the aircraft position at the moment of exposure. The accuracy of these records may therefore be estimated at 0.5°, which is sufficient for the correction of the eccentricity.

3.4 Overall image quality

Only the combination of all previously mentioned features

- Forward Motion Compensation (FMC)
- Pulsed shutter with constant access time
- Exposure control based on image quality priority and
- Stabilized suspension mount

permits full utilization of the lens and film capabilities. The outstanding feature of the redesigned RMK TOP lenses is their enhanced image quality extending into the very corners of the photo. In batch-produced cameras delivered until now, an average resolution of approx. 100 lp/mm (AWAR) is attained with the PLEOGON A3 4/153 lens at full aperture and using KODAK PANATOMIC-X aerial film. The comparisons made so far show that these results correspond very closely to the resolution data established by the US Geological Survey.

4. PHOTOFLIGHT MANAGEMENT

The T-TL terminal is the central unit for the control and monitoring of the complete camera system. All relevant parameters for the camera control can be entered and stored in the terminal before the mission. An interface which can be optionally installed in the T-CU camera control unit, permits connection to an external on-board system. The selected operating mode can also be configured on the terminal. This also paves the way to the generation of an **'integrated photoflight management system'**.

4.1 Data annotation

Various auxiliary devices such as a clock, altimeter and noteboard are usually imaged at the margin of each frame. In many cases, however, the client requires subsequent annotation with additional data in a specified format - a procedure which involves a great deal of work. Each photo taken with the RMK TOP therefore contains two data lines, each with 48 characters, for additional information. The characters can be easily read with the naked eye. Subsequent data annotation becomes superfluous.

The contents and format of the additional information can be freely selected by the user on the terminal. Data from the following sources is available for this purpose:

- internal camera control data, e.g. moment of exposure
- data from the terminal, e.g. mission identification, date
- data from an external on-board system, e.g. exposure station (latitude/longitude).

4.2 External interface

This interface enables an external on-board system to perform various camera control functions such as

- Activation and deactivation of **serial photography.**
  In this mode, the external system activates the camera at the beginning and deactivates it at the end of a run. During the flight, the exposures are triggered by the internal camera control system in accordance with the preselected overlap and the measured v/h value.

- **Triggering of single exposures.**
  In this mode, each individual exposure is triggered at the preselected station.

The exact moment of exposure is transmitted to the external system, e.g. for assignment to the GPS measurements.

A data interface such as RS 232 permits data to be transmitted by the external system to the camera for exposure on the photo. The contents and format of this data can also be specified by the external system and transmitted to the camera control system using a configuration command.

4.3 Film report

During a mission, all functions performed and messages emitted by the camera system are stored in the T-TL terminal. This log can afterwards be transferred to a PC and processed into a film report. In much the same way, the camera control parameters required for a mission can be collected on the PC and then transferred to the T-TL terminal.

4.4 Integrated management system

Based on these components, we are now launching the **'advanced aerial photography management system'** for the RMK TOP which comprises the following functions:

- **Photo mission planning**
- **Survey navigation, camera control and automatic data acquisition,**
- **Post-mission report.**

All these functions are performed by separate software modules which operate independently and can also be used as stand-alone programs.

4.4.1 Photo mission planning (T-PLAN)

Mission planning runs on a PC equipped with AutoCAD and a graphics display terminal. It offers the following functions:

- Definition of all mission parameters and recording in a mission parameter file,
- Conversion from geodetic systems into WGS84,
- Definition and graphic display of the project area,
  - import of existing data in the .DXF format
  - use of digitized data,
  - entry of numeric data either by keyboard or ASCII file,
- Design of a flight schedule that conforms to all parameters defined in the mission parameter file,
- Preparation of a data transfer file containing the information for survey navigation and camera control, e.g.
  - project area,
  - first and last exposure station for each run,
  - intermediate exposure stations (if applicable).

4.4.2 Survey navigation (T-NAV)

All necessary functions for survey navigation, camera control and data acquisition are performed by the navigation computer in the multitasking mode.

Photogrammetrische Woche 1991
Schriftenreihe, Heft 15, 1991
Institut für Photogrammetrie

Experience gained with GPS-guided survey missions shows that efficient flight procedures can only be initiated from an appropriate display environment:

A graphic **horizontal situation display (HSD)** provides user-friendly 'real-time' interaction between the navigator and the system. Capable of instantly extracting the coordinates of any displayed point and all relevant parameters, the HSD will suppress cumbersome waypoint inputting and associated errors. It will thus allow the navigator to guide the aircraft and to supervise all aspects of the photoflight in an efficient way.

The **pilot display** is designed to present all information in line with conventional aviation practice: for instance, cross track error is represented by a course deviation indicator similar to the standard HSI which currently equips most aircraft. The information displayed to the pilot is reduced to the strict minimum required to guide the aircraft on the survey line in order to distract the pilot as little as possible from his responsibilities.

The camera can either be triggered at predetermined exposure stations or at exposure intervals controlled by GPS measurements. In an alternative procedure, the system only starts the serial exposure mode of the camera at the beginning of a run and stops exposures after the end of the run, while all intermediate exposures are triggered internally by the camera control system according to the preselected overlap. The pilot display also shows the status of the camera cycle and warns the pilot that the camera is about to fire.

The exact time of exposures is recorded directly by the GPS receiver, while the GPS raw data required for high-precision exposure station control are recorded on a suitable mass storage device. Additional information, e.g. from electronic pressure sensors, can also be recorded.

As mentioned already, latitude and longitude coordinates and other data can also be sent to the camera for data annotation directly on the frames.

4.4.3 Post-mission report (T-REP)

Mission evaluation also runs on the PC used for mission planning. It is used for the compilation of the **flight report** and production of the **flight index maps.**

The following procedures are involved:

- Reading and processing of GPS (pseudorange) and altimeter data,
- Determination of pseudorange coordinates of exposure stations,
- Transformation into the appropriate geodetic system,
- Listing and graphic display of exposure stations,
- Compilation of the film report using the camera data recorded in the terminal.

4.5 Post-processing of GPS phase measurements

GPS phase measurements can be recorded by the T-NAV module. Their evaluation, however, is not part of the management system for the RMK TOP, but is performed using the software developed by the INPHO GmbH at Stuttgart.

ABSTRACT

The RMK TOP aerial survey camera launched two years ago is the first photogrammetric camera to be developed which takes into account the special requirements of FMC in its design principle. The pulsed rotating-disk shutter permits long exposure times without adverse effects on the overlap. This, in combination with the innovative automatic exposure control and the stabilized suspension mount, allows full utilization of the improved image quality of the lenses.

Photogrammetrische Woche 1991
Schriftenreihe, Heft 15, 1991
Institut für Photogrammetrie

The new shutter also meets all requirements for optimum use in GPS-supported photoflights. Starting with the T-TL terminal for central operation of the system, a description is given of the photoflight management system for the RMK TOP which integrates the camera control into the mission cycle - from the initial photoflight planning to the compilation of the flight report.

DAS LUFTBILDKAMMER-SYSTEM RMK TOP

ZUSAMMENFASSUNG

Mit der Reihenmeßkammer RMK TOP wurde vor zwei Jahren erstmals eine photogrammetrische Kamera vorgestellt, bei deren Entwicklung die besonderen Gesichtspunkte des FMC-Einsatzes bereits im grundlegenden Konzept berücksichtigt wurden. Durch den gepulsten Rotationslamellenverschluß können auch längere Belichtungszeiten ohne nachteilige Auswirkungen auf die Überdeckung verwendet werden. In Verbindung mit der neuartigen automatischen Belichtungssteuerung und der stabilisierten Aufhängung kann die gesteigerte Abbildungsqualität der Objektive voll ausgenutzt werden.

Der neue Verschluß bringt auch alle Voraussetzungen für den optimalen Einsatz bei GPS-unterstützten Bildflügen mit. Ausgehend von der zentralen Bedienung des Systems über das Terminal T-TL wird das Bildflug-Managementsystem für die RMK TOP vorgestellt, das die Kamerabedienung in den Ablauf eines Projektes von der Bildflugplanung bis zur Erstellung des Flugprotokolls integriert.

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