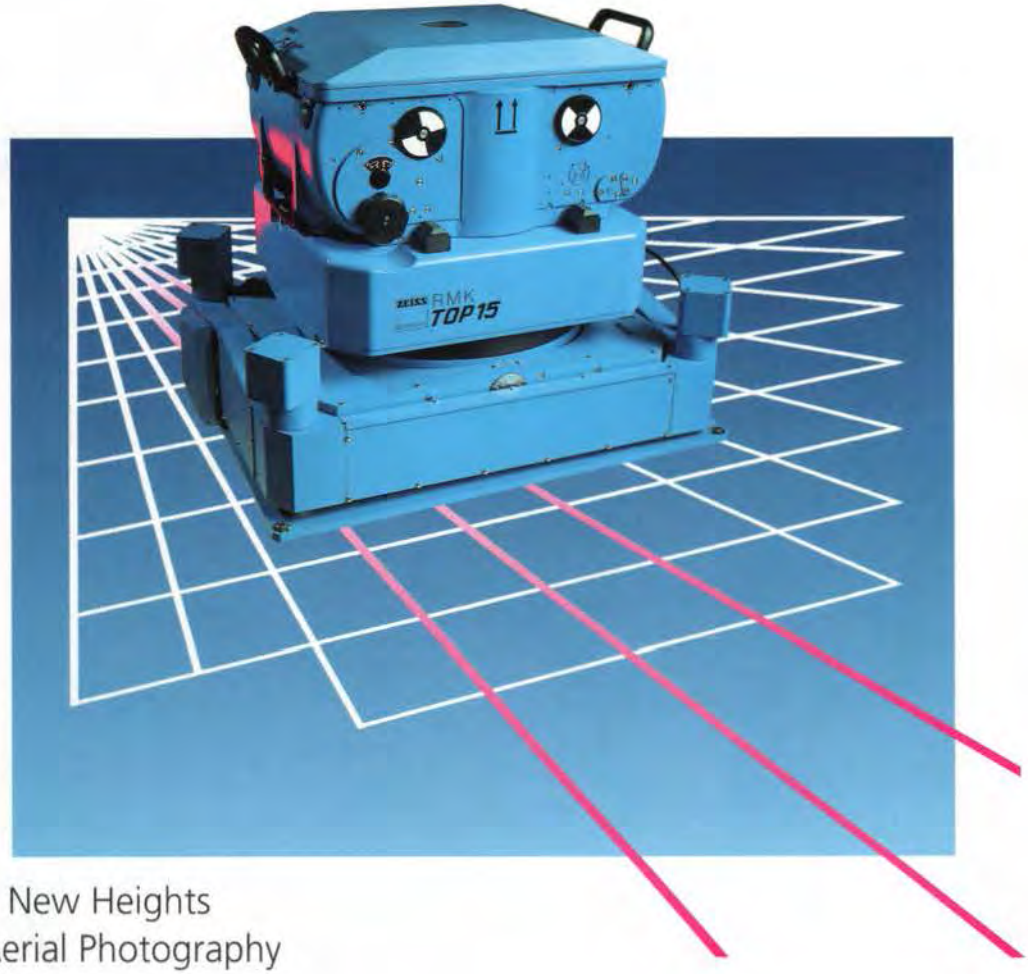
RMK TOP
Aerial Survey Camera System



New Heights
in Aerial Photography

ZEISS

Performance Features and Benefits

The 12 decisive benefits of the **RMK TOP** system:

1 Modular design with easy-to-change components and compatibility with RMK A

2 New high-performance lenses with internal filters and significantly enhanced image quality

3 Comprehensive image motion compensation by FMC and gyro-stabilized suspension mount

4 Stabilized camera axis ensuring small nadir angles

5 Unique pulsed rotating-disk shutter with a constant access time of 50 ms

6 Precise overlap control and pin-point photography

7 Menu-driven central control by a compact computer and logging of the mission data

8 Automatic v/h measurement for overlap control and FMC

9 Automatic exposure control using the principle of image quality priority

10 Ideal for GPS-supported navigation and aerotriangulation

11 Integration into the GPS-supported T-FLIGHT photoflight management system

12 Outstanding reliability and flexibility

Goal

For many decades now, the RMK A aerial survey camera from Carl Zeiss has been successfully used all over the world as a high- performance system for aerial photography.

Increasingly critical demands in practical application and new technological possibilities have recently resulted in the development of a new camera generation, the

RMK TOP.

The new system was designed with the following goals in mind:

- central, flexible and easy operation
- marked improvement of image quality by new lenses and comprehensive image motion compensation
- avoidance of variable access times and overlap fluctuations
- unproblematic connection to GPS and navigation systems
- connection to external computers to meet EDP requirements in mission planning and evaluation
- integration into a photoflight management system
- further improvement of reliability.

Care was taken in the development to ensure that major components of the previous RMK A family could continue to be used by guaranteeing their compatibility with the principal components of the RMK TOP.
The RMK TOP offers the perfection in performance expected of a state-of-the-art photogrammetric camera:

Geometrically accurate, high-resolution photos of immense information content - taken in fast sequence, easily produced, rapidly available and suited for direct interpretation and evaluation by the user.

The photos taken with the RMK TOP will form the basis of photogrammetric work for decades to come.

RMK TOP - Experience and Innovation

Modular Design and System Components

The RMK TOP features a systematic, modular design. The individual components form logical functional units optimized to the needs of both practical application and economical use. Special consideration has been given to the space available in the aircraft, the installation conditions and the necessity of component change.

The RMK TOP system comprises:

- RMK TOP 15 camera body with PLEOGON A3 4/153 wide-angle lens or
- RMK TOP 30 camera body with TOPAR A3 5.6/305 normal-angle lens
- T-CU central control unit with microprocessor
- T-TL terminal with compact computer for operation and monitoring of the camera
- T-MC film magazine with FMC
- T-AS gyro-stabilized suspension mount or
- T-AL suspension mount and
- navigation instruments for visual or automatic navigation and overlap control.

The following navigation instruments are available:

- T-NT navigation telescope for navigation, visual overlap control and drift determination
- T-NA automatic navigation meter for automatic overlap control.

The RMK TOP can be integrated into photoflight management systems such as

- T-FLIGHT photoflight management system.

RMK TOP 15 | RMK TOP 30 | T-CU | T-TL | T-MC | T-AS | T-NT | T-FLIGHT

Camera Body

The camera body is a compact unit with a rugged enclosure accommodating the lens cone with the focal plane frame and auxiliary data field, the pulsed rotary shutter, 4 controllable internal filters, the diaphragm and the motorized drive assemblies.

The control electronics are installed in the T-CU control unit.
For changing the focal length, the complete camera body is exchanged. Compared with other systems, this offers the following outstanding advantages:

- fast, easy and reliable in-flight change of the focal length within a matter of a few minutes
- protection of the assemblies which are vital for the accuracy and high constancy of the interior orientation
- minimum of mechanical and electrical interfaces and
- filter change within seconds due to controllable internal filters.

Control Unit

The T-CU control unit contains the control and power electronics including the microprocessor and interfaces for GPS and navigation systems. As the central distributor, it interconnects the components of the entire system.

The advantages of a central control unit are:

- service-friendliness due to good accessibility and
- easy upgradability

Terminal

The T-TL terminal is used for the operation and monitoring of the complete camera system. Its basis is a programmable compact computer which is connected to the T-CU with a cable of optional length and can therefore be installed anywhere in the aircraft or on the navigation instruments.

The terminal also permits data interchange with an external computer used in the office for mission planning and the evaluation of the mission data.

Suspension Mount

The T-AS suspension mount connects the camera body and the floor of the aircraft. Its main purpose is to ensure vibration-free vertical photography, while also making allowance for drift. The essential new feature which decisively improves performance is the gyro-supported stabilization of the camera body in 3 axes.

Film Magazine

The T-MC film magazine contains the supply spool for the unexposed film, the take-up spool for the exposed film, the pressure plate for film flattening and the device for forward motion compensation (FMC). The FMC control system is installed in the T-CU control unit.

Compared with a cassette design where the supply and take-up spools are installed in separate housings, the magazine approach offers the following important benefits:

- fast and easy film change during the flight in less than a minute by merely exchanging the magazine
- a film can easily be exposed in sections without any need for cutting.

Navigation Telescope

The T-NT navigation telescope is used for strip-by-strip navigation, manual overlap control by continuous v/h measurement (v = velocity above ground, h = flying height above ground) and for drift correction. In addition, the navigation telescope features controls and indicators for photoflight operation and monitoring, enabling a single operator to simultaneously perform the procedures of navigation, overlap control and camera control (two-man photoflight).

Automatic Navigation Meter

To relieve the operator's workload in a two-man photoflight, especially if large image scales and long missions are involved, the overlap control should be transferred to the T-NA automatic navigation system which measures the v/h value continuously in an opto-electronic process. The sensor is integrated into the camera body.

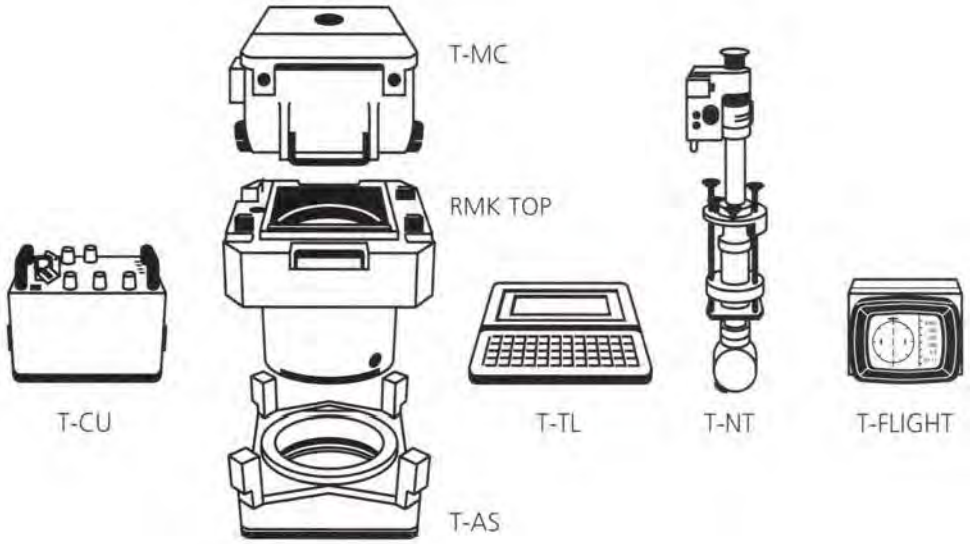
Photoflight Management System

The T-FLIGHT photoflight management system is used for mission planning in an interactive, graphic working environment, for GPS-supported photoflight navigation and for the documentation of the completed photoflight.

Basic and Complete Configuration

The basic RMK TOP configuration comprises the RMK TOP camera body, the T-CU control unit and the T-TL terminal.

A complete camera system comprises the basic configuration, a suspension mount, a film magazine and a navigation instrument. The focal length is changed by merely exchanging the camera body.
Recommended configuration for a two-man photoflight:



Control and Operation - Computer and Software Technology for

Principle

The control and operation principle of the RMK TOP is based on state-of-the-art electronics and computer technology. Like other systems from Carl Zeiss, the RMK TOP features three interacting functional areas, each playing a clearly defined role:

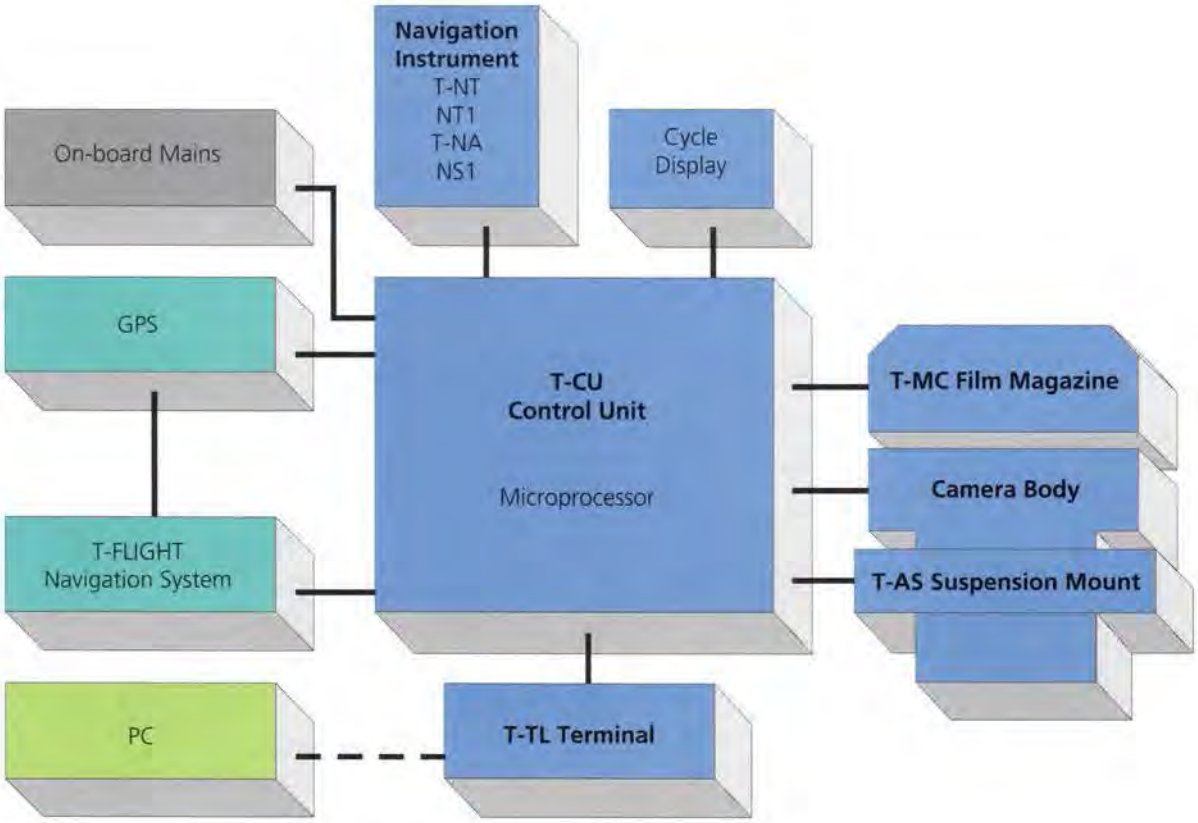
- analog and digital electronics for the performance of hardware functions, e.g. drive control of the shutter
- microprocessor and firmware for measured data processing and internal control, e.g. exposure control by variation of the aperture and exposure time
- computer and software for photoflight preparation and camera operation, e.g. input of mission parameters

This concept offers three essential advantages:

- implementation of the instrument-related basic functions by the hardware and firmware
- full utilization of EDP capabilities and high flexibility for user-oriented tasks
- easy upgrading of the camera system by firmware and software adaptation.

Hardware

The T-CU control unit is the central module of the control system containing the control and power electronics, the microprocessor with the firmware and the interfaces with the system components and external systems. Cables connect it with all camera components, the external GPS and navigation systems and the on-board mains. The control unit imports and processes measured data and status data, and controls the operational sequences in conjunction with the terminal. The installation of the electronics in a separate enclosure offers flexibility, a service-friendly design and sufficient space for future upgrading.



Aerial Photography

The T-TL terminal is a rugged, compact computer designed for extreme operating conditions. It features

- a display field with 8 lines of 40 characters each and with graphic capabilities
- an alphanumeric input keyboard and function keys in a special version for RMK TOP
- a 1 MB memory
- two RS232 interfaces and
- facilities for the long-term protection of the software and data.

Firmware

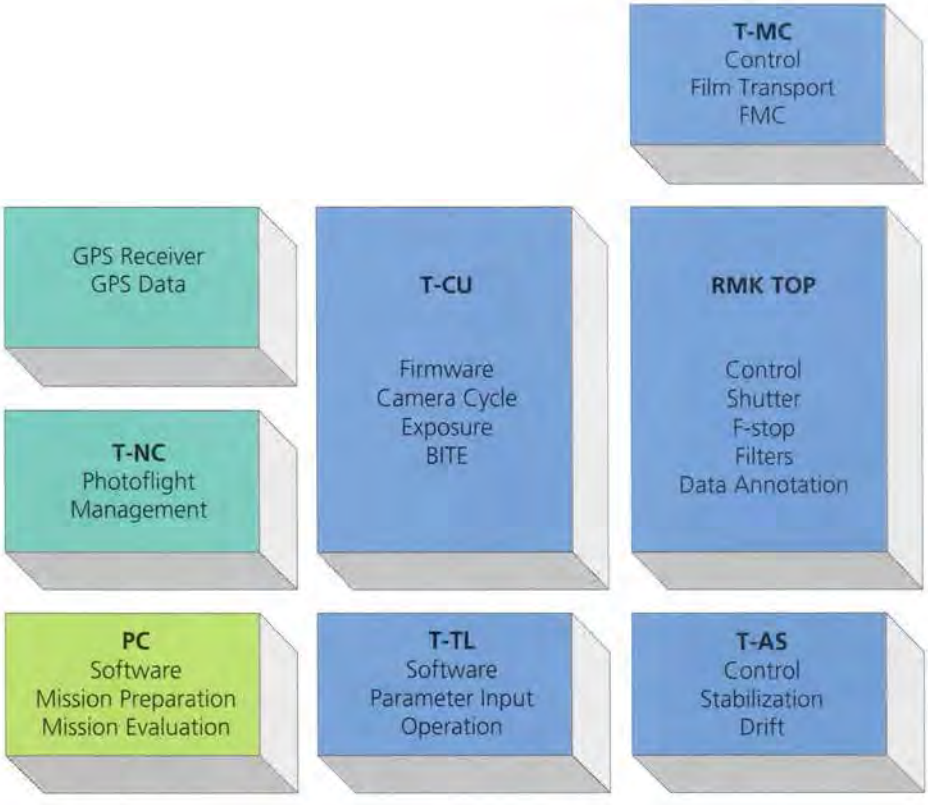
The firmware implemented in the microprocessor controls the system and monitors its functions. The following processes and components, in particular, are controlled using measured data and preset parameters:

camera cycle
shutter
exposure
FMC
data annotation

The firmware also includes BITE functions performing the power-on self-test of the camera system and continuous function monitoring.

Software

The software package implemented in the terminal controls the operation and monitoring of the camera system and permits the incorporation of the RMK TOP into EDP systems for mission planning and mission evaluation.

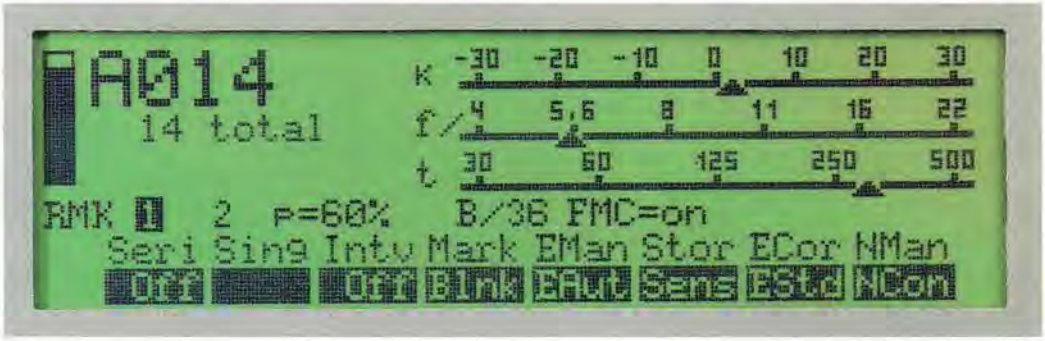


User Interface

The principal features of the user interface are:

- menu prompting and dialog control for the input of control parameters and of data to be exposed on the photo
- alphanumeric and graphic display of the operating status
- command and parameter input with dedicated function keys.

Part of the graphic display is in real time and offers the operator the familiar type of data presentation. It provides information on the current operating status at a glance.



Main Menu

The main menu offers the following functions:

1 System Configuration
Input and editing of the tables for film, filter and camera data

2 Operating Modes
Input of the parameters for operating modes, e.g. for automatic exposure control

3 Data Annotation
Definition, management and editing of the data exposed in the auxiliary data field

4 Mission Parameters
Mission name, definition, editing and management of the mission parameters such as camera, film and filters

5 Ground Test
Selection and checking of all taking and operation parameters before the start of the mission

6 In-flight Check
In-flight checking of the operation parameters directly before photography is started

7 PhotoFlight
Control of the camera cycle, display and change of the current operation parameters (drift, exposure time, aperture etc.)

8 PC Communication
Transfer of the data stored in programs 5, 6 and 7 to the PC and transfer of data tables between the PC and terminal

The programs 1 to 4 are used for preparing the photoflight in the office. Before the start of the mission, only the relevant mission file needs to be called up.

The programs 5 and 6 are used for checking the function of the camera before photography is started.

Program 7 PhotoFlight is the actual operating program for photography within which various camera modes can be selected, e.g.

serial exposure,
single exposure,
blank-frame advance
input of the flight strip
manual and automatic exposure control
filter selection

During camera operation, the mission data is automatically displayed and stored. Program 8 PC Communication permits the data to be transmitted to an external PC for output or further processing.

Image Quality of the RMK TOP

The quality of the aerial photo - a decisive performance parameter in the photogrammetric process - is mainly dependent on

- the optical quality of the lens,
- image motion or residual image motion and
- the resolution of the film emulsion

To obtain maximum quality in the final product, all three factors must be individually optimized and then matched to each other.

The goal therefore must be

- to manufacture top-quality camera lenses
- to reduce image motion to a minimum
- and thus to create the conditions necessary for the use of high-resolution emulsions.

Carl Zeiss has achieved this goal in the RMK TOP by the use of state-of-the-art technologies in optics, mechanics and electronics.

High-Performance Lenses with Internal Filters

Using the high quality standard set by the RMK A lenses as a basis, the wide-angle and normal-angle lenses have been recomputed for RMK TOP. The new lens types are:

PLEOGON A3 4/153
with a focal length of 153 mm and maximum aperture of f/4, and

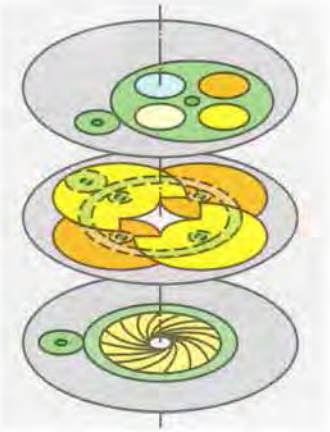
TOPAR A3 5.6/305
with a focal length of 305 mm and maximum aperture of f/5.6

These two lenses permit the production of photographic material for all major tasks in practical photogrammetry.

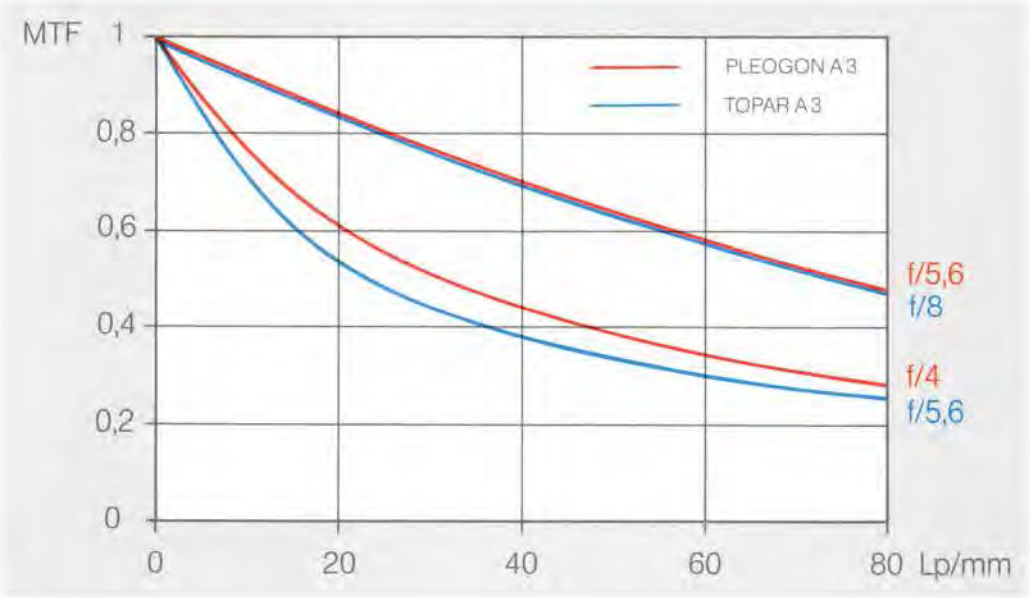
The outstanding features of the new lenses are:

- significantly enhanced image quality right to the corners, especially for high spatial frequencies and high-resolution film types,
- integration of internal filters into the optical system and
- high geometrical accuracy and markedly improved colour correction for the entire spectral range - from the visible to the near infrared.

The lenses contain controllable iris diaphragms which stop down the maximum aperture continuously to f/22.



Internal filters, shutter and diaphragm of the RMK TOP



AWAM values (Area Weighted Average Modulation values) as a function of spatial frequency

The four internal filters

KL (clear glass)
A2 (haze)
B (yellow) and
C (orange)

are selected on the terminal and inserted within seconds using a filter turret. Customized filter configurations are available on request.

In addition to the internal filters, external filters (graded-density filters or sandwich filters) can be used. The external filters are coded and are automatically taken into account in the exposure control.

The stability of interior orientation is ensured to a high degree by the permanent installation of the lens in the camera body.

Comprehensive image motion compensation makes the optical quality of the lens a factor of paramount importance.

Aerial photo taken with FMC, without stabilization

Comprehensive Image Motion Compensation - FMC and Stabilized Suspension Mount

Movements of the aircraft while the shutter is open lead to image motion which considerably impairs the quality of the aerial photo, especially if long exposure times are involved. This can only be avoided by compensating both the forward movement of the aircraft and its rotary movements - pitch, roll and drift - about the transverse, longitudinal and vertical axes.

As early as in 1984, Carl Zeiss started to eliminate the influence of forward motion in the RMK A by means of the CC24 compensation magazine. This first step permitted the use of longer exposure times and therefore of high-resolution, low-speed film in good flying conditions.

The second step was then taken with the gyro-stabilized T-AS suspension mount which compensates the rotary aircraft movements about its vertical, longitudinal and transverse axes in difficult flying conditions. Combined with improved vibration damping for short-period vibrations, the advantages of image motion compensation can now be used in their entirety:

- utilization of the high resolution and excellent modulation transfer properties of the RMK TOP lenses
- use of low-speed, high-resolution film emulsions
- photoflights with high v/h values, i.e. high velocity and low flying heights
- standard flying of vertical photos with minimal residual deviations from perpendicularity.

Aerial photo taken with FMC and stabilization

T-MC Film Magazine with FMC

The T-MC film magazine features a FMC range of 0-64 mm/s. Correction is achieved by shifting the pressure plate in the flight direction in accordance with the v/h value and focal length.

The FMC amount is indicated by the FMC mark which is exposed on the photo. The fiducials are exposed at the mid-point of the shutter open time, thus ensuring that they are exactly point-shaped even with high FMC values.

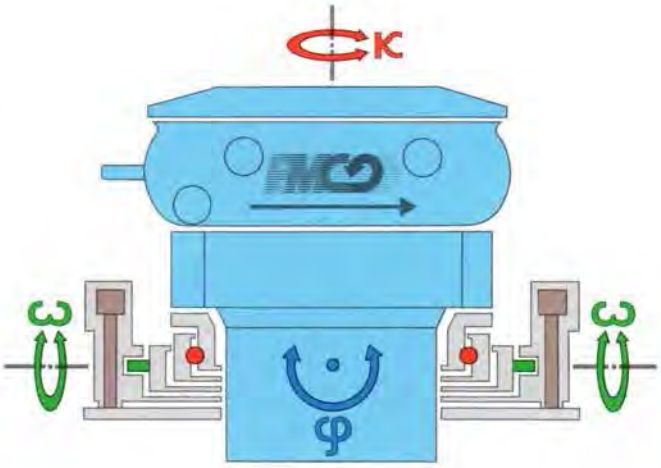
Further features of the T-MC magazine are:

- monitoring of the vacuum by a differential pressure sensor,
- film supply indicator on the terminal (digital) and magazine (analog)
- exposure of the pressure plate number on the film.

T-AS Stabilized Suspension Mount

The suspension mount connects the camera body and the floor of the aircraft. Its principal task is to ensure vibration-free vertical photography, while also making allowance for drift. The new T-AS suspension mount comprises:

- a base plate with vibration damper connecting the mount with the aircraft floor,
- a gyro-stabilized platform also featuring horizontal sensors for φ and ω
- a rotatable mounting ring between the camera body and the platform for motorized drift correction and gyro-supported stabilization about the vertical axis.



The stabilization of the platform is performed by digital servo- systems using the nominal values supplied by three precision gyros and the levelling sensors. A stabilization level of 1:10 to 1:30 is achieved within a range of ±5° in φ and ω, which ensures that the camera body is permanently kept in a vertical position - like an island in rough seas.

The angular position at the moment of exposure is recorded in the flight report of the T-TL.

High-Resolution Films

The comprehensive image motion compensation provides a wider scope for exposure, thus permitting the use of sophisticated film emulsions in the photoflight. The following film types can be used:

- high-resolution b/w emulsions such as Kodak Panatomic-X and Agfa PAN 50 and
- low-speed colour and false colour films.

The Economic Factor

The new RMK TOP lenses and image motion compensation improve not only image quality, but also the cost-effectiveness of the photoflight:

- more options for the flying height and image scale,
- photoflights in difficult light and weather conditions and therefore
- more flying hours and less idle time on the ground
- improved utilization of camera and aircraft and
- higher return on investments

The Aerial Photo with Programmable Data Annotation

An aerial photo differs from a normal photo in that the lens forms the image in strict accordance with the law of central projection, and the interior orientation of the camera is defined by fiducials and calibration data.

The geometric accuracy of the RMK TOP lenses conforms to the high standard set by the RMK A lenses. As a result, distortion lies in the range of a few micrometers, and the fiducial centre and the optical point of symmetry coincide within 0.02 mm.

Fiducials
The aerial photo produced with the RMK TOP contains 8 numbered fiducials midway along the edges and in the corners. They are exposed at the midpoint of the shutter open time, ensuring that they are exactly point-shaped, even with maximum FMC movement.

Auxiliary Data
The auxiliary data is exposed as alphanumeric information. The contents and format of the data can be freely selected by the user. It is exposed in a field of 210 mm x 10 mm in easy-to-read characters with a size of 4 mm. The auxiliary data comprises:
- frame number, 4 digits, presettable on the terminal,
- two information lines for internal and external data, each with 48 alphanumeric characters,
- number of the pressure plate,
- FMC mark
- camera type and serial number

The alphanumeric information lines may include, e.g.:

Mission number, run number, image scale, overlap, focal length, date, time, filter, f-stop, exposure time, v/h value, release number.

If, for example, the release number and the name of the flying company are exposed, the subsequent marking of the photos becomes superfluous.

RMK TOP Flight Report

Mission: CZ test flight 7
Date: 20-07-94 **Time:** 12:47:53

Camera system

RMK TOP 15	S/N 141 473
Lens:	Pleogon A3 S/N 140816; cfl = 0 153.667; cal. 03-11-89
Configuration:	T-NT, T-MC, AS2

Mission parameters

Initial frame number: A120			Frame counter:	1
Filter: B, 36%	Filter factor:	4,2		
Film: PAN 200	EAFS:	200		
Correction factors:	Exposure	1.0	Auxiliary data	1.0
	Fiducials	1.0	Logo, magazine ID	1.0
Exposure profile:		max. f-stop	max. exposure time	
	Priority	5,6	250	
	Standard	4.7	125	
	Tolerable	4.0	60	
Exposure control:	auto			
Overlap:	90%			
FMC:	on			

Photo sequence

	Time	Frame number	f/	1/t	Drift
Serial: on	12:48:16.7	A120	5.6	300	0.0
Serial: off	12:49:08.5	A160	5.6	300	0.0
Blank, mark					
Exposure control: man.					
Single	12:52:34.1	A161	5.2	400	0.0
Blank, mark					
Camera: off				Frame counter: 42	

Flight Report
The alphanumeric information of the auxiliary data, supplemented by further data if required, is stored in the terminal. After completion of the mission, the data is transferred to the PC and output as a flight report, containing:

- the general mission data and mission parameters,
- the data of the camera system,
- data of the individual photos in the order they were taken.

This means that all exposure-related information is documented in the flight report.

Calibration
The calibration of the RMK TOP follows the recommendation of the International Society of Photogrammetry and Remote Sensing and covers:

- coordinates and spacing of the fiducials
- distortion in 4 radii and mean value
- coordinates of the fiducial centre and the point of autocollimation,
- resolving power.

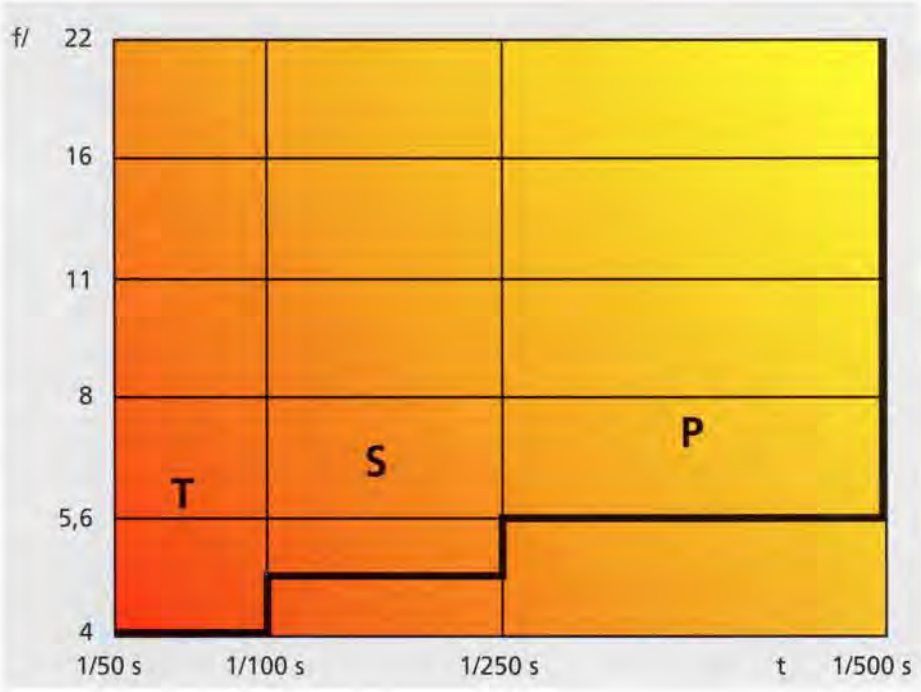
Intelligent Exposure Control

The automatic exposure control of the RMK TOP is based on the principle of "image quality priority". This means that the optimum combination of aperture and exposure time is automatically selected for the prevailing lighting conditions, taking into account the specified film speed and filter factor.

One of the factors determining image quality is the aperture used. The best quality is obtained with the "optimum aperture" which is generally one stop below the maximum aperture of the lens. Stopping down beyond the optimum aperture usually does not provide any further increase in quality.

Even with optimum image motion compensation, residual motion of the image must always be expected. Its influence decreases with shorter exposure times. As a general rule, it may therefore be said that the optimum aperture and the shortest possible exposure time should be used.

To obtain as close an approximation to the ideal setting as possible in all lighting conditions, a distinction is made in the RMK TOP between three exposure ranges in line with the principle of "image quality priority":



Exposure range P
(Priority)
with the optimum or a smaller aperture and a short exposure time, in favourable lighting conditions and for critical demands on image quality.

Exposure range S
(Standard)
with an extended range for aperture and exposure time, in medium lighting conditions and for normal demands on image quality.

Exposure range T
(Tolerable)
with the largest range of apertures and exposure times, permitting photos of acceptable image quality to be taken even in unfavourable lighting conditions.

The limits of the individual exposure ranges can be selected as parameters by the operator (program "Operating Modes"). The exposure control system then automatically selects the range ensuring the best image quality in the given lighting conditions.

A high degree of flexibility is offered to the camera operator before and during the photoflight:

- choice between manual and automatic exposure control,
- storage and retention of the current exposure data above special types of surface (e.g. water) and
- manual input of an exposure correction in steps of 1/3 of a stop.

Exposure metering itself is performed internally using a silicon photovoltaic element with a spectral range from 400 nm to 700 nm. Integral exposure metering has proved its excellence many times over in the RMK A.

Constant Access Time - Precise Overlap Control

An aerial survey camera is characterized by the possibility of automatically triggering the exposure sequences to obtain a desired overlap. Single photos, however, can also be triggered either manually or by the on-board navigation system. Needless to say, an immediate exposure is always essential; it should be taken at the exact time specified. This is only possible if the access time, i.e. the interval between the triggering of exposure and the mid-point of the shutter open time, is short and constant.

In conventional rotating-disk shutters, the access time varies randomly and uncontrollably between approx. 0.5 and 1.5 seconds with an exposure time of 1/100 s. This variable access time may lead to overlap errors of up to 20 %. This is not critical if the photos are taken without FMC as the exposure times used here are short enough in any case to avoid unacceptable image motion. In photography with FMC, however, the advantages of image motion compensation are substantially reduced if long exposure times must be avoided to retain the selected overlap.

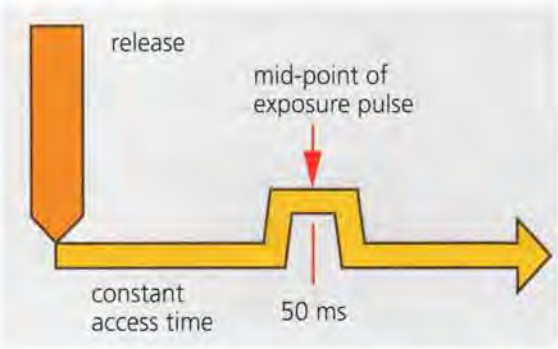
In the RMK TOP, a fundamental solution to this problem has been found by the development of a new, pulsed rotating-disk shutter with a constant access time of 50 ms. In the pulsed shutter, the disks are controlled after triggering of the exposure in such a way that the mid-point of the shutter open time is reached after 50 ms. For external triggering, e.g. from a navigation system, this constant access time can be taken into account, permitting the moment of exposure to be preset with an accuracy of a few milliseconds.

At the mid-point of the shutter open time, the shutter emits a pulse with a maximum error of 2 % of the exposure time. This pulse, which also triggers the exposure of the fiducials, can be used for recording the exact instant of exposure, e.g. in a GPS receiver.

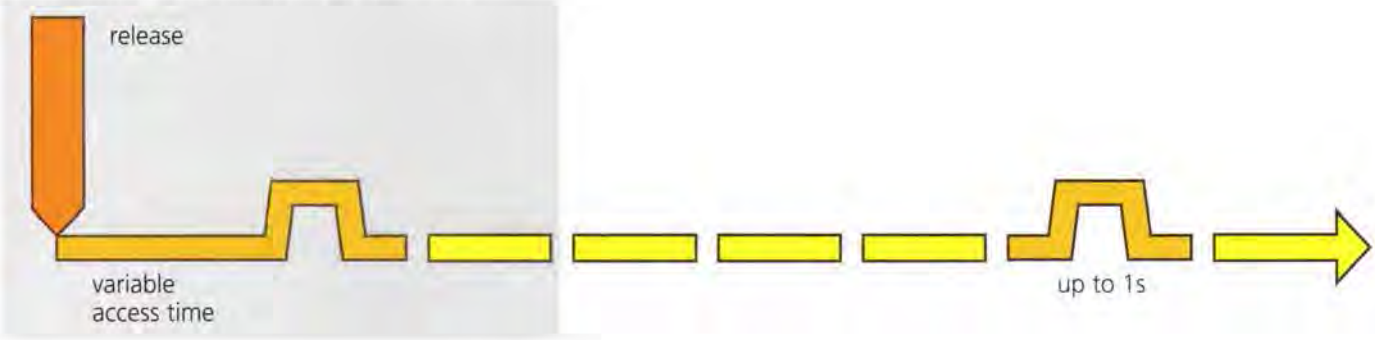
The benefits of the RMK TOP shutter are:

- precise overlap control based on v/h measurement
- direct exposure of single photos (pin-point photography)
- exact triggering of exposure sequences by the on-board navigation and GPS systems,
- good synchronization possibilities for 2 cameras, even when photographing moving objects

RMK TOP



Convential rotating disk shutter



Reliability - Flexibility - Cost-effectivness

The preparations and costs involved in photoflights and the limitations frequently imposed on flying operations by the weather conditions inevitably lead to exacting demands being placed on the reliability of the camera system. The RMK TOP ideally meets these requirements:

- integrated test facilities and procedures (BITE = Built-In Test Equipment) for monitoring the camera functions before and during the flight,
- use of wear-free components requiring little maintenance,
- listing of all important mission parameters for quality monitoring,
- service-friendly design of the hardware for easy maintenance and on-site repair.

Function monitoring and error display by BITE has been implemented in the RMK TOP in two areas:

- power-on selftest of the camera to check the functions and operating conditions such as
  - data transfer between T-TL and T-CU
  - interval control
  - vacuum test
  - setting of aperture and filters
  - exposure control

- continuous monitoring of the exposure cycle during the flight, covering
  - film advance and film flattening
  - FMC control
  - shutter control
  - exposure of fiducials and data.

The BITE test result is transferred to the T-TL terminal and displayed in the event of an error.

The display informs the operator directly on

- the correct operating status of the camera,
- tolerable malfunctions and
- serious malfunctions which require on-board servicing or termination of the mission.

The BITE facility also forms the basis of fast and effective maintenance on the ground.

Aerial survey cameras are used in very rough conditions:

- extremely high and low temperatures
- high and low humidity in rapid alternation
- shock and vibration loads

The RMK TOP has been designed for operation in the temperature range between -40° C and +50°C. The cameras are subjected to stringent acceptance tests in our plant in the specified ambient conditions.

Quality, reliability and flexibility are the guarantee of the cost-effectiveness of the aerial survey cameras from Carl Zeiss.

The Overall Solution for Photoflight Navigation

Photoflight navigation is centered on three major tasks:

- flying the aircraft on the intended strip axes (navigation)
- determination of drift, i.e. the angle between the aircraft axis and the flying direction above the ground
- triggering the exposures in accordance with the specified overlap or the preselected exposure stations.

The instruments and methods to be used for this purpose depend to a large extent on the number of persons performing the photoflight:

- in the one-man photoflight (pilot) the camera operation and navigation must be largely automatic; the pilot can only monitor the processes
- in the two-man photoflight (pilot, operator) the operator performs the three above-mentioned tasks either alone or with the aid of automatic instruments
- in the three-man photoflight (pilot, navigator, camera operator) navigation and overlap control are performed by two persons.

Carl Zeiss offers a wide range of equipment and options for photoflight navigation:

Task	T-NT navigation telescope	NT1 navigation telescope	NS1 navigation sensor	T-NA automatic navigation meter	T-FLIGHT photoflight management system
Navigation	X	X			X
Overlap control	X		X	X	(X)
Pin-point photography	(X)				X
FMC control	X		X	X	
Drift determination	X	X	X		X*
Camera operation/ control	X		(X)		X

* if a compass is available, (X) possible with limitations

For visual navigation, the combination of T-NT or NT1 with T-NA is recommended. The operator's workload is lightened by the automatic measurement of the v/h value.

In GPS-supported navigation with T-FLIGHT or other systems, it is advisable to use the T-NA to perform continuous measurements of the v/h value for FMC control.

The design of the RMK TOP control system and interfaces ensures compatibility of the camera not only with T-FLIGHT but also with other navigation systems. The optional external interface of the control unit permits data to be imported for exposure in the auxiliary data field of the aerial photo. The data must be provided in the internal format of the camera. Optional data converters also enable the direct data transfer from an ARINC bus or GPS receiver.

Navigation Instruments

T-NT Navigation Telescope

The T-NT navigation telescope is used for navigation, for the measurement and control of overlap and drift, and for the operation and monitoring of specific camera functions. In the two-man photoflight, it is essential to have these control and monitoring elements within direct view and reach on the eyepiece of the telescope. The telescope offers a 85° forward coverage and 5° backward coverage from nadir.

For v/h measurement, moving luminous marks are visually synchronized with the image of the ground.

Control and monitoring elements are provided e.g. for starting and stopping serial photography and for triggering single exposures. For mere visual navigation and for drift determination, the NT 1 navigation telescope can be used; its telescope unit has an identical design to that of the T-NT.

NS 1 Navigation Sensor

The NS 1 navigation sensor is an instrument for visual overlap control and drift determination and is primarily used in three-man photoflights. The terrain is imaged on a 14 x 14 cm viewing screen where it can be observed with both eyes and synchronized with a moving chain of splines. The NS 1 features various controls and displays for camera operation.

T-NA Automatic Navigation Meter

Long photoflights in economical two-man missions place an enormous strain on the operator, especially at low flying altitudes. Carl Zeiss therefore started at an early stage to look for possibilities of reducing the operator's workload, and successfully developed the NA as an instrument for automatic v/h measurement.

The T-NA measures the displacement of the ground image using an opto-electronic sensor and transforms it into v/h values in a correlation process. These values are transferred to the T-CU control unit for continuous overlap and FMC control. Automatic v/h measurement enables the operator to concentrate on navigation and monitoring.

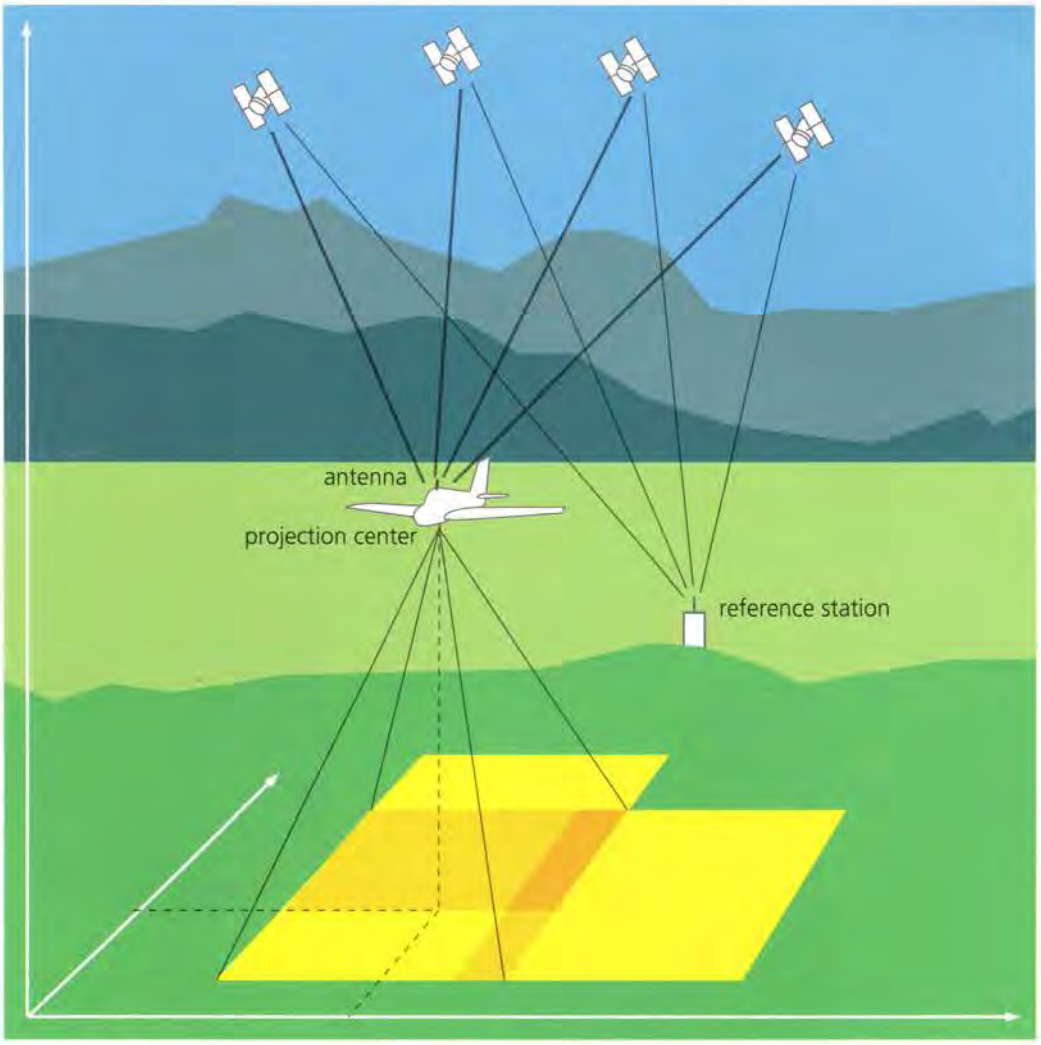
The sensor of the T-NA, an upgraded version of the NA, has been integrated into the RMK TOP camera body. The control electronics are installed in the T-CU. The T-NA therefore requires no additional opening in the aircraft floor.

The automatic navigation unit has proved to be a reliable and economical instrument for photoflight navigation - even in difficult flying conditions.

GPS - A New Dimension for Photoflights

GPS (Global Positioning System) is a method of position determination by measuring distances from satellites and opens up new possibilities for surveying and navigation. The combination of an aerial survey camera with a GPS receiver installed in the aircraft permits

- the accurate determination of the projection center coordinates and
- navigation and triggering of the camera on a GPS basis.



Principle of GPS measurement

Camera functions for GPS

The RMK TOP is specially equipped for combination with GPS. Its shutter, control system and interface ensure optimum interaction of the camera and navigation system. The following functions are available:

- recording of the actual instant of exposure (mid-point of shutter open time) in the GPS receiver with a maximum error of 2 % of the exposure time,
- triggering of exposures at the positions defined by the navigation system and
- exposure of data such as the approximate camera station, true north and the instant of exposure.

The RMK TOP is equipped with a special, pulsed rotating-disk shutter featuring a constant access time of 50 ms, regardless of the exposure time.

Allowance can therefore be made for the access time in the computation.

As a result, the shutter permits

- pin-point photography with an accuracy of a few milliseconds and
- serial exposures with a precise, constant overlap in accordance with the v/h measurement, even if FMC and long exposure times are used.

GPS-based Aerotriangulation

The exact determination of the exposure stations by GPS increases the efficiency of aerotriangulation, due to

- stabilization of the photo block by the correlation of projection centers determined with maximum accuracy and
- reduction of the number of control points in the block.

The precise determination of the projection centers is achieved by kinematic differential GPS measurements and their evaluation using suitable software.

The hardware comprises geodetic precision receivers such as ASHTECH M XII B installed in the aircraft and at the reference station. The aircraft position is continuously measured and stored in the GPS receiver. At the mid-point of the shutter open time, the camera transmits a pulse to the GPS receiver, permitting the instant of exposure to be recorded with an accuracy of better than 2 % of the exposure time.

The GPS raw data and the recorded time tags are used to compute the antenna position at the instant of exposure. The antenna coordinates are converted from the WGS 84 system into the geodetic system. Carl Zeiss offers the SKIP program (Static and Kinematic Positioning with GPS) for this purpose.

GPS versions of the PAT and BINGO block adjustment programs are available for processing the GPS-determined antenna positions. The eccentricities between the antenna position and the projection centers can be taken into account in the block adjustment. If the T-AS gyro-stabilized suspension mount is used, the position of the suspension mount at the instant of exposure is recorded, permitting the eccentricity to be determined for each exposure. The use of the projection centers markedly improves the efficiency of aerotriangulation.

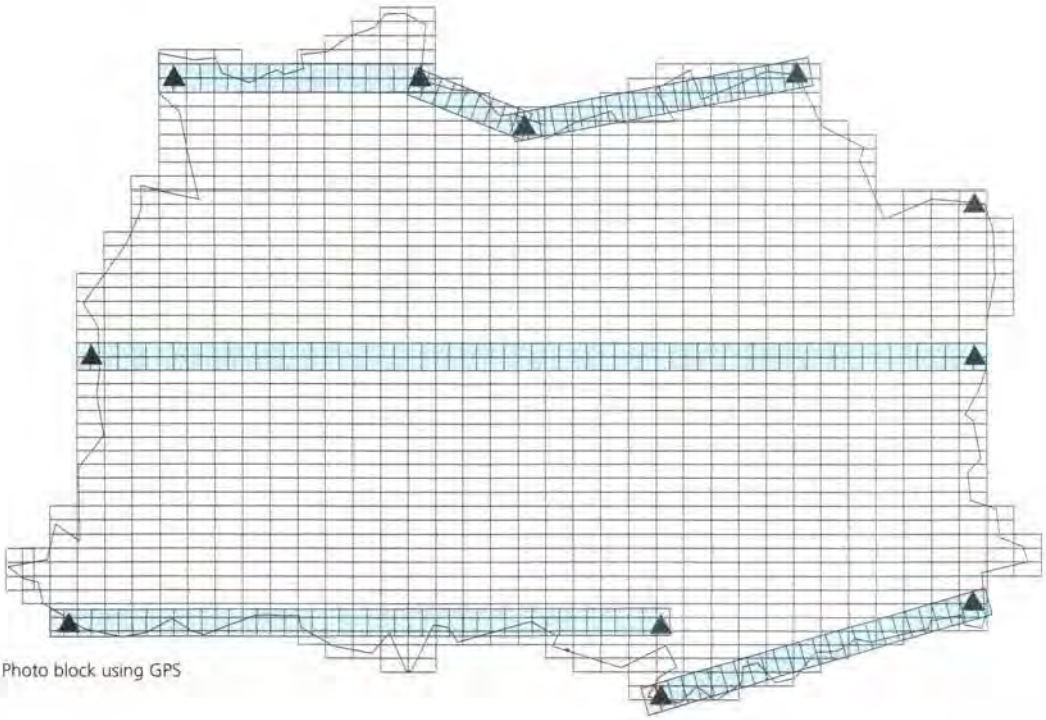


Photo block using GPS

T-FLIGHT
GPS-Supported Photoflight Managemen

The T-FLIGHT photoflight management system from Carl Zeiss has been designed for computer-supported mission planning, GPS-supported photoflight navigation and documentation of the completed mission.

T-FLIGHT comprises the following software and hardware components which, depending on their function, are used in the office, the aircraft or at a ground station for differential GPS measurement:

T-PLAN for project-oriented, graphic mission planning

T-NAV for photoflight performance with GPS-supported navigation, camera control and recording of the exposure stations

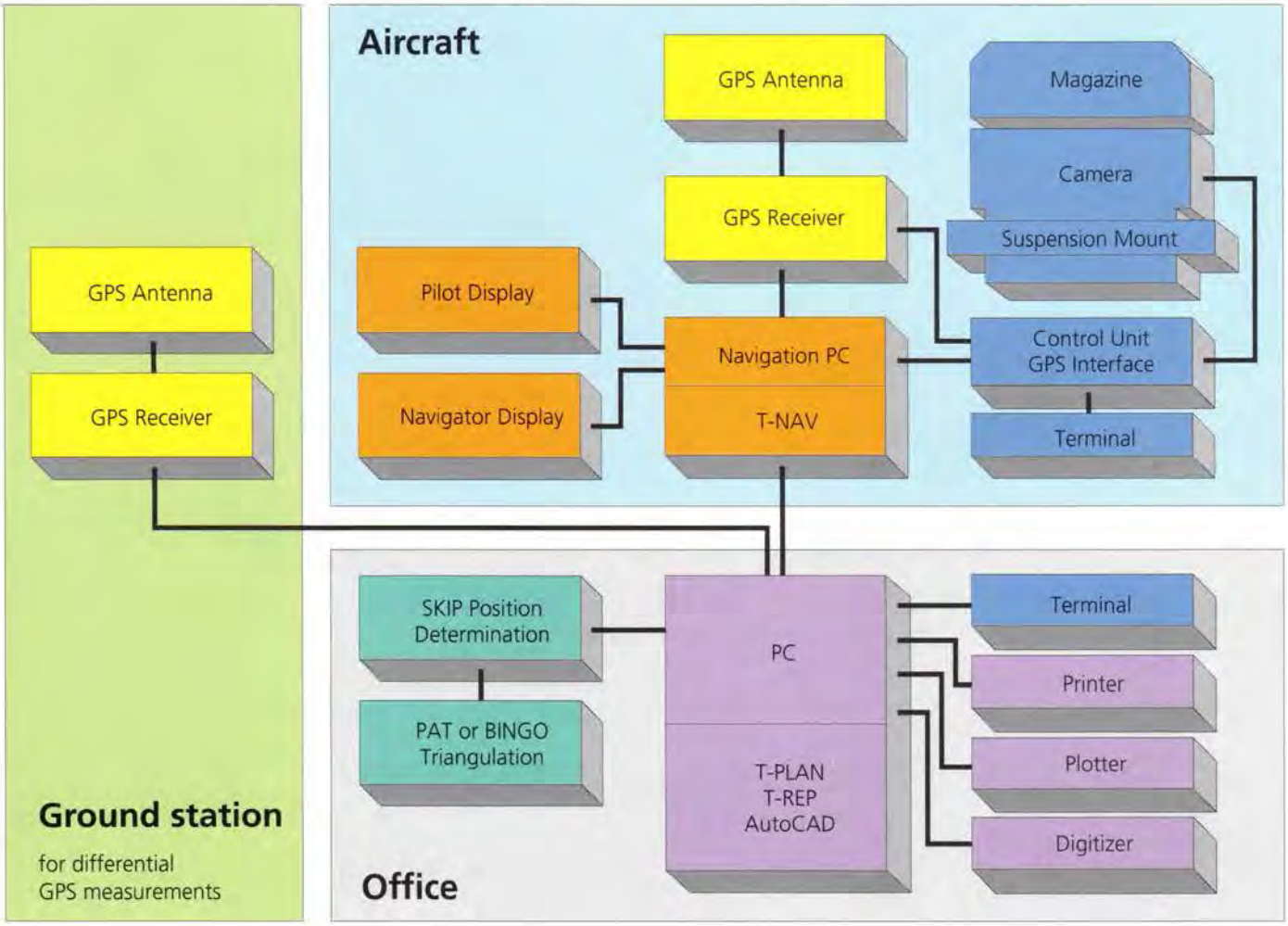
T-REP for photoflight documentation with recording of the mission data and graphic representation of the exposure stations.

T-NC navigation computer in the aircraft with a graphics monitor (touch screen) for the photoflight operator

Pilot display for navigation and aircraft control

Interface in the T-CU control unit interconnecting the RMK TOP, the navigation computer and GPS receiver.

T-FLIGHT can also be used with the RMK A.



System

Pilot display, navigation computer with touch-screen monitor

The software modules run on PCs under MS-DOS; T-PLAN and T-REP are based on AutoCAD and can be implemented on both the navigation computer and a suitable office PC.

The navigation computer is a compact PC with a touch-screen graphics monitor suitable for photoflight applications. The specially developed pilot display permits correct interpretation of the displayed information by the pilot, even in unfavourable light conditions.

T-FLIGHT significantly increases the efficiency of the photoflight:

- Optimum mission planning in an interactive, graphic working environment
- Automatic transfer of the planning data to the navigation system
- Pin-point photography precisely at the precomputed exposure stations in line with the layout of the model, map sheet or photo mosaic,
- Compliance with close tolerances due to precise navigation, resulting in a reduction of the flight distances and film material required
- Efficient navigation allowing increased flying speed and fast response to changes in the flight and weather conditions
- Reliable performance of two-man photoflights - with only the pilot and camera operator
- Fast and reliable compilation of quotations in accordance with the tender specifications
- Complete documentation and comprehensive quality control
- Combination of navigation and the precise determination of projection centers for GPS-supported aerotriangulation

T-FLIGHT was jointly developed by Carl Zeiss and MAPS geosystems.

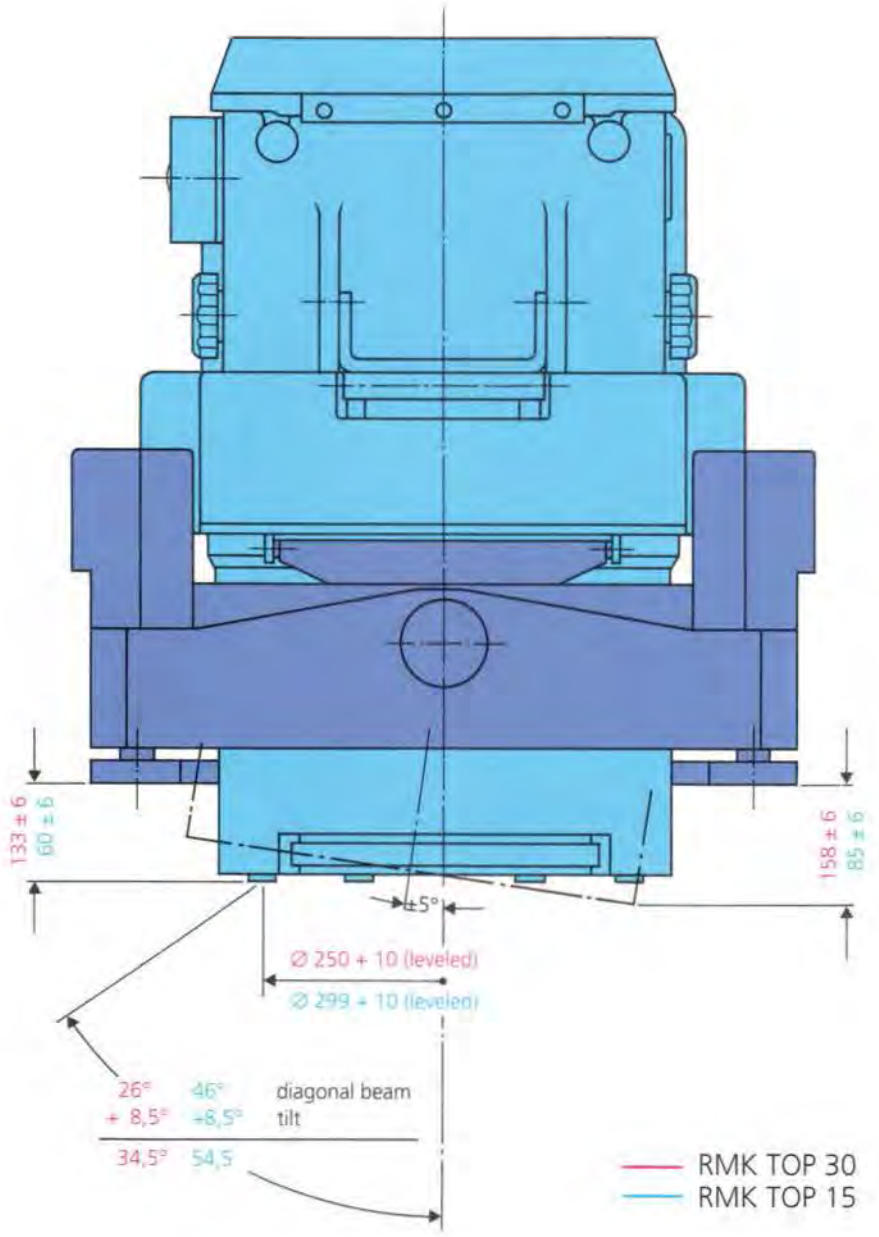
Installation in the Aircraft - Flexible and Practice-Oriented

Aerial survey cameras are installed in a wide range of aircraft differing substantially in size and configuration. Installation especially in small aircraft is facilitated by

- a small camera port,
- compact design and small dimensions of the camera
- low weight of the individual modules and
- physical separation of the camera and control unit, and their interconnection by cables of optional length.

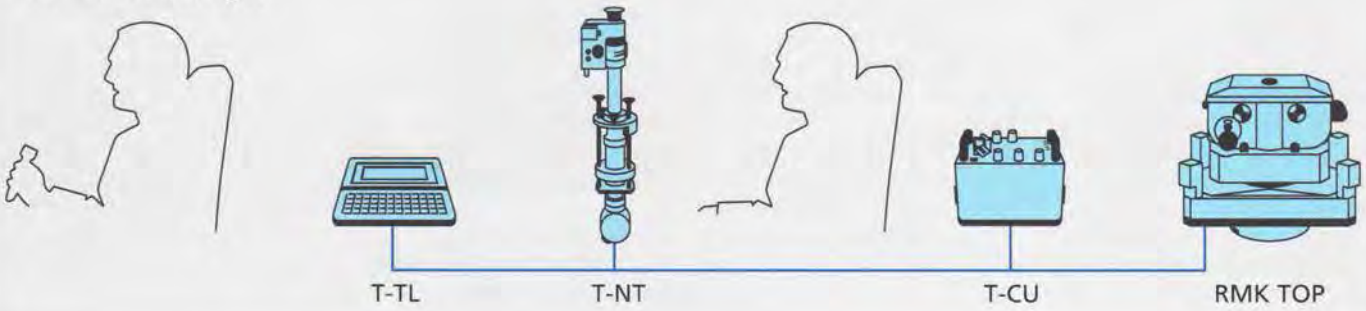
The RMK TOP meets all these requirements. Only a small camera port is required due to the reduction in size compared with the RMK A, the favourable positions of the entrance aperture of the lens and the pivot point of the T-AS suspension mount. The compact design of the RMK TOP modules ensures easy handling.

The concentration of all controls in the T-TL terminal permits the installation of the RMK TOP anywhere in the aircraft, even in places which are difficult to access or outside the pressurized cabin - an advantage which cannot be rated too highly for practical use. The installation of two cameras is no problem, as they are both operated from one single terminal.

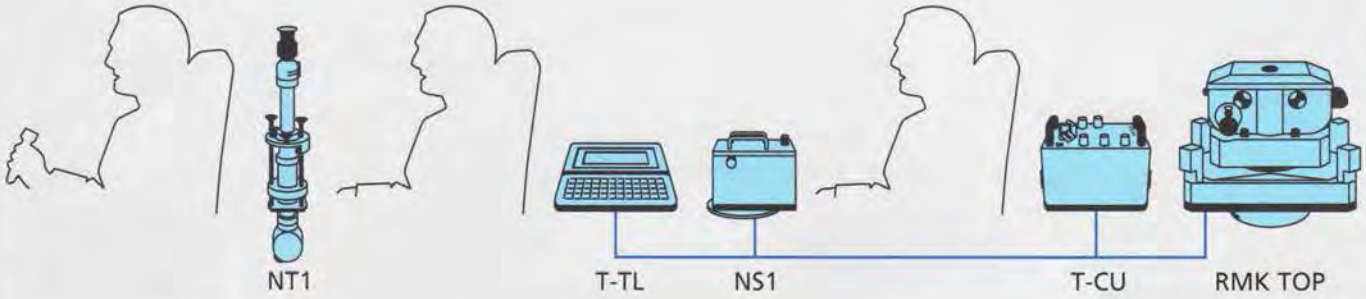


One-man Photoflight

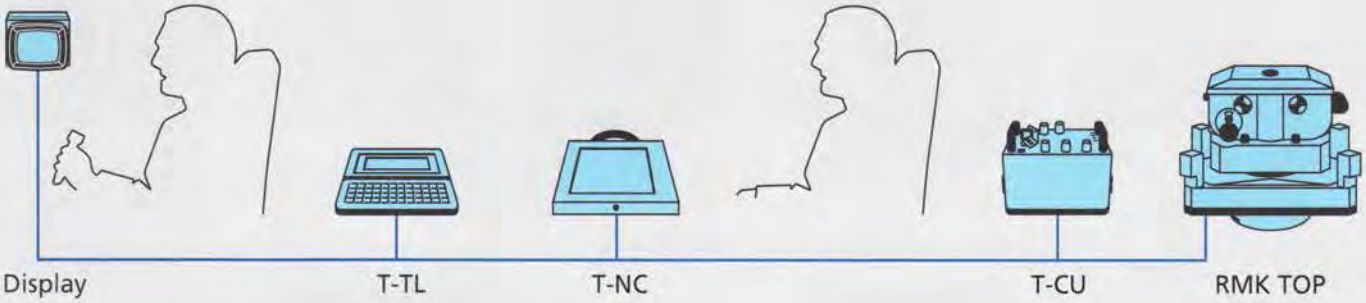
Two-man Photoflight



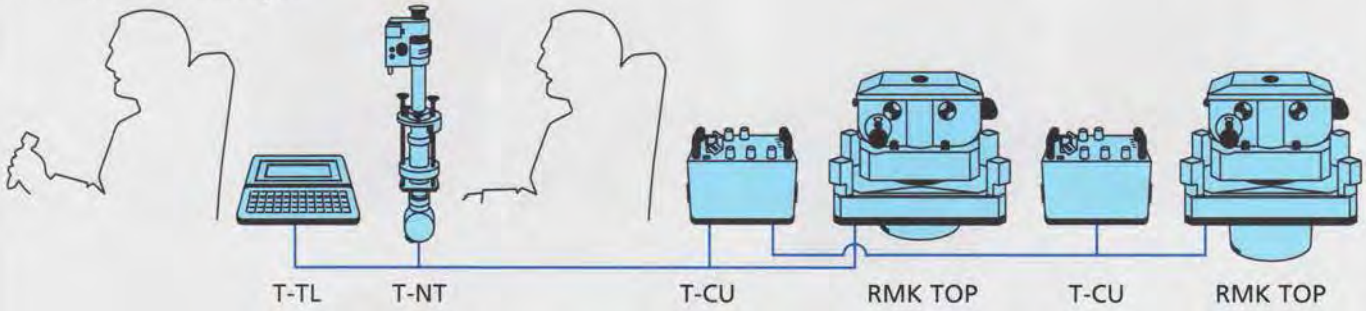
Three-man Photoflight



T-FLIGHT Photoflight



Two-camera Photoflight



Compatibility with RMK A - Continuity and Progress

The RMK TOP is a new camera system whose components have been optimally matched to each other. Its many benefits can only be utilized to the full if all components of the new system are employed.

For economic reasons, however, it may be advisable and desirable to combine existing components of the RMK A system with RMK TOP components. The two systems are therefore fully compatible on their major interfaces.

The following RMK A components can be combined with the main modules of the RMK TOP:

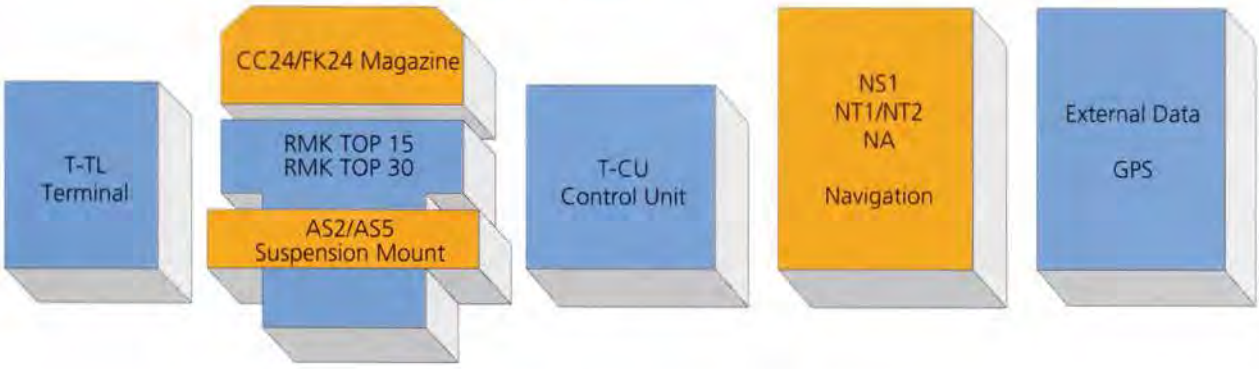
- AS 2 or AS 5 suspension mount with adapter,
- film magazines CC 24 (with FMC) and FK 24 (without FMC),
- NT 1, NT 2, NS 1 and NA navigation instruments.

On the other hand, the following new RMK TOP modules can be used with the RMK A camera body and its ICC control unit:

- T-AS stabilized suspension mount,
- T-MC film magazine in conjunction with the FMC control unit CC-CON
- T-NT navigation telescope.

The compatibility between RMK TOP and RMK A means that earlier high investment is not endangered, while allowing the user to benefit from the essential aspects of technical advance.

The compatible RMK A components



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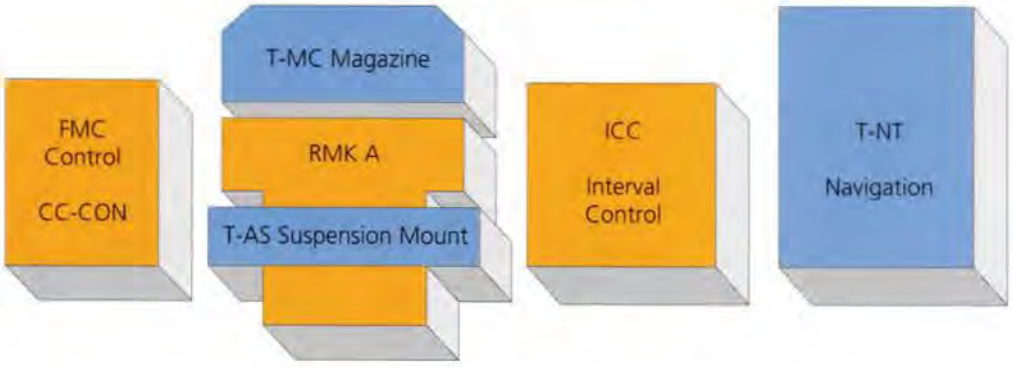

Technical Data

Camera body

RMK TOP 15
with Pleogon A3 wide-angle lens, focal length 153 mm (6"), angular field 93° (diagonal), aperture f/4 to f/22 continuously, distortion ≤ 3 µm.

RMK TOP 30
with TOPAR A3 normal-angle lens, focal length 305 mm (12"), angular field 56° (diagonal), aperture f/5.6 to f/22 continuously, distortion ≤ 3 µm.

Shutter:
pulsed rotating-disk shutter with 50 ms constant access time.

Mid-point of exposure pulse:
max. deviation ±2 % of the exposure time

Exposure time:
1/50 s to 1/500 s, continuously

Fiducials:
8 point-shaped fiducials in the corners and midway along the edges, numbered 1 to 8, spacing 113 mm, point diameter 100 µm,
crosslines with 50 µm line thickness, exposure at mid-point of shutter open time.

Auxiliary data:
field size approx. 210 mm x 10 mm, located at the top of successive photos
- exposure of internal and external data in two lines, each with 48 alphanumeric characters, programmable by the user, character size 4 mm
- pressure plate number
- mark for FMC function
- camera type and serial number
- four-digit frame number, presettable on the terminal, size of figures 4 mm (inside frame format)

Counter:
counter for hours of operation and number of exposures

Filters:
- 4 internal filters, selectable on the terminal:
KL clear glass
A2 cut-off wavelength 420 nm (haze)
B cut-off wavelength 490 nm (yellow)
D cut-off wavelength 535 nm (orange)
- customized configurations possible on request

- external filters for PLEOGON
  - KL 36 graded-density filter 36% center transmission
  - KL 60 graded-density filter 60% center transmission
  - sandwich filter with graded density
  - special colour filters with graded density

- external filters for TOPAR
  - sandwich filter
  - special colour filters

Control and operation

T-TL terminal
Compact computer with alphanumeric entry keyboard, function keys, 8-line display with 40 characters each (alphanumeric, graphic), 1 MB RAM, 2 RS 232 interfaces for connection to T-CU or PC

T-CU control unit
Central control, power supply and interface unit with microprocessor

Minimum exposure cycle time:
1.5 s
v/h range:
0 to 0.2 rad/s
overlap range:
0 to 99 % in steps of 1 %

Exposure system
Principle:
image quality priority with integral exposure metering and three exposure ranges
Sensor:
silicon photovoltaic element, spectral range 400 nm to 700 nm, max. response at 560 nm, angular coverage 60°, temperature-independent

FMC control
0 to 64 mm/s continuously, in accordance with v/h value and focal length.

BITE
Built-In Test Equipment for power-on self-testing of the camera system and for continuous function monitoring during operation. Display of results on the T-TL terminal.

Connection with personal computers
for bidirectional data exchange between the terminal and PC in the office via RS 232 interface for photoflight preparation and transfer of the mission data recorded in the terminal.

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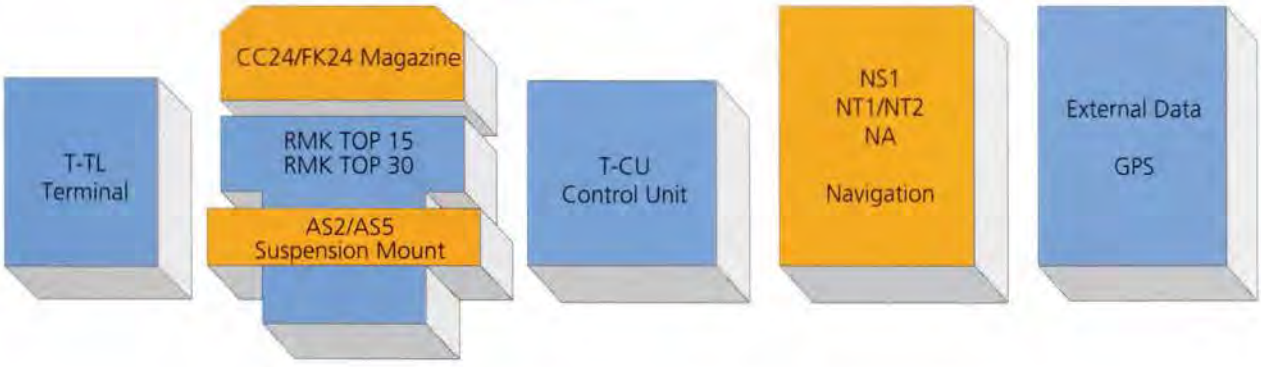
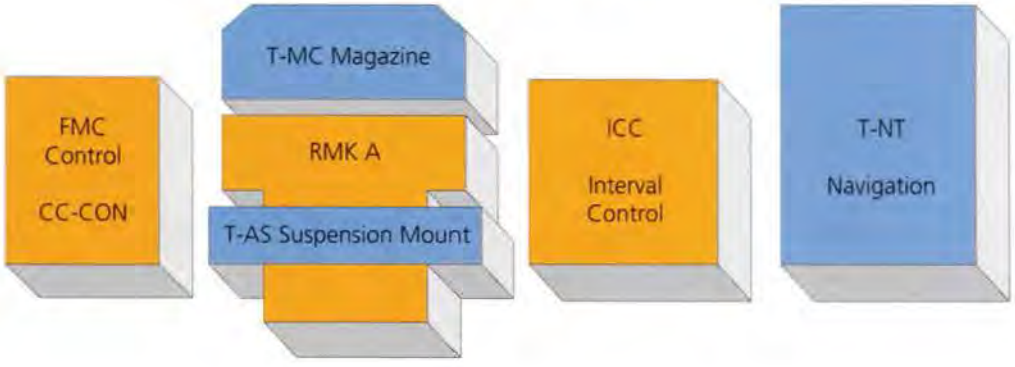


The compatible RMK TOP components



T-MC magazine

Film magazine with spools for exposed and unexposed film, pressure plate with vacuum system and FMC.

Film size:
width 240 mm
length 150 m (500 ft) for 0.10 mm film thickness

Supply indicator:
- digital on the terminal,
- analog on the magazine.
Differential pressure sensor for vacuum monitoring.

Pressure plate:
flatness ± 5 µm, plate number is exposed on the film.

Suspension mount

T-AS gyro-stabilized suspension mount

Stabilization range:
± 5° in φ, ± 5° in ω, ± 6.5° in κ
max. angular speed: 10°/s
max. angular acceleration: 20°/s²
stabilization level: 1:10 to 1:30
vertical alignment: ± 0.5° (standard deviation)
tracking range in drift: ± 30°

T-AL suspension mount with DCON

Drift: ± 30°
tracking speed: 1.5°/s
φ: 0 - 5° (ω = 0°)
1 - 4° (ω = 2.8°)
ω: ± 7° (φ = 2.8° fixed)

Navigation instruments

	T - NT	NT 1	NS1	T-NA
Navigation	x	x	-	-
Overlap control 0 to 0.2 rad/s	visual	-	visual	autom.
Drift determination	x	x	x	
In-flight operation and monitoring	x		x	
Angular coverage				
total	90°	90°	42°	16° lateral
forward	85°	85°	21°	1°
backward	5°	5°	21°	1°

Ambient conditions

Operating temperature:	
RMK TOP, T-CU, T-AS:	- 40° C (-40° F) to + 50° C (+ 122° F)
T-TL, navigation instruments:	- 20°C (- 4°F) to + 50°C (+ 122° F)
Storage temperature:	- 40° C (-40° F) to + 70° C (+ 158° F)
Max. relative humidity:	95 %

Electrical data

Rated voltage:	28 V DC
Operating voltage:	24 to 30.5 V DC, available at the on-board connector
Residual ripple:	2 Vpp (peak-to-peak)
Power cable T-CU/on-board mains:	6 m, line cross-section 2x (+ 1x) 6 mm²
Mean power consumption:	6 A max. (complete system)
Maximum power consumption:	25 A for 0.12 s in each cycle release
	32 A with T-AS

The camera system is powered centrally by the T-CU control unit. The specified power consumption data refer to the rated voltage and normal ambient temperatures (20° C). If the on-board mains do not meet the power consumption specifications, a buffer unit 51 37 26-9001 is required.

Weights of RMK TOP

RMK TOP 15 camera body	60.0 kg
RMK TOP 30 camera body	55.0 kg
Cable for camera body/T-CU	2.0 kg
External filter	1.7 kg
T-CU control unit	11.4 kg
Power cable T-CU/aircraft mains (6 m)	5.0 kg
T-TL terminal with cable	1.7 kg
Mount for T-TL	2.1 kg
Pilot display	0.3 kg
T-AS stabilized suspension mount with cable	48.0 kg
T-AL suspension mount with DCON	26.9 kg
AS2 suspension mount	19.1 kg
DCON drift control with cable	2.0 kg
T-MC film magazine (empty)	21.8 kg
T-MC film magazine with 150 m film and spools	28.9 kg
Cable for T-MC/T-CU	1.3 kg
T-NT navigation telescope with cable	21.0 kg
NT 1 navigation telescope	16.0 kg
NS 1 navigation sensor	10.0 kg

Total weights of standard configurations

RMK TOP 15 with T-MC (empty), T-AS, T-NT	176.3 kg
RMK TOP 30 with T-MC (empty), AS2/DCON, T-NT	149.4 kg
RMK TOP 30 with T-MC (empty), T-AS, T-NT	171.3 kg
RMK TOP 30 with T-MC (empty), AS2/DCON, T-NT	144.4 kg

Dimensions of RMK TOP

Dimensions and weights of the cases

Case	Width mm	Depth mm	Height mm	Weight kg
Camera body	600	600	600	23.0
T-CU, T-TL	600	600	600	23.0
T-MC	600	600	400	17.5
T-AS, AS 2	800	600	400	20.5
T-NT	1200	400	400	22.0
Filter (4)	249	189	305	1.0
Filter (1)	385	295	70	0.5

Cable lengths (standard, other lengths on request)

T-CU control unit to on-board mains	6 m
T-CU control unit to camera body, T-MC, T-AS, AS2/DCON	6 m each
T-CU control unit to T-TL, T-NT, NS 1	6 m each

RMK TOP with FMC and T-AS

Date of photo flight:	22th March, 1994
Area:	Wuppertal
Photo scale:	1:1000
f-stop:	16 (depth of focus)
Shutter speed:	1/100 s
FMC amount:	500 µm

Photogrammetric accuracy in planimetry: ± 5 mm
Survey by Fachhochschule Bochum

Aerial photos publisched by courtesy of MAPS GmbH, München
Terra Bildmessflug GmbH, Marbach
Hansa Luftbild GmbH, Münster

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