THE EQUIPMENT SYSTEM OF VEB CARL ZEISS JENA FOR REMOTE SENSING

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Numerous experiments in past years have proved that recording of the earth's surface in heights between 200 and 800 km supplies photographs and other information, which are of greatest scientific, technological and economic importance for both interpretation and cartography.
Photography of the earth's surface from satellites opens up new possibilities for interpretation in the fields of geology, geophysics, agriculture, hydrology, environmental protection and others. But it also inaugurates a new era of map production and map revision.
Aerial cameras for the production of photographs of the earth's surface from aircraft on rollfilm have been known and in use since about 1915. Aerial photographs gained in this way are the basic material for the interpretation and the production of topographic and thematic maps.
So far this recording technology has in general not been directly suited for the application in space. The major obstacle to its adoption was the large weight of about 150 kg of the standard version of an aerial camera. Besides, the most versatile information is expected from photographs taken from satellites, i. e. images in several highly limited spectral ranges with a maximum resolution.
Along with the evolving satellite technology the scanner recording and transmission systems developed very rapidly because they allow the production of images in several spectral regions with fast transmission of the data to earth. There have been, and still are, two major limitations for the application of this technique to map production: the resolving power and the geometric accuracy of the images.
In these two points the optical-photographic method has decisive advantages over the opto-electronic methods of the scanner technology.
In 1976 the first model of the MKF-6 Multispectral Camera was completed in Jena and practically tested in the Soviet Soyuz 22 space mission from 15 to 23 September 1976. The results proved to be so promising that the development of the camera and evaluation techniques was intensively carried on. Since 1976 the MKF-6 Multispectral Camera has been almost permanently in use in Soviet space experiments with international participation, but also in aircraft for producing aerial photographs.

The whole camera system and the copying and restitution equipment of VEB Carl Zeiss JENA are schematically shown in Fig. 1. Practical experience gained so far allows the conclusion that the optical-photographic MKF-6M camera system has important advantages over opto-electronic scanners regarding

resolving power
information content
geometric accuracy

Concerning the parameters

time expense and
costs of image transport

from space to earth opto-electronic techniques have their particular advantages. A practical consequence for the future may be that specific tasks will be defined and allocated to these techniques. This becomes already manifest for two applications. The scanner technology with electronic image transmission will certainly be used for meteorologic recordings where high resolution and geometric accuracy are no consideration, while the short transmission time is a point that matters. For cartographic purposes the speed of image transmission is not decisive, whereas resolution and image geometry are of utmost importance. Participants in the ISP Congress 1980 in Hamburg largely agreed that for cartography, i. e. for the production of maps at the scales of about 1 : 50000, 1 : 100000 and below and for map revision the optical-photographic technique is better suited than the scanner technology.

For the evaluation of aerial photographs taken from helicopter, aircraft, balloons or satellites from any heights we may distinguish between the techniques referred to in Fig. 2.
For all five evaluation techniques
- visual interpretation
- image digitization and digital image evaluation
- photographic restitution
- digital point - by - point evaluation
- graphical plotting

used for derivation of
- interpretation results
- photomaps
- line maps
- representation of digital results

the GDR industries produce the equipments, computers and materials and also supply the relevant technologies.
Visual interpretation is and continues to be an important technique for quickly obtaining information from photographs. Newcomers in the field of the well-known stereoscopes and methods are the multispectral technology and additive colour projectors.
Visual interpretation is an autonomous evaluation technique, but also an operation for preparing the graphical, digital and photographic image restitution.

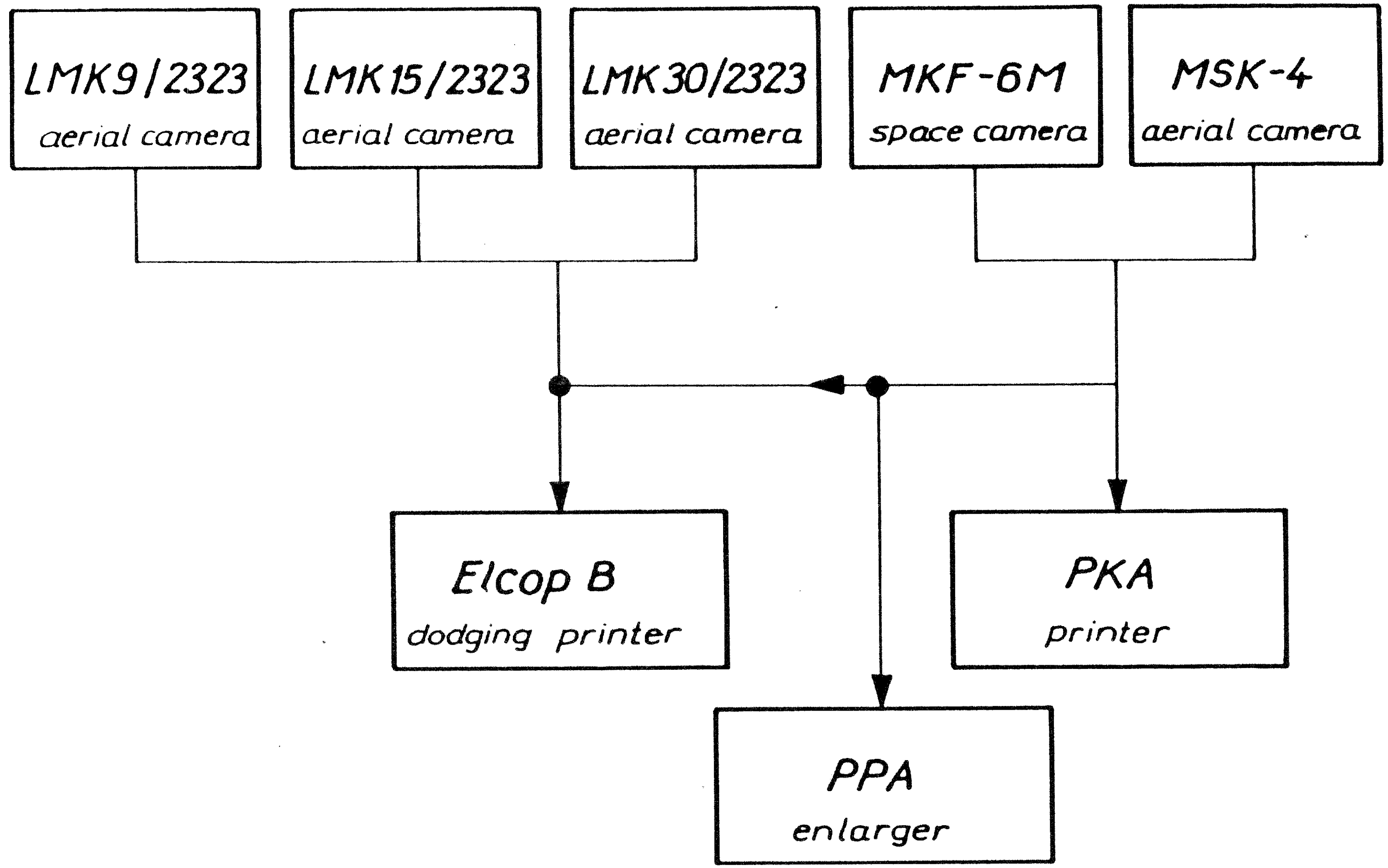

Fig. 1 Aerial camera system and printing/enlarging equipment

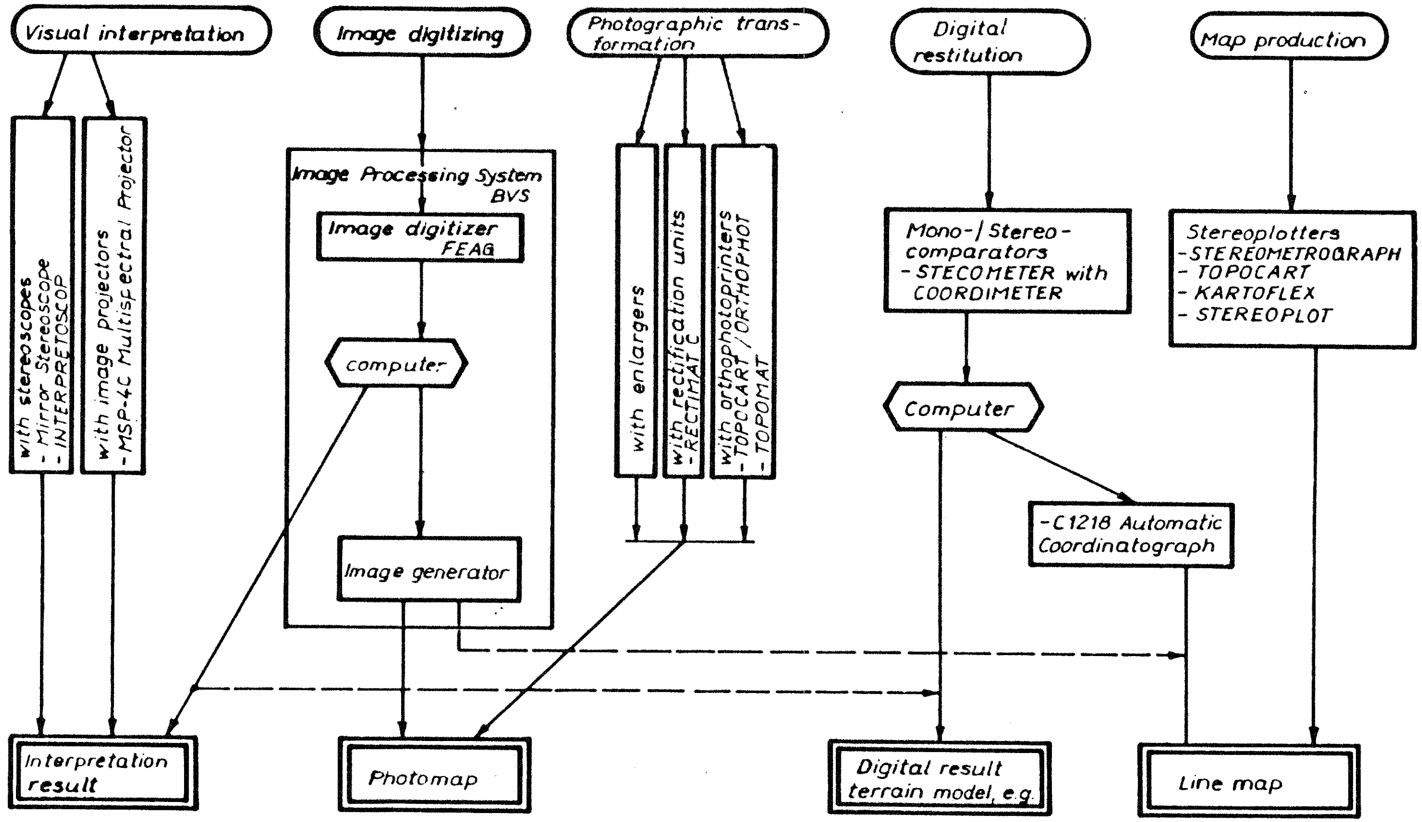

Fig 2 Derivation of informations from aerial and satellite photography

Image digitization with subsequent data processing for the automatic ascertainment of interpretation results, for geometric rectification, for changing the grey values or colour values or for the derivation of line representations from photographs offers almost unlimited possibilities for the automation of photogrammetry and remote sensing.
The most economic and fastest technique of cartographic image restitution is the photomap production. Photomaps with very high geometric accuracy and high information content can be derived from cosmic photographs or aerial photos by photographic magnification, reduction, rectification or differential rectification.
Through digital point-by-point measurement and restitution aerial triangulation networks can be calculated with cosmic photographs and aerial photos in almost the same way. Applicable for this purpose are the well-known stereo and monocomparators. Also the production of digital terrain models and digital relief models is possible with both space and aerial photographs. The line map constitutes at present and will certainly also in the foreseeable future continue to be the major part of topographic representation of the earth's surface. With photogrammetric stereoplotters new maps are produced from aerial and/or space photographs and existing maps are revised and updated. Using photographs taken with the MKF-6 from a height of 250 km at an image scale of 1 : 2000 000 first a premagnification by a factor of 2.4 to 1 : 830 000 is carried out with the PPA Automatic Precision Enlarger. These enlarged pictures may for example be used with the Stereometrograph or Topocart for map production/map revision at 1 : 100 000 (8.3x magnification) or also 1 : 50 000 (16.6x).
The accuracy of the MKF-6 photographs and the resultant mapping accuracy achievable with them are sufficient for the map scales 1 : 100 000 to 1 : 50 000 regarding planimetry.
Our present "Remote Sensing" equipment system comprises:
LMK Aerial Cameras (Table 1)
MKF-6M Multispectral Camera (Table 2)
MSK-4 Multispectral Camera (Table 2)
PKA Automatic Precision Printer (Table 3)
ELCOP-B photoprinter with electronic contrast compensation (Table 4)
PPA Automatic Precision Enlarger (Table 5)
MSP-4C Multispectral Projector (Table 6)
INTERPRETOSCOP-B/C (Table 7)
RECTIMAT-C rectifier (Table 8), Stereoplotters (Table 9)
Orthophoto equipment (Table 10)
Digital photogrammetric restitution systems (Table 11)
FEAG Image digitizer and generator (Table 12)

For digital metric image processing Kombinat Robotron Dresden has developed and marketed the BVS A 6471-73 Image Processing System. It consists of a flexible and expendable combination of the following basic units: FEAG, K1630 minicomputer, display.

The image processing system is suited for the automated interpretation of photogrammetric photographs of all kinds and for the most versatile fields of application. It can, however, also be employed with great use in other sectors, such as medicine, microscopy, astronomy etc.
While aerial photogrammetry being concerned with the production and restitution of photographs taken from aircraft or helicopters is mastered from a scientific-technical, technological and economic point of view and has successfully been emplbyed for many years, the application of satellite photography and evaluation of space photographs is at present still in an advanced test stage. The results achieved so far in the fields of interpretation and map production/map revision are rather promising.

Summary

On the basis of available practical experience in the production of photographs of the earth's surface from satellites the various techniques can be subdivided into two fundamentally different groups: 1. Scanner technique and digital image transmission to ground stations and 2. photographic exposure technique with transportation of the films back to earth by landing modules.
The advantages of the 1st group lie especially in the low expense of time for image transmission to earth and the flexible adaption to desired spectral ranges. Disadvantages are the limited resolving power (detail recognizability: 20-80 m referred to the earth's surface) and the restricted geometric accuracy.
The assets of the 2nd group are the high resolving power (detail recognizability: 10-25 m) and the very good geometric accuracy.

For the production of topographic maps and for map revision the geometric accuracy and the information content (detail recognizability) are of primary importance. In the equipment system from Jena these two parameters were optimized:

Resolution of MKF-6 and MSK-4 150 l/mm
Mean coordinate error in the photographs ± 5 μm

As far as their performance is concerned the processing equipments (PKA, PPA, ELCOP-B, RECTIMAT-C, FEAG) as well as the other photogrammetric machines meet these high requirements. Thus a versatile instrument system has been made available for the further rationalization of map production and map revision and for the efficient photointerpretation.

Table 1. LMK Aerial Camera (1982)

	Superwide-angle	Wide-angle	Normal-angle
Image format	9″ × 9″ (23 cm × 23 cm)	9″ × 9″ (23 cm × 23 cm)	9″ × 9″ (23 cm × 23 cm)
Calibrated focal length	$3^1/_2$″ (90 mm)	6″ (152 mm)	12″ (305 mm)
Standard distortion, max.	±5 µm	±4 µm	±2 µm
Resolution, AWAR, high contrast	39 L/mm	70 L/mm	55 L/mm
Film length		120...150 m	
Application		aircraft/helicopter	
Flight altitude	0.1...15 km	0.2...15 km	0.3...15 km
Photo scale	1:500...1:150000		

Table 2. Multispectral Cameras Type MKF-6M (1976) and Type **MSK-4 (1982)**

	MKF-6M		MSK-4
Image format	$2^1/_2$″ × $3^1/_2$″ (55 mm × 81 mm)		
Calibrated focal length	5″ (125 mm)		
Standard distortion, max.	±3 µm		
Resolution, photo center, high contrast	150 L/mm		
Film width	70 mm		
Film length	110...220 m (6×)		110...220 m (4×)
Spectral range	Channel 1 480 nm blue-green, 40 nm bandwidth Channel 2 540 nm green-yellow, 40 nm bandwithd Channel 3 600 nm yellow, 40 nm bandwidth Channel 4 660 nm red, 40 nm bandwidth Channel 5 720 nm near IR, 40 nm bandwidth Channel 6 840 nm near IR, 100 nm bandwidth		Colour filter for centroid wavelengths: 480, 540, 600, 66 660, 720, 840 nm
Application	Satellite/aircraft/helicopter		aircraft/helicopter
Flight altitude	250 km (Soyuz, Salut); 0.1...15 km		0.1...15 km
Photo scale	1:2000000 at hg = 250 km	1:800 to 1:120000	1:800 to 1:120000

Table 3. PKA Automatic Precision Printer (1979)

Film width	70 mm
Resolution	100 l/mm
Printing cycle	min. 7 s
Modes of operation	3 (with different degrees of automation)
Density measurement	differential, automatic

Table 4. Elcop B Photoprinter with electronic contrast compensation (1978)

Printing format	from 6 cm × 6 cm to 46 cm × 46 cm
Resolution	100 l/mm
Contrast regulation	≧90%
Scanning spot size	≧2 mm ∅
Exposure time	5...10 s

Table 5. PPA Automatic Precision Enlarger (1982)

Image format	66 mm × 81 mm
Film width	70 mm
Optical magnification	2.4× and 4.6×
Resolution	~140 l/mm
Mode of operation	all-automatic, partially automatic
Productivity	120 magnifications/hour

Table 6. MSP 4C Multispectral Projector (1979)

Channels	4
Image format	70 mm × 91 mm
Projection format	350 mm × 455 mm
Magnification	5×

Table 7 Interpretoscop B (1975), C (1976)

	Interpretoscop B	Interpretoscop C
Max. image format	300 mm × 300 mm	240 mm × 240 mm
Magnification	2× to 6× and 5× to 15×	
Max. resolution	100 l/mm	
Illumination	incident and transmitted light	
× parallax measurement	90 mm to 310 mm	90 mm to 415 mm

Table 9. Stereoplotting machines and equipments for map revision

	Stereometrograph G Precision Plotter	Topocart D Stereoplotter	Stereoplot Stereoplotter	Kartoflex equipment for map revision
Image format	23 cm x 23 cm	23 cm x 23 cm	23 cm x 23 cm	30 cm x 30 cm
Calibrated focal length	85 ...310 mm	45 ... 310 mm	84-91 mm 149-156 mm 209-216 mm	-
Max.magnification image to map	25x	25x	20x	15x
Mean coordinate error	± 5 μm	± 7 μm	± 10 μm	accuracy of tracing
Mean height error	± 0.03‰ h_g	± 0.06‰ h_g	± 0.07‰ h_g	
Plotting tables	Precision coordinatograph 120x120 DZT Digital Plotting Table 90x120		Internal plotting table	

Table 8. Rectimat C Rectifier

Magnification range	0.85...8.0× (f = 150 mm) 3.0...18.0× (f = 70 mm)
Max. image format	300 mm × 300 mm
Resolution	image centre 100...150 l/mm image edge 40 l/mm
Easel size	1100 mm × 1200 mm

Table 10. Orthophoto equipment

	Topomat-B Automatic Plotting System	Orthophot D-300 Topocart D Off-Line System	Orthophot D-300 Topocart D On-Line System
Image format		23 cm × 23 cm	
Magnification image: orthophoto		0.7...5.0×	
Mean coordinate error in orthophoto		±0.15 mm	
Image correlation	yes	–	–
Digital Control Unit	–	yes	yes
Cross Slope Corrector	yes	yes	yes
Mean height error of digital relief model	±1.0‰	–	–

Table 11. Digital photogrammetric plotting machines

	Ascoremat Monocomparator	Steco 1818 Stereocomparator	Stecometer C Precision Stereocomparator
Image format	30 cm × 30 cm	18 cm × 18 cm	23 cm × 23 cm
Mean coordinate error	±0.4 μm	±2 μm	±1 μm
Recording unit	E60 (PDP 11/03, V03)	MDR 1 MDR 2	Coordimeter G
Point transfer		with Transmark B	

Table 12. FEAG Digital Film Scanning and Writing System

Mode of operation	Scanning and writing
Film format size	Scanning: 24 × 36 mm (strips of 5 photos each) 70 × 91 mm 110 × 110 mm 190 × 195 mm 180 × 240 mm 240 × 260 mm Writing: 105 × 148 mm (Mikrofiche) 240 × 300 mm
Spot sizes	Scanning: 10, 20, 40, 80 μm Writing: 10, 20, 40 μm
Density range (specular)	Scanning: 0...2 D 0...3 D Writing: 0...2,3 D
Density discrimination	Scanning: 256 gradations Writing: 64 gradations
Data rate (data points/second)	Operating mode 1: 200 kbyte per sec Operating mode 2: 400 kbyte per sec
Positional accuracy	±10 μm in the whole format range
Resolution	10 μm 50 line pairs/mm