Comparison of High Resolution Satellite Imagery for Mapping

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O. Abstract

High resolution photographic imagery of the Soviet camera systems KFA-1000 and KATE 200 has been obtained for the areas of Hannover and Munich in the F.R.Germany. These images and their use for mapping are compared with other existing space imagery over these areas, such as from Spacelab 1, LFC, and SPOT. The comparison is made for analog and digital procedures.

1. Introduction

Since 1957 the use of satellites has greatly progressed. In communications and in meteorology satellites have become operational tools. In remote sensing satellite systems, starting with Landsat in 1972, have promoted the discipline itself, and remote sensing using satellite images has found applications in many disciplines.

One of the disciplines is topographic and thematic mapping. Other than meteorology, which requires low spatial but high temporal resolution and other than most remote sensing applications (e.g. in agriculture, forestry, geology, hydrology), which need intermediate spatial resolution and intermediate temporal resolution, cartographic applications require high spatial resolution in order to see the transportation network, and stereo-viewing capability in order to survey the 3rd dimension.

In this respect only the latest satellite imaging systems can be qualified as cartographic satellite systems.

Among the Western European attempts to obtain cartographic coverage from space has been the German Spacelab-1 Metric Camera, flown on ESA's Spacelab mission on NASA's Space Shuttle in 1983. It brought back 1100 b & w or color IR images with stereo-overlap and a photographic ground resolution of 20 to 25 m yielding a digital pixel equivalent of about 10 m.

The followup mission was NASA's LFC in 1984 with about twice the resolution and improved base-height ratio for stereoscopic determination of heights.

A new digital approach was the French Spot system with 20 m multispectral or 10 panchromatic pixels, permitting overlapping orbital images up to a base-height ratio of 1. Unfortunately not many of these stereo pairs have been acquired. This in turn limits the demand for such images, since the potential customers sofar do not have positive experiences with this type of imagery using analytical plotters, orthophoto equipment or digital image processing systems. Spot is, however, the only present Western operational cartographic satellite system, which is capable to be programmed and used for world mapping requirements.

It is most interesting that the Soviet efforts in providing cartogrpahic coverage are becoming known at this time, and that products of space camera systems used by the Soviet Union, such as the MKF 6, KATE 150, KATE 200 and KFA 1000 are now available worldwide through Sojuzkarta.

2. Comparative Investigations for Cartographic Space Systems

The Institute for Photogrammetry and Engineering Surveys of the University of Hannover (IPI) has carried out under support of the Federal Minister of Research and Technology (BMFT) comparative investigations with the following space cartographic sensors:

1) RMK-Spacelab 1, Metric Camera (MC) over North Germany, the Alpes, Eastern USA, Sudan and China.
2) Large Format Camera (LFC) over North Germany and Switzerland
3) Spot-panchromatic and multispectral images over Marseille and Hannover
4) Spot-digital data tapes over Marseille and Hannover
5) KATE-200 images over Bavaria
6) KFA-1000 images over Hannover and Munich

The aim of these investigations has been to test

- the possibility to orient the images by an aerial triangulation procedure
- to determine positions by these images
- to determine elevations by the images (e.g. in the form of a DTM or by contours)
- to test the extraction of topographic map data at a limiting scale
- to generate orthophotos at a scale commensurate with the resolution of visible details.

The results of these investigations are summarized for the various sensors:

3. Metric Camera

The North German test area, which contained control points within a homogeneous geodetic network of high accuracy, and which had an accurate mapping system 1:5000 based on this control proved clearly that a positioning accuracy of ± 7.7 m can be reached by the MC images (f = 30 cm, format 23 x 23 cm, hg = 250 km, image scale 1:820 000) using aerial triangulation of 5 imges. The elevation determination has been possible with an accuracy of ± 20.2 m.

This high accuracy could not be obtained in other areas due to various reasons: In the Alps a total of 5 countries were overflown (Switzerland, F.R.Germany, Austria, Italy, Liechtenstein). Most of these had separate reference systems in position and elevation. The control points were digitized in maps with scales 1:5000 up to 1:50 000. The bundle block adjustment with program system BLUH of 5 images resulted in a positional error of ± 14.9 m and an elevation error of ± 32.5 m.

For other test areas the poor ground control situation becomes even more obvious. In China the resulting positional and elevation accuracy was ± 47 m. In the Sudan control points were first taken from old 1:250 000 maps with unacceptable results (discrepancies of several hundred meters in the block adjustment). Then in collaboration with the Sudan Survey Department some control points determined by ground surveys and astro-observations were used, resulting in position and height errors of ± 32 m.

The possibility to derive topographic details was tested by compiling the following maps on the analytical plotter:

a) 4 sheets of the topographic map 1:50 000 in the area of Zeven/Sittensen, North Germany (see map, Fig.1). The map content at the scale 1:50 000 showed considerable deficiencies (see table Fig.1) in depicting individual housing and minor roads.
   However, while a depiction of details at the scale 1:100 000 did not fully meet the mapping specifications set for German standards, presentable map content resulted at that scale. In the Sudan special difficulties were encountered due to the low contrasts between desert, settlements and roads (Table 1).
b) For the Production of orthophotos the planimetric requirement of ± 0.2 mm at the scale 1:50 000 can always be reached. However, likewise the resolution makes it more advisable to produce orthophotos at the scale 1:100 000. Experimental sheets have been compiled for the area of Innsbruck, Munich and the Sudan.
c) The elevations were best determined by measuring a DTM in the anlytical plotter.This is possible with the method of progressive sampling. Contours were interpolated using the University of Hannover's contour interpolation program TASH.

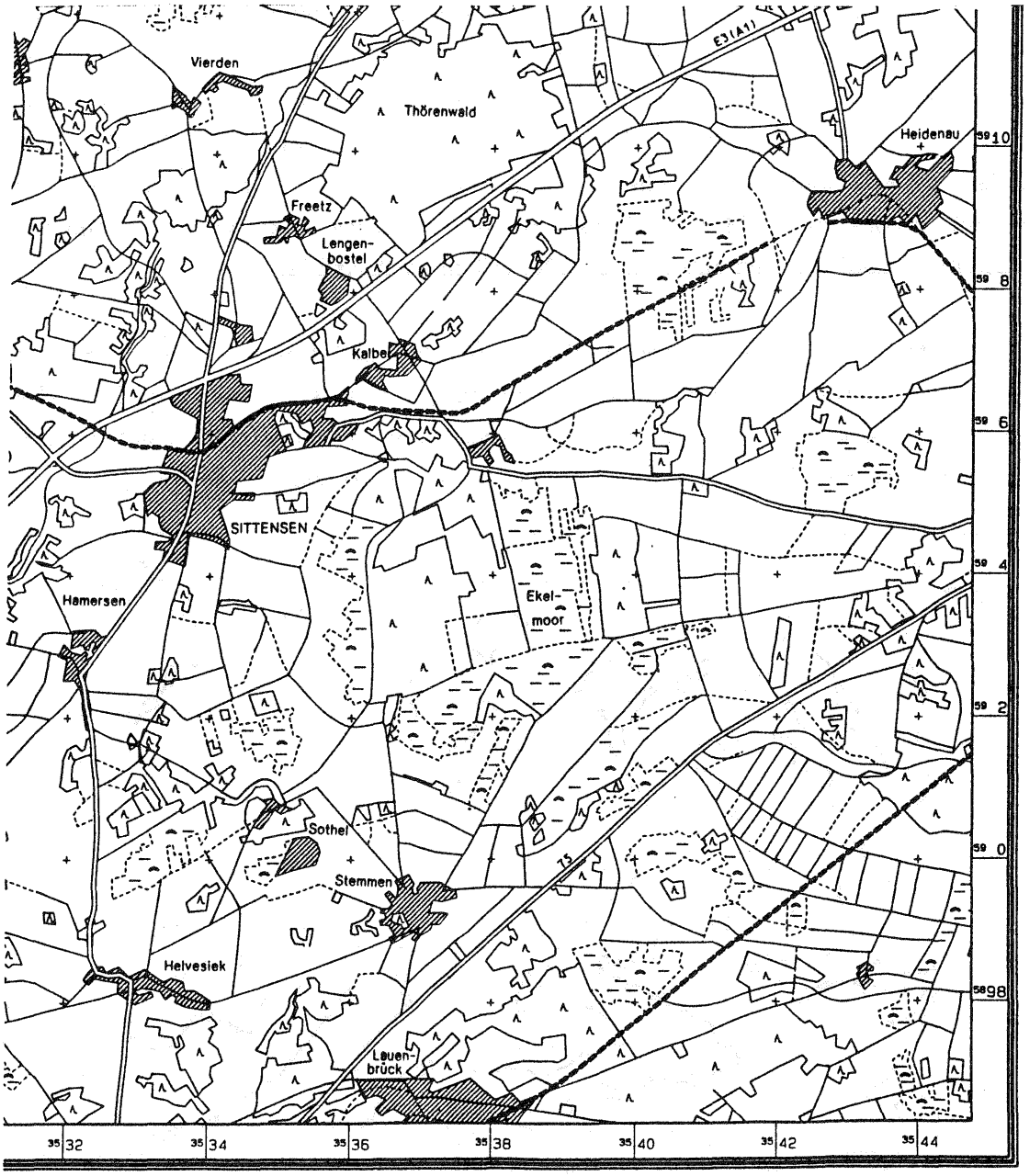

Fig.1: Part of MC map 'Sittensen'

Table 1: Completeness of MC map "Sittensen 1:50 000"

line type	length [km] in 1:50 000	correct	not classified	incorrect	not recognized
highways	26.5	100.0 %	---	---	---
roads IA order	82.5	31.5 %	---	68.5 %	---
roads IB order	141.7	89.9 %	2.5 %	2.5 %	14.1 %
roads II order	451.0	38.7 %	16.8 %	2.2 %	42.3 %
field-paths	864.0	7.2 %	11.8 %	6.0 %	75.0 %
railroads	37.5	90.6 %	4.0 %	5.3 %	---
drainage	50.0	28.0 %	---	---	72.0 %

For a test area in the Alps, the interpolated contours were compared with those of an existing map 1:10 000 (Fig.2). With a mean terrain slope of 32°, the mean square planimetric discrepancies of 83.3 lead to an accuracy of ± 52 m for the contours. A comparison of test profiles digitized in the existing map and in the sheet of the interpolated contours resulted in height errors of ± 53 m . These results indicate that in mountaineous regions a contour line interval of 100-150 m is possible.

Contours were also directly drawn in the analytical plotter. For this purpose the analytical plotter real time program was supplemented by the Hannover background program SURF, which compensates the effect of the earth curvature. These contours proved to be of equivalent accuracy.

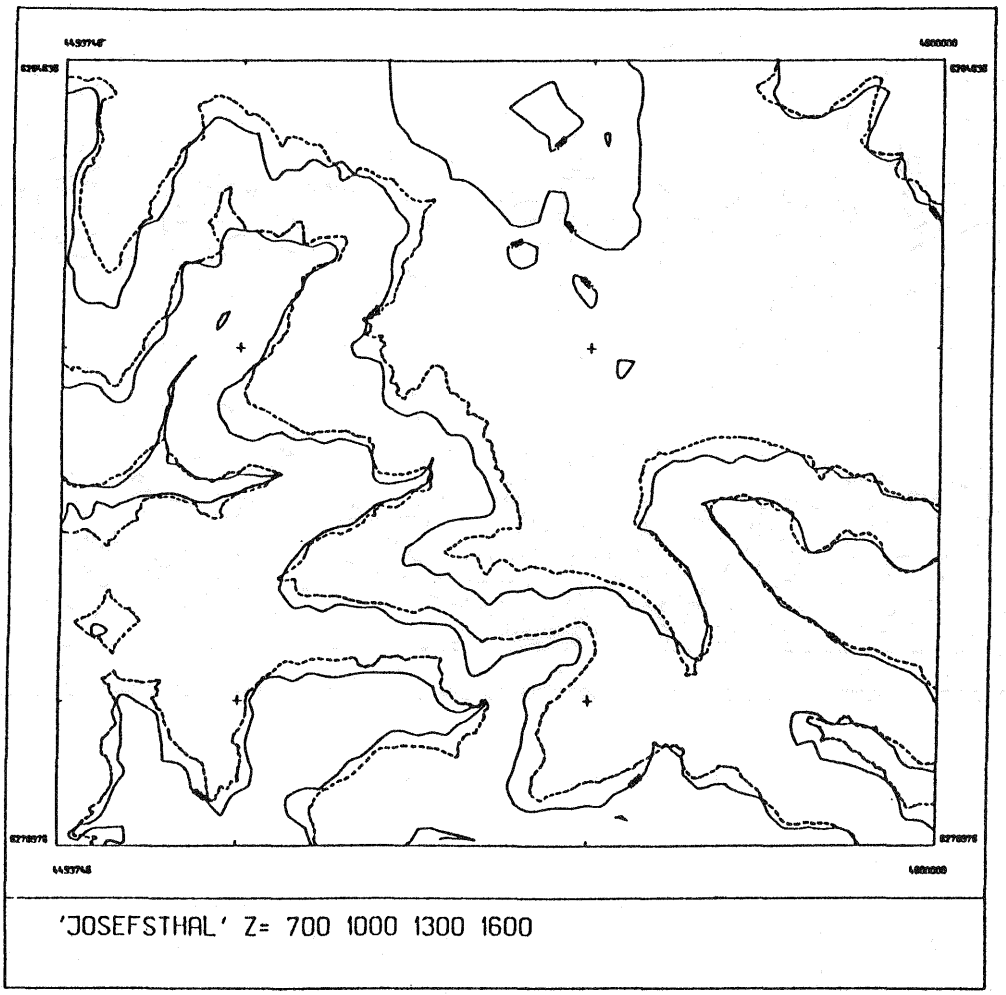

Fig. 2: Interpolated contour lines (solid) compared with map (dashed)

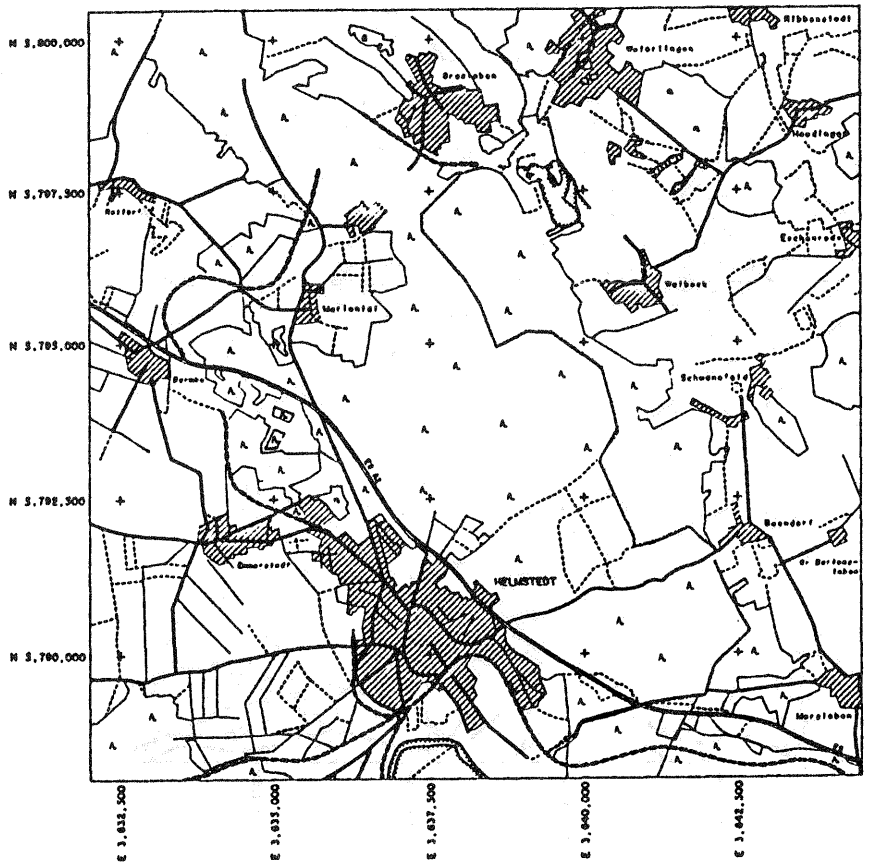

Fig.3: Map 1:50 000 produced by LFC photos

4. LFC-tests

The aerial triangulation tests over N-Germany with 4 images were first carried out using 4th generation copies. They resulted in positional errors of ± 10.0 m and elevation errors of ± 14.0 m. The tests were repeated with 2nd generation film copies obtained from the NOS, USA with positional accuracies of ± 8.5 m and elevation accuracies of ± 8.5 m. Caused by haze the image contrast on these images is not optimal.

A second test was carried out with 3 images over Switzerland, where the contrast was higher. The resulting positional accuracies were ± 5.8 m and the elevtion accuracy was ± 8.6 m. A map portion 1:50 000 was drawn in the region of Helmstedt, N-Germany with rather satisfactory results.

The contouring capability was tested in Switzerland. A 50 m contouring interval is possible even for a longitudinal overlap of 70 %.

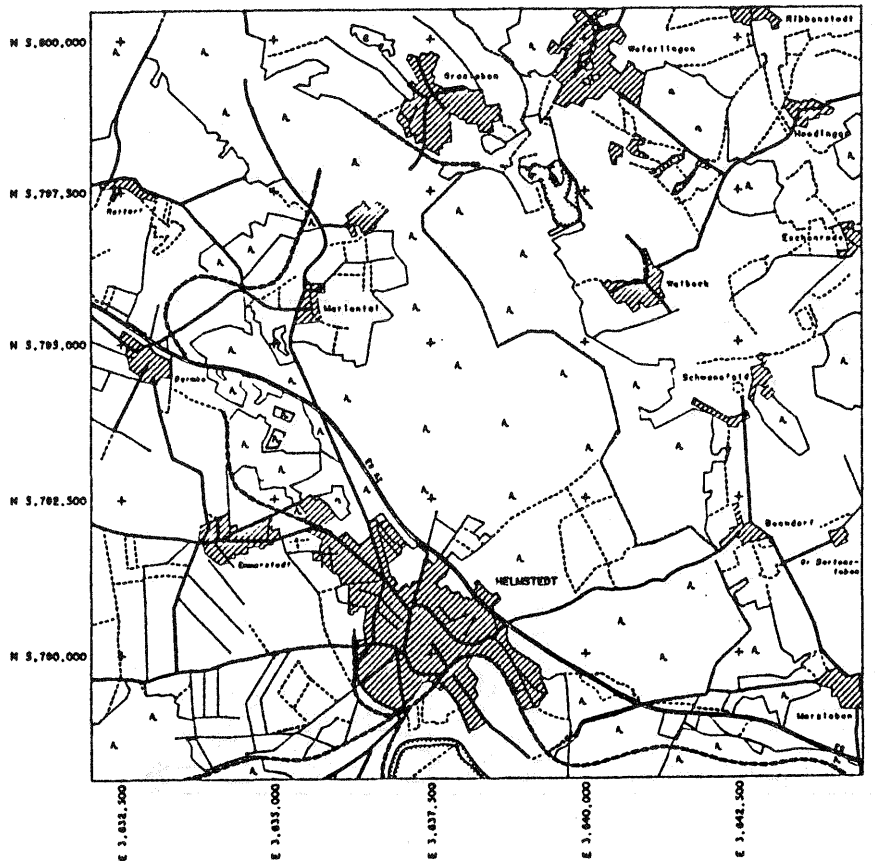

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Table 2: Completeness of mapping with LFC photos, area Helmstedt

object	highways	roads	railroads	field paths
completeness of mapping	100 %	93 %	88 %	90 %

5. Spot-Images

To test the geometric capability of the Spot-System a panchromatic stereoscopic model with 10 m pixels and with a base-height ratio of 1 has been obtained over the Marseille area.

To evaluate Spot-images on the Zeiss Planicomp analytical plotter, a real time program, based on the aerial triangulation package BINGO has been developed [Picht 1987]. The evaluation of the stereomodel gave a planimetric positional error of ± 12.3 m and an elevation error of ± 6.5 m. This accuracy is based on control of map features in the IGN maps 1:25 000. Relative discrepancies between points included in the adjustment resulted in mean positional discrepancies of ± 3 m in position and ± 5 m in elevation. Through the PEPS-program a multispectral stereo-model of Hannover has been made available. This model with 20 m pixels and with a base height ratio of only 0.3 resulted in positional errors of ± 9.6 m and in elevation errors of ± 50.2 m. This proves that topographic evaluation should only be made with panchromatic Spot-imagery and with high base-height ratios.

The topographic mapping at the scale 1:100 000 over the Marseille area showed similar difficulties like those encountered for Spacelab images. Nevertheless it appears possible to generate products of acceptable 1:50 000 standards for non-European conditions.

The Spot-evaluation program was also adapted to produce orthophotos on the Zeiss Z-2 orthoprojector with satisfactory results at the scale 1:100 000. This was shown for Marseille and for Hannover.

6. Spot - Digital Data

A system development is still under way using the Terragon-ContextVision Image Processing System, which has been modified at the IPI to include a digital stereo-observation module.

Digital Data are preferable to the analytical plotter solutions, since contrast enhancements are directly applicable at the image processing station. Furthermore digital image correlation may be applied for DTM measurement.

7. KATE-200 Images

2 overlapping simultaneous images hve been obtained with 3 cameras (green 510-600 mm, red 600-700 mm, infrared 700-850 mm). An aerial triangulation was carried out with the 6 transparencies. The red films gave the best results with ± 27.0 m in position and ± 46.6 m in elevation (see Fig.4). The infrared films gave ± 54.1 m in position and ± 94.9 m in elevation.

The contouring accuracy was comparable to that of the Metric Camera.

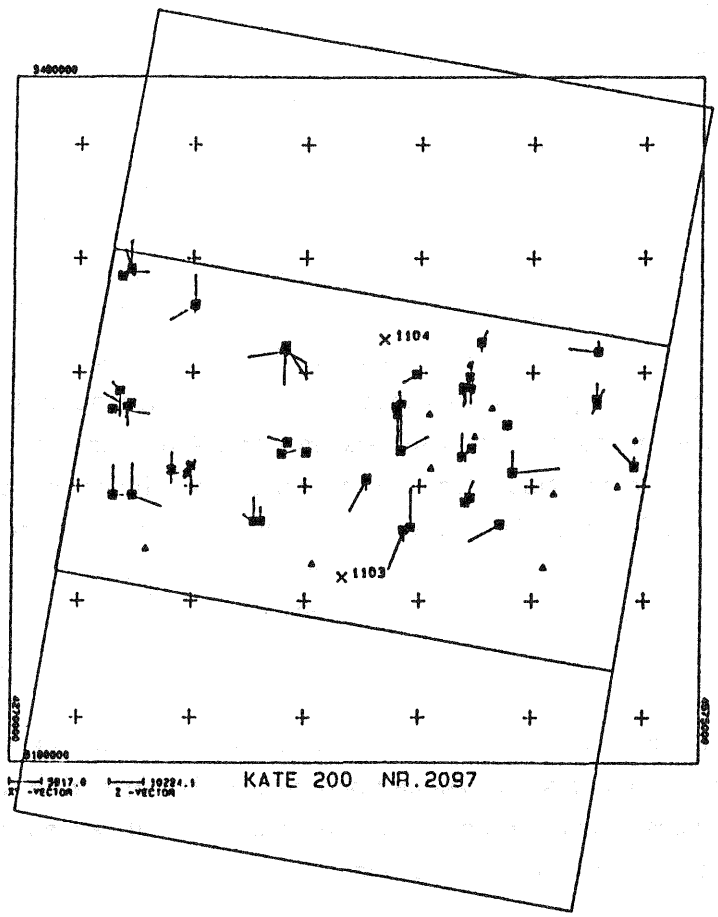

Fig.4: Result of bundle block adjustment

8. KFA-1000 Images

The bundle block adjustment of 4 images over Munich, with control points determined from 1:25 000 maps resulted in positional errors of ± 10.6 m and height errors of ± 29.9 m. Over Hannover with 3 images a positional error of ± 6.9 m was reached. Elevations determined from two images gave an error of ± 32.9 m. Elevations from 3 images resulted in an error of ± 23.7 m.

With regard to the mapping of topographic details the KFA 1000 permits a better result than Spot in towns and villages, and a roughly equivalent result in rural areas.

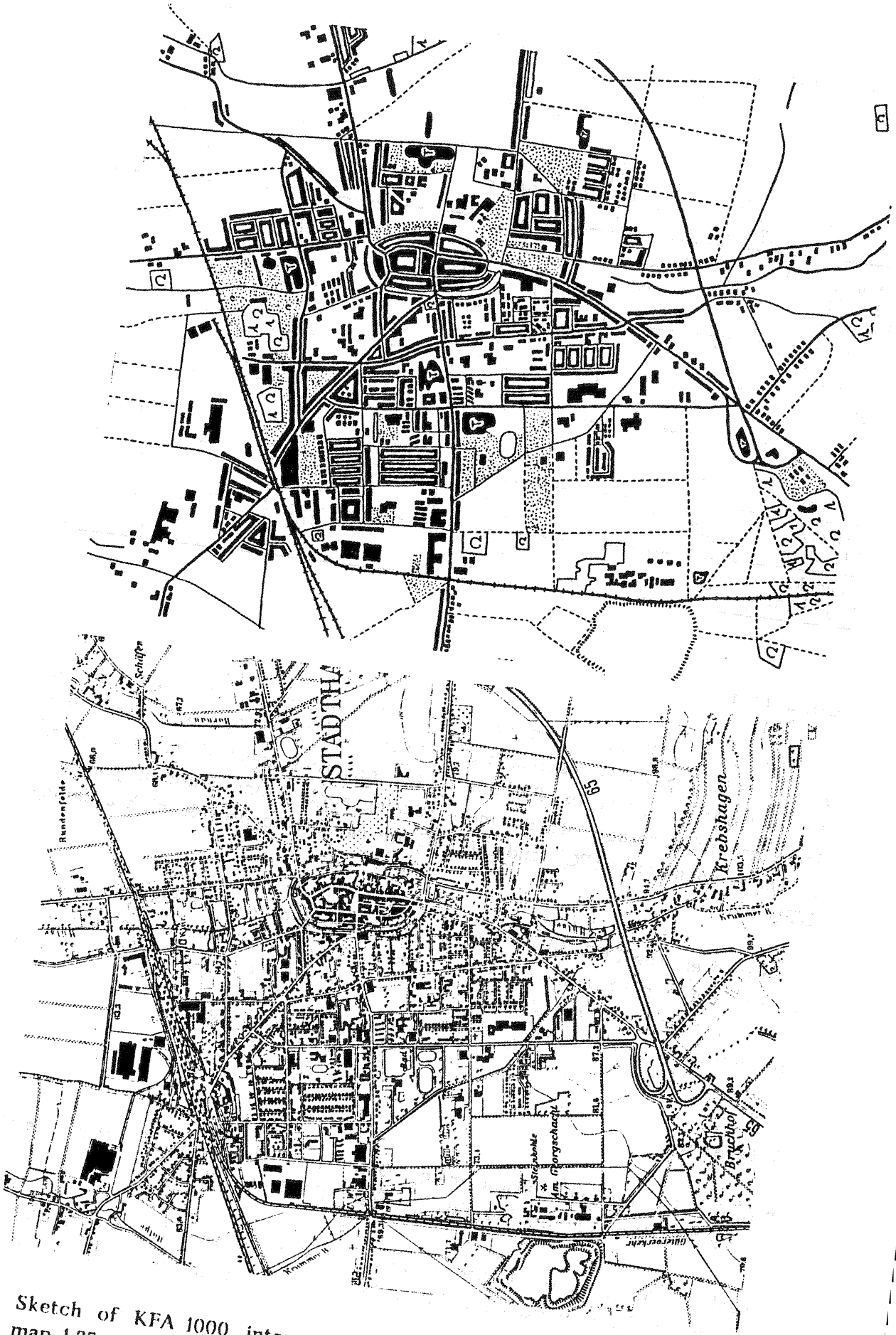

Fig.5: Sketch of KFA 1000 interpretation and corresponding topographic map 1:25 000 (scales reduced to 1:32 000)

Table 3: Completeness of sketch maps 1:25 000 "Stadthagen" (derived by interpretation of KFA 1000 and multispectral SPOT images) upper figures = KFA, lower figures = SPOT

	lenght [km] in 1:25 000	roads IA, IB	roads II	field paths	streets	rivers	creeks	not recognized
roads IA, IB order	51	37 37	59 62	2 -	- -	- -	- -	2 1
roads II order	77	- -	89 91	9 7	- -	- -	2 -	- 2
field paths	450	- -	- 1	35 30	- -	- -	4 1	61 68
streets inside towns	75	- -	- -	- 2	55 35	- -	- -	45 63
rivers (> 3 m)	38	- -	- -	11 -	- -	81 91	- -	8 9
creeks (< 3 m)	100	- -	- -	4 8	- -	40 35	- -	56 57

Conclusions

Among the operational cartographic remote sensing systems, the KFA 1000 seems to have a better resolution than SPOT. The KATE 200 is less suitable for cartographic purposes. But due to the different spectral bands and the large ground coverage, other remote sensing applications could be possible. At the moment only SPOT and the LFC are capable to provide high accuracy DTM data.

However, the LFC, like other space photographs can be easily evaluated with standard photogramemtric equipment. It can be expected that also the next generation of photos taken with a modified MC with forward motion compensation will find their users.

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