ADVANTAGES AND DISADVANTAGES OF DIFFERENT SPACE IMAGES FOR MAPPING

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Abstract

The lack of actual maps, especially in developing countries cannot be solved by traditional photogrammetry. The use of space images may reduce the problem.

Images of following cameras used in space have been used for mapping: Metric Camera, KFA 1000, KATE 200, MK4 and SPOT. The specifications of these sensors like image scale, height to base relation, geometric film stability and ground resolution are quite different. The KFA 1000 and SPOT have the best ground resolution but the MK4 is not so much different. The handling of the MK4 in analytical plotters is more simple and for limited applications also analog plotters can be used. The stereoscopic impression of SPOT models is influenced by the time periode between the creation of both scenes. The KFA 1000 has a limited film stability. In addition the results of mapping are quite depending upon the landscape.

Key Words: Mapping, Space Images, SPOT, Bundle Adjustment

1. Introduction

Actual maps are of fundamental importance for the development of any country. The economic planing of resources cannot be done without. Especially the map scale of approximately 1 : 50 000 is important. According to the UN statistics from 1987 (Brandenberger, Gosh 1990) only 56% of the land area is covered by maps of the scale range around 1:50000. With the annual increase of 2% by theory in 22 years the whole world should be covered. But the status of mapping is quite different in the different continents. In South America only for 30% and in Africa only for 34% of the area such maps are existing.

The figures about the map coverage are not reflecting the whole reality. Actual maps are required but in many countries no update procedure has been established.

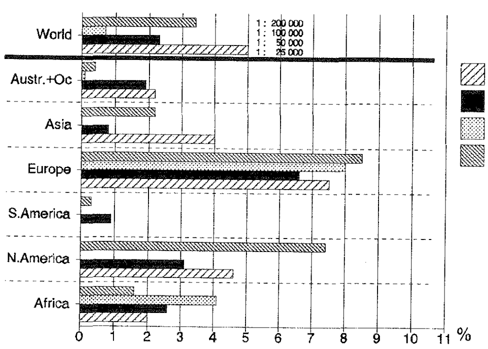


Figure 1: worldwide map update per year for the periode from 1980 - 1987

The mean value of 2.3% map update per year for the scale range 1 : 50 000 means, by theory maps are updated every 43 years. For the scale range 1 : 100 000, the annual update is just reaching 0.7%. In Germany the update cycle is between 4 years (25% annual update rate) for industrial areas and 7 years (14% annual update rate) for rural areas. Of course, the required update cycle is depending upon the changings but 43 years as mean value means, very often it is more easy to create new maps instead of a map revision. It seems new technics are required to solve this problem. The use of space images may be the solution.

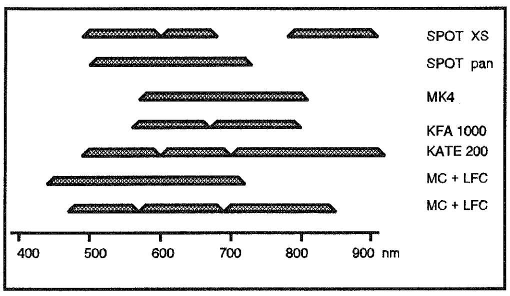
2. Used space images

The German Metric Camera test in 1983 was the first project for mapping with space images. This was followed in 1984 by the US Large Format Camera test. Since 1986 the operational digital images from the French SPOT satellite are available. The former Sowjet Union made the operationally used space photos taken with the KFA 1000, the KATE 200 available since 1987. In 1989 the new MK4 followed. The other space images like Landsat TM and the Indian IRS do not have a sufficiant resolution and stereoscopic coverage.

The geometric relations listed in table 1 have to be completed with the spectral range and spectral resolution of the systems. The object identification is depending upon this. For example water surfaces are imaged with a better contrast in the near infrared. With more than one spectral range (colour film or multispectral SPOT) the object classification can be done not only based on the texture information.

	focal length	image size	flying height	scale number	ground resolution / pixel size	height / base	
MC	305	23*23	250	820000	16-33	3.3	German test 1983
LFC	305	46*23	225 352	740000 1150000	10-25 10-25	1.8 1.6	test USA 1984
KFA	1000	30*30	275	275000	5-10	8.0	Sojuzkarta available since 1987 operational
KATE	200	18*18	275	1400000	25-40	1.8	
MK4	300	18*18	275	900000	8-10	4.0	
SPOT	2087	15*15	840	400000	10/20	>1.	France since 1986 operational

Table 1: technical data of the space images for mapping



spectral range of space images

Figure 2: spectral range and resolution

3. Accuracy aspects

The accuracy requirements for mapping are not uniform all over the world. In the US ±0.3mm in mapping scale is required, in several countries there is no specification. In small scale mapping the effect of generalization has to be respected. Under extreme conditions objects can be shifted up to 1mm for getting a clear impression about the details. Examinations in the University of Hannover with maps from several countries have shown coordinate accuracies of the existing maps 1 : 50 000 between ±0.2mm and ±0.7mm. Only few countries have fixed accuracy requirements for the height. The relation between the contour intervall and the standard deviation for Z in some countries is specified.

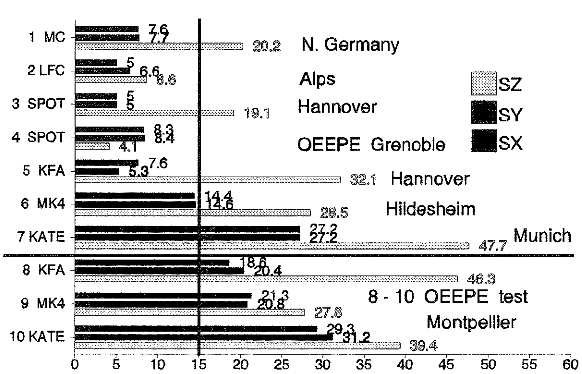


Figure 3: accuracies of independent check points determined by bundle adjustment [m]

Images of the sensors listed in table 1 were used in the University of Hannover. The geometric conditions have been analysed by bundle adjustment with the Hannover program system BLUH.

3.1 Horizontal accuracy

Usually no better accuracy than ±0.3mm in the map is required (corresponding to ±15m in the scale 1 : 50 000). As shown in figure 3, this requirement was reached with images of all sensors with the exception of the KATE 200. Mainly caused by the poor ground resolution of the KATE 200 the control and check points could not be identified accurate enough. The block adjustments were made with self calibration by additional parameters in an orthogonal coordinate system - a tangential plane system to the ellipsoid. A computation in the national net coordinate system will lead to not acceptable errors in the height up to 202m and to errors in X and Y up to 23m (Jacobsen 1986). The self calibration is necessary especially for images from Sojuzkarta, but also SPOT. The systematic image errors are reaching 100µm in the case of the KFA 1000, 45µm in the case of the MK4 and 50µm in the case of SPOT. These differences cannot be accepted.

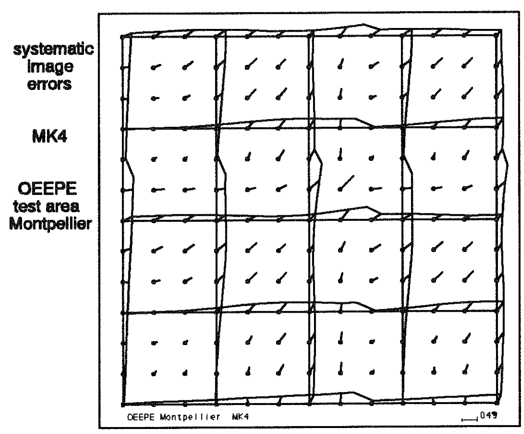
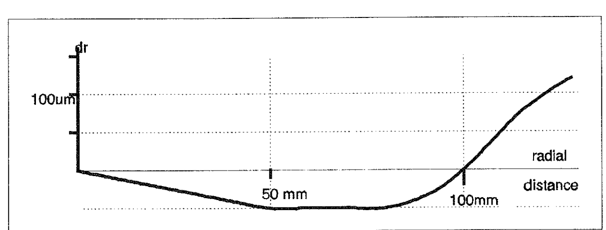


Figure 4: systematic image errors of the MK4

In addition to this, in one case no information about the radial symmetric lens distortion was available. So it was necessary to determine it by selfcalibration. In the corner of the photos 100µm were exceeded.



MK4 radial symmetric lens distortion determined by selfcalibration Hildesheim

Figure 5: lens distortion of the MK4 determined by selfcalibration

The results of the bundle block adjustments of the OEEPE test area Montpellier are exceeding the limit of ±0.3mm ≙ 15m for all 3 cameras. Also with the KFA 1000 poor data have been achieved. In this case the control and check points are digitized from existing maps 1:50000. That means, the maps have been checked and not the block adjustments. The map accuracy seems to be limited to ±20 m in X and Y. This is a typical problem for handling of space data in most of the countries. As control points usually digitized map points are used and the discrepancies of the ground coordinates are dominated by the existing map quality. But reverse can be said, with the exception of the KATE 200, there is no problem of the horizontal mapping accuracy based on space images.

The model handling has to be done in analytical or digital stereo plotters. Especially the photos from Sojuzkarta should be improved by using the systematic image errors, determined by bundle adjustment with selfcalibration, as correction to the loop. The necessary programs for the loop correction have been developed in the University of Hannover.

3.2 Vertical accuracy

Under the assumption of the approximately same size of the standard deviation of the photo coordinates in relation to the x-parallax, the vertical accuracy of block adjustment and also model handling is corresponding to the horizontal accuracy multiplied by the height- to-base relation ($Sz = Sx * h/b$). As shown in figure 3, this relation of the standard deviations is reduced in the case of the bundle adjustments.

camera / area	Sx´,Sy´	Spx
1 Metric Camera	9.2μm	7.5μm
2 LFC	5.0μm	4.7μm
3 SPOT Hannover	12.5μm	16.5μm
4 SPOT Grenoble	21.5μm	10.2μm
5 KFA 1000	23.6μm	14.6μm
6 MK4	16.1μm	8.9μm
7 KATE 200	19.4μm	21.3μm
8 KFA 1000 OEEPE	70.9μm	21.0μm
9 MK4 OEEPE	23.0μm	7.7μm
10 KATE 200 OEEPE	21.6μm	21.3μm

Table 2: results of the block adjustments - standard deviations of the photo coordinates and the x-parallaxes

The results of the bundle adjustments, determined with independent check points, transformed to the standard deviations of the photo coordinates and the x-parallax like shown in table 2 are demonstrating the problems of the horizontal control. Only the SPOT-adjustment Hannover resulted in a vertical accuracy larger than horizontal accuracy times height-to-base-ratio. But in this case the horizontal control was very good and the height measurement was influenced by the time period between imaging both scenes. Especially the three adjustments of the OEEPE test area Montpellier are demonstrating the effect of the limited quality of the horizontal control, but the standard deviations of the x-parallax are showing that there is no or just a limited influence to the vertical accuracy.

The vertical accuracy achieved at control and check points is not the same like at grid points for a digital height model (DHM). The grid points are located also in areas with poor contrast.

sensor	p	h/b	pointing	absolut
MC	60%	3.3	7.8m	22m
MC	20%	1.7		11m
LFC	60%	1.7	3.2m	11m
LFC	20%	0.8	1.5m	5m
SPOT pan	-	2.9	8.6m	22m only 38%
SPOT XS	-	3.4	8.4m	36m
KFA 1000	60%	8.0	16.3m	15m

Table 3: accuracy of height measurements (test areas in Germany)

The pointing accuracy of grid points is ranging between ±2.5μm and ±7.4μm standard deviation for the x-parallax. This is corresponding to usual aerial photos. But there is usually a larger difference to the absolute height determination. In table 3 only for the KFA 1000 the pointing accuracy is close to the absolute accuracy. Especially for the KFA 1000 in other areas there was a large discrepancy between both, caused by the limited film stability and it was necessary to use a height correction for model subareas (approximately 5km*5km) to split of the systematic effects.

The results achieved with the SPOT images are disappointing. The absolute accuracy of the grid measurements are quite different from pointing accuracy. In areas with poor contrast the pointing is very difficult. Control points are located only in areas with high contrast, by this reason the results at the control points are much better. In addition in the model of the panchromatic SPOT scenes only 38% of the points could be measured. One scene is from June, the other from August. During this period the grain is chainging it´s colour from green to yellow. By this reason in large areas no stereoscopic pointing is possible.

3.3 Handling of SPOT data

The bundle adjustments of the SPOT data were made with program BLASPO of the program system BLUH. This program is using the orbit data, that means, for every image point another projection center located on the orbit. The first version of BLASPO was based on the ephemeries included in the SPOT header data. If SPOT film products are used, very often these header data are not available for the operator. By this reason BLASPO was modified. Now only the standard orbit data (semi major axis, inclination and excentricity) are used. With the sensor orientation (ψx, ψy), the image points and the control points the actual orbit data are computed. An improvement of the semi major axis and the inclination is possible. The handling of such a SPOT-bundle adjustment is very simple and the results are the same like based on the ephemeries.

The partitioning of the SPOT data into scenes is just a question of organisation. By this reason the scenes of the same orbit can be joined together and be handled as one long scene in the bundle adjustment. Only 4 control points have been necessary for the orientation of such a model with a size of approximately 200km*60km (see figure 6). Based on 4 control points in the OEEPE SPOT-test area Grenoble the accuracy shown in figure 6 was reached, this is the same like for the individual pairs of scenes.

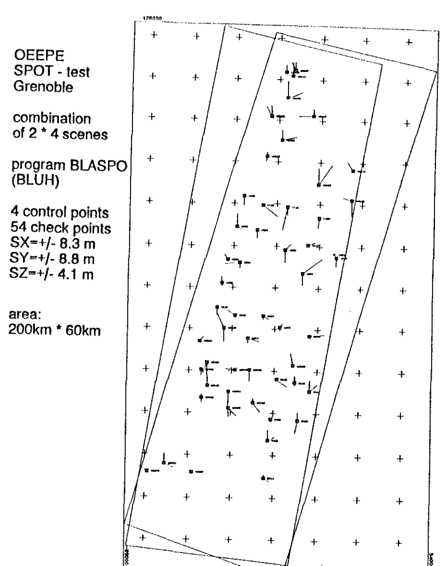


Figure 6: results of the block adjustment of a combination of 2*4 SPOT scenes

4. Cartographic Information of space images

The mapping with space images is not restricted by the geometric quality in X and Y. The vertical accuracy is only sufficiant for contour intervals of 50m to 100m, but for map updating no height information is required. So the semantic information included in the space images is more important than the geometric aspects. The semantic information is depending upon the ground resolution, the spectral information and the contrast. As a rule ot thumb, a ground resolution of at least 0.2mm in the map scale is required, but if it is exceeding 5m, some important information will be lost.

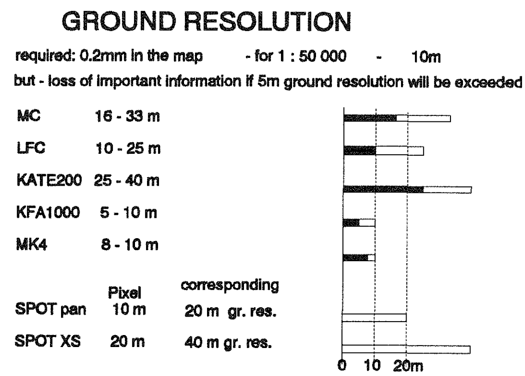


Figure 7: nominal ground resolution

Corresponding to the mentioned rule of thumb for the ground resolution topographic maps 1:50000 should have at least a ground resolution of 10m. But also with 10m ground resolution some objects, important for mapping, are not visible.

The ground resolution of the MC and LFC listed in figure 7 was determined with the available images. The data for the KATE 200, the KFA 1000 and the MK4 are published by Sojuzkarta. These data are to optimistic, especially the specifications for the MK4. The MK4 can be compared with the LFC (same scale, forward motion compensation and similar film), which has a ground resolution between 10m and 25m. The pixel size of the SPOT data can be compared with the ground resolution by multiplication with 2.0. The Kell-factor for the comparison has the value 2.8 but the contrast of the digital data is usually better, so by experience the factor 2.0 is more realistic.

Many tests for mapping with space data have been made in the University of Hannover. For practical applications the operational systems are important, by this reason the results achieved with the Metric Camera and the Large Format Camera are shown only with 2 examples.

camera area	MC Sittensen	LFC Helmstedt
highways	100 %	100 %
roads	57 %	93 %
railroads	96 %	88 %
field pathes	13 %	90 %

Table 4: completeness of mapping in 1:50000

It is not easy to compare the completeness of mapping with different sensors in different areas. This may cause misleading results. For example the mapping of railroads was more complete based on MC-data than on LFC-images. In the case of the Large Format Camera the railroad was crossing a forest. The results listed in table 4 are demonstrating that the poor ground resolution of the Metric Camera is not sufficiant for mapping in the scale 1 : 50 000. The results of the LFC are not bad.

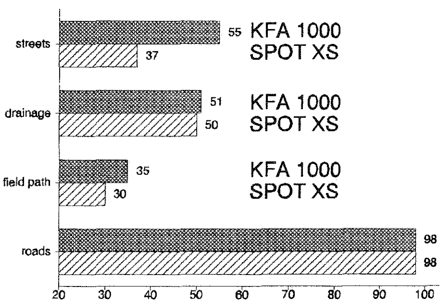


Figure 8: completeness of mapping in 1:50000 SPOT XS / KFA 1000 area: Stadthagen

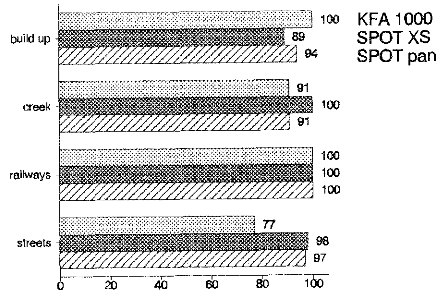


Figure 9: completeness of mapping 1:25000 KFA 1000 / SPOT XS / SPOT pan area: Wustorf

In two test areas close to Hannover in the Northern part of Germany the completeness of mapping with SPOT images and KFA 1000 photos have been compared (see fig. 8 and 9). The results are not very different. In the area of Stadthagen it was more easy to identify the streets in the KFA 1000 images, in Wunstorf it was reverse. But in areas with good contrast, the better ground resolution of the KFA 1000 images enabled the identification of more details. Especially in the not so dense build up areas individual buildings can be identified (fig 11 - 13). In downtown areas the lower contrast of the KFA 1000 is a disadvantage against SPOT images. The double pixel size of the multispectral SPOT images in relation to panchromatic SPOT images is mainly compensated by the spectral information. Creeks can be identified more easy in multispectral SPOT images than in panchromatic. The high contrast in the near infrared is supporting the identification of water surfaces.

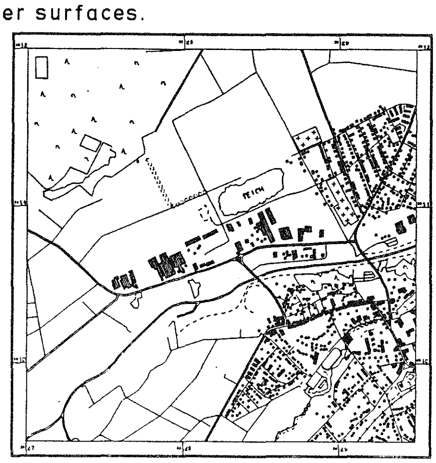


Figure 10: mapping with hight altitude photos photo scale 1 : 120 000, area Wunstorf

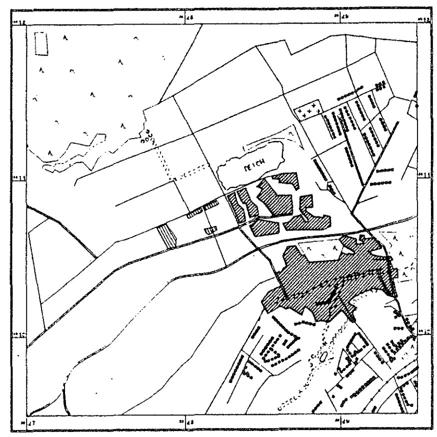


Figure 11: mapping with KFA 1000 images

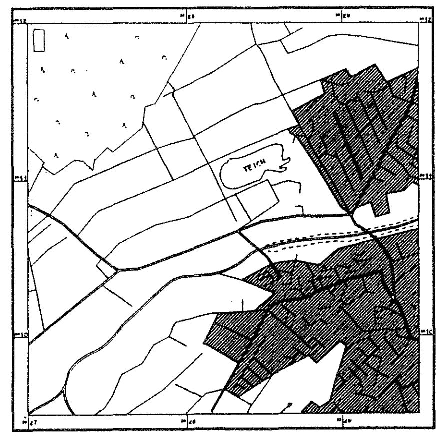


Figure 12: mapping with panchromatic SPOT images

Figure 13: mapping with multispectral SPOT images

The efficiency of the different space photos from Sojuzkarta were compared in the area of Montpellier with the photos distributed by the OEEPE.

	without map			supported by map		
	KFA	MK4	KATE	KFA	MK4	KATE
highway	100	100	100	100	100	100
road wide	97	89	61	97	96	61
road narrow	55	31	28	83	44	28
by-street	49	35	24	59	30	40
field path	23	6	4	29	16	10
railway	100	100	100	100	100	100
river	100	100	100	100	100	100
creek	76	59	53	76	68	53

Table 5: completeness of mapping in 1:50000 [%], OEEPE test area Montpellier

Figure 14: mapping with KFA 1000 images OEEPE test area Montpellier

Figure 15: mapping with MK4 images

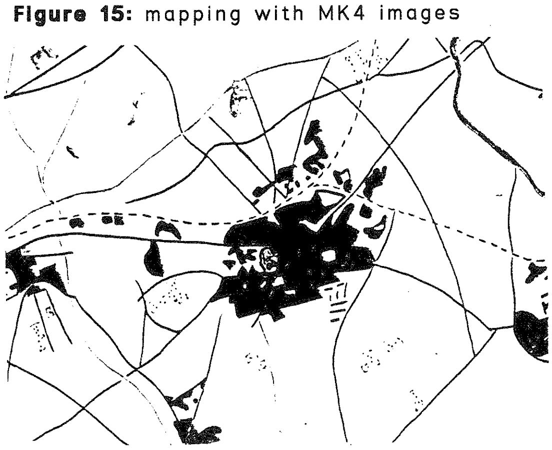


Figure 16: mapping with KATE 200 images

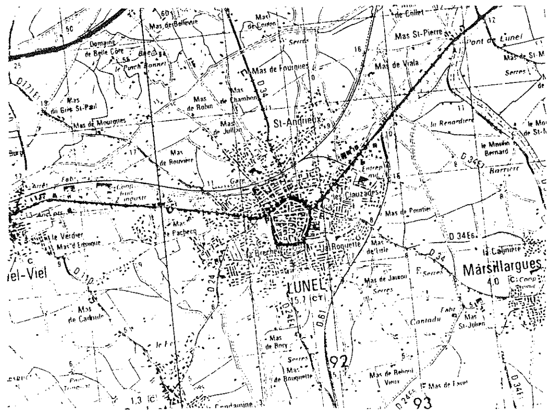


Figure 17: topographic map 1 : 50 000 OEEPE test area Montpellier

As shown in table 5 the completeness of mapping with KFA 1000, MK4 and KATE 200 images in relation to the existing topographic map is quite different. It is clearly depending upon the ground resolution. The poor resolution of the KATE 200 enables not the identification of important details. KFA 1000 images without doubt are better than the MK4 images. The images were used in the first step without support of the existing topographic map. Table 5 shows the results in the left part. Missidentifications are not separated, they are included in the correct class. In a second step the mapping was supported by the topographic map 1 : 50 000. Of course no missidentifications are possible but also a lot of elements can be identified if preinformation are available. So for example in the MK4 model 89% of the roads with 2 lanes (road wide) have been identified without map support and 96% with map support or in the KFA 1000 model the completeness of the by-streets raised from 49% to 59%. The total length of lines which is dominated in the test area by the by-streets, followed by field pathes raised with map support for the KFA 1000 model from 56.1% to 64.7%, for the MK4 model from 42.7% to 49.3% and for the KATE 200 model from 33.8 % to 37.8%.

If no information about the mapping area is available missidentifications cannot be avoided. The city of Kanchipuram, India was mapped based on panchromatic SPOT images in cooperation with the Anna University, Madras. After a first mapping an intensive field check was made. Based on the result of the field check the missidentifications of the roads and railways disappeared. Missing street connections and also parts of the railway hidden by trees can be identified after field check. The missing 17.7% of the highways could be plotted afterwards. After field check no important information are missed.

5. Conclusion

With the exception of the KATE 200 the necessary horizontal accuracy for mapping in the scale 1 : 50 000 can be reached without any problem. The limited vertical accuracy enables only contour intervalls of 50m to 100m. The direct measurement of contour lines is possible with special software for analytical plotters develloped in the University of Hannover but it is only possible in mountainous regions. The messurement of grids of height points should be prefered. But the height information is only necessary for new maps, not for map updating. Especially the height measurements are negative influenced by the time period between imaging both SPOT scenes. The advantage of a possible good height-to-base-ratio of SPOT images are more theoretical because only a very limited number of such models are existing.

Caused by the poor resolution the KATE 200 images are not sufficient for mapping. Also mapping in smaller scales than 1:50000 cannot be done because important elements are not visible. If different actual space images are available KFA 1000 images should be prefered against SPOT images but the difference between both is not very significant. MK4 images are also usable for mapping 1:50000. They do have the advantage of a more simple handling similar to usual aerial photos. With a loss of the geometric accuracy they can be used also in analog stereo plotters. The charge for the different space images is very similar but the covered area is different. MK4 images are covering approximately 26000km^2, KFA 1000 images 6800km^2 and SPOT scenes 3600km^2. But the economic handling of the space images is much more dominated by the expenses for the data aquisition.

A field check is necessary to avoid miss-identifications and for raising the completeness of mapping. But this is also the case (on a lower level) for usual aerial photos.

In general space images are offering an economic possibility of mapping and map updating in the scale 1 : 50 000. Of course not so many details can be identified like in aerial photos. But for a lot of applications it is sufficiant and much better than the use of old, not updated maps. For civilian use no problem of classification is existing which is the case in many countries, especially in develloping countries. By this reason space images may solve also problems for large projects where no or no actual maps are available.

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