

## EXAMPLES OF TOPOGRAPHIC MAPS PRODUCED FROM SPACE AND ACHIEVED ACCURACY

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### ABSTRACT:

The Institute for Photogrammetry and Engineering Surveys has conducted tests to establish the topographic mapping potential with a number of French, Russian, Indian and German high resolution sensors with resolution varying from 20m to 0.8m pixels. These tests carried out over test sites in Lower Saxony (Wunstorf, Göttingen) are presented.

Only sensor systems with pixel sizes better than 6m are suitable for mapping production of topographic maps 1 : 50 000. Updating may be possible with 6m pixel size for a scale 1 : 25 000.

The lower resolution images may be useful, however intensive field checks are required. The overall procedure of using lower resolution images is not recommended.

Pixel sizes of 1m or better fulfill the capability of mapping at scales up to 1 : 10 000 or updating scales up to 1:5000.

### 1. Sensors

The first not classified high resolution sensors used in space have been photographic sensors. The first commercial digital sensor with a very high resolution is IKONOS-2, which is operational since January 2000, but with these images up to now in the University of Hannover no maps have been created because up to now no images are available over Germany.

sensor	f [mm]	image size [mm]	flying height [km]	covered area [km]	ground resolution [pixel]	height / base - ratio
<i>KFA1000</i>	1000	300•300	220 / 350	66•66 / 105•105	2.5 – 5	8.2
<i>KFA3000</i>	3000	300•300	220 / 350	22•22 / 35•35	1 – 2.5	no stereo
<i>KVR1000</i>	1000	180• (180)	220 / 350	26•(26)	1 – 2.5	no stereo
SPOT	(2086)	(150•150)	830	60•(60)	10/20m (digital)	up to 1.0
MOMS-02	220/ 660	6000 pixel/ 9000 Pixel	295	78• ... 37•...	13.5/4.5m /digital)	1.3
MOMS-2P			390	100•./48•.	16.5/5.8m	1.3
IRS-1C/1D PAN	980	12 000 pixel (3•4096)	817	70•(84)	5.8m/23.5m (digital)	up to 1.0
DPA ms (airborne)	40	6 000 pixel	(3.2)	(4.5)	(0.8) (digital)	-
DPA pan	80	12 000 pixel	(3.2)	(4.5)	(0.4)	1.1

table 1: technical data of the used high resolution sensors

In table 1 the photographic ground resolution is shown in pixel size, based on the relation: 2 pixel = photographic ground resolution. The relation is more complicate, but this is sufficient, because for the photographic resolution only approximate values are known. Also the pixel size includes only a limited information about the elements which can be identified in the images – this is strongly depending upon the contrast.

The listed sensors have been used beside others with lower resolution by the University of Hannover for mapping purposes. The first three are high resolution Russian photographic cameras. The KFA1000 and the KFA3000 are perspective cameras. Because of the long focal length of 3m, the area covered by the KFA3000 is very limited, so a stereoscopic coverage is not possible – it would correspond to an imaging sequence below 2 seconds. This not often used camera is operated in a tilted mode, so for orthophotos a higher vertical accuracy is required than corresponding to the focal length. The KVR1000 (sometimes also named KWR1000) is a panoramic camera with the typical high resolution, it is still in use and has covered the largest part of the world. The black and white images of the KVR1000, also distributed in digital form as SPIN2-images (1.5m pixel size) are usually used together with the TK350 for getting also a stereoscopic coverage.

The problems caused by the loss of SPOT 3 have been solved now with SPOT 4, launched at March, 24,1998. SPOT 4 has the advantage of an additional mid infrared band, corresponding to IRS-1C and IRS-1D which is useful for the classification of vegetation. But for usual mapping purposes the ground resolution of 10m for the panchromatic mode and 20m for the multispectral mode is limiting the use.

The German modular optical multispectral sensor MOMS was used as MOMS-02 during the German Spacelab Mission D2 in the spring 1993 and is on the Priroda module of the MIR space station as MOMS-2P since 1996. It has the advantage of a viewing with the high resolution pan-channel and 4 different spectral bands to the nadir and with one panchromatic band forward and with another afterward, so a stereoscopic coverage is directly available. But the MOMS-2P is affected by all the problems of the MIR station, so only few images have been taken

The Indian Remote Sensing Satellite IRS-1C, launched in 1995 and the identical IRS-1D, launched in 1997 are equipped with a high resolution panchromatic camera (PAN), which can be rotated across the orbit, enabling a stereoscopic coverage like SPOT, with a linear self scanning camera (LISS, 23m pixel size, 4 spectral bands) and a wide field sensor (WiFS). The PAN-camera has against SPOT the advantage of a better ground resolution (5.8m pixel size) and a larger swath width, but the field of view is separated to 3 linear sensors for which the relation has to be determined.

The development of the DPA by the German DASA was influenced by the space applications. It is designed and it was used in an aircraft, that means the images cannot be compared directly with the space images, the pixel size is much smaller depending upon the actual flying height. Like the MOMS it has a stereoscopic coverage based on the combination of a forward, a nadir and an afterward view. The use of a line sensor from aircraft is different from the use in space, because it is affected by the not regular movement of the aircraft. By this reason it must be operated together with GPS and INS. The synchronous operation of the systems has to be guaranteed which was not the case all the time. Of course it cannot be compared with the very high precision which is possible by aerial cameras, but it enables a direct digital imaging without the time consuming and also costly scanning of photos.

## 2. Geometric Accuracy

The geometric potential of the different sensors can be checked by a block adjustment. This is not resulting in the same accuracy like for the determination of usual object points and heights, because only well defined points are used for control. The correct mathematical model is required. The KFA1000 and the KFA3000 are central perspective cameras, for which the usual colinearity equation is valid, but the existing systematic image errors are requiring an improvement by additional parameters based on control points. The panoramic images of the KVR1000 have been handled with a panoramic correction supported by additional parameters. For the satellite line scanner images the perspective model is only existing in the sensor line. In the other direction, the lines are connected by the satellite movement and rotation, which is approximated in the used program system BLUH by a space oriented ellipse. In the case of the IRS-1C, the 3 sensor lines had to be connected by special additional parameters (Jacobsen, 1997).

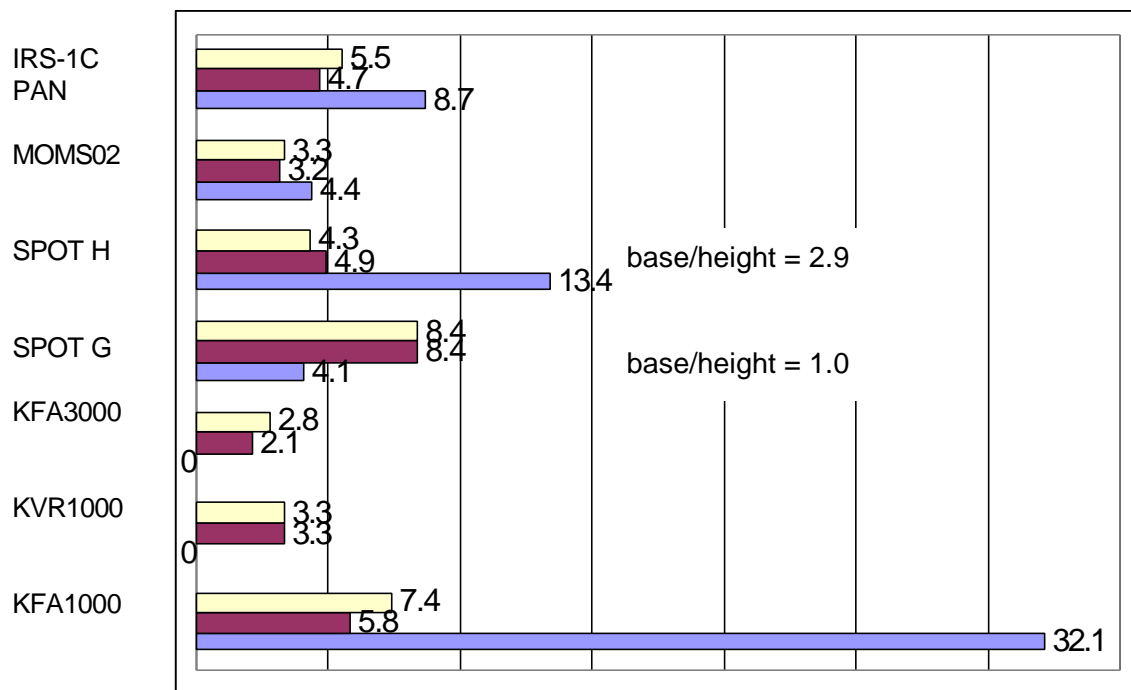


figure 1: accuracy achieved with space images

The achieved horizontal accuracy is sufficient for mapping in the scale 1 : 25 000 (0.25mm are corresponding to 6.25m). The limited accuracy of the SPOT-test-area Grenoble (SPOT G) is caused by the limited horizontal quality of the control points as it can be seen in comparison to the SPOT-test-area Hannover (SPOT H).

The situation for the height is more complicate – there are no fixed rules for the required standard deviation, because it is depending upon the area. Caused by the missing stereoscopic function, the height cannot be determined with KVR1000 and KFA3000 images. In the case of SPOT and also IRS-1C (-1D), the vertical accuracy is depending upon the base to height relation. This is the limiting factor for the KFA1000. The best relations are existing for MOMS with the stereoscopic coverage within the orbit.

### 3. Mapping of test area Wunstorf

For the planimetric representation a stereometric capability is not required if the height information is available. An orthophoto can be used for mono plotting, but nevertheless a stereoscopic view is supporting the object identification.

As a rule of thumb, the pixel size on the ground shall not exceed 0.05 up to 0.1mm in the map scale, corresponding to 1.25 up to 2.5m for mapping in the scale 1 : 25 000. If this condition cannot be matched, not the whole required map contents can be extracted. The range between the lower and the upper value of this rule is depending upon the structure of the area, the national map standards and the imaging conditions.

For the area of the city Wunstorf, located close to Hannover, IRS-1C PAN-, multispectral and panchromatic SPOT-, KFA1000-, KVR1000- and high altitude photo flight images (1:120 000) are available. All images have been used for mapping. The IRS-1C PAN-images do have a quantization of 6bit or 64 different gray values and they have been taken in December 1996 with a sun elevation of just 13°. The poor contrast of the original images was improved with a not linear look up table resulting in satisfying images. Long shadows in the case of the IRS-1C PAN-images are disturbing the object identification, nevertheless nearly all objects available in the topographic map 1: 50 000 could be mapped. With the KVR1000 images there was no problem, the higher resolution made the mapping more easy. There was no doubt with the optimal results based on the high altitude photos with a photo scale 1 : 120 000 corresponding to a ground resolution of 3m/lp or a pixel size of 1.5m. With these images all details of the topographic map 1:25000 could be seen.



figure 2: IRS-1C test area Wunstorf



figure 3: KVR1000 test area Wunstorf

Not only the pixel size is important, the spectral information supports the object identification. So in spite of the different pixel size, the information contents of the panchromatic and the multispectral SPOT images was approximately the same. In the multispectral images the water bodies do have a good contrast and can be identified

more easy than in the higher resolution panchromatic images. But in general the pixel size of SPOT with 10m and 20m is not sufficient for the creation of maps with the contents of German topographic maps 1 : 50 000. Especially the details in the build up areas cannot be seen. Only wide streets can be identified and in the rural areas a separation between a boundary line with a hedge and a small road is not possible. No individual buildings, even if they are large, can be recognized.

The situation with the KFA1000 is better, only in the city itself the identification of streets is difficult. In the area outside the city with individual houses, individual buildings can be mapped.



figure 4: SPOT PAN test area Wunstorf

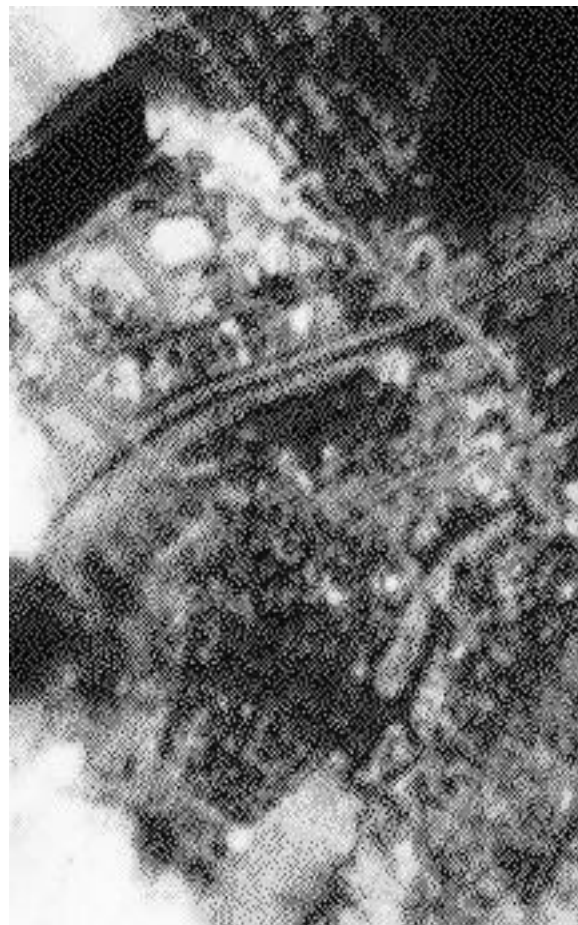


figure 5: KFA1000 test area Wunstorf



figure 6: topographic map 1 : 25 000  
test area Wunstorf

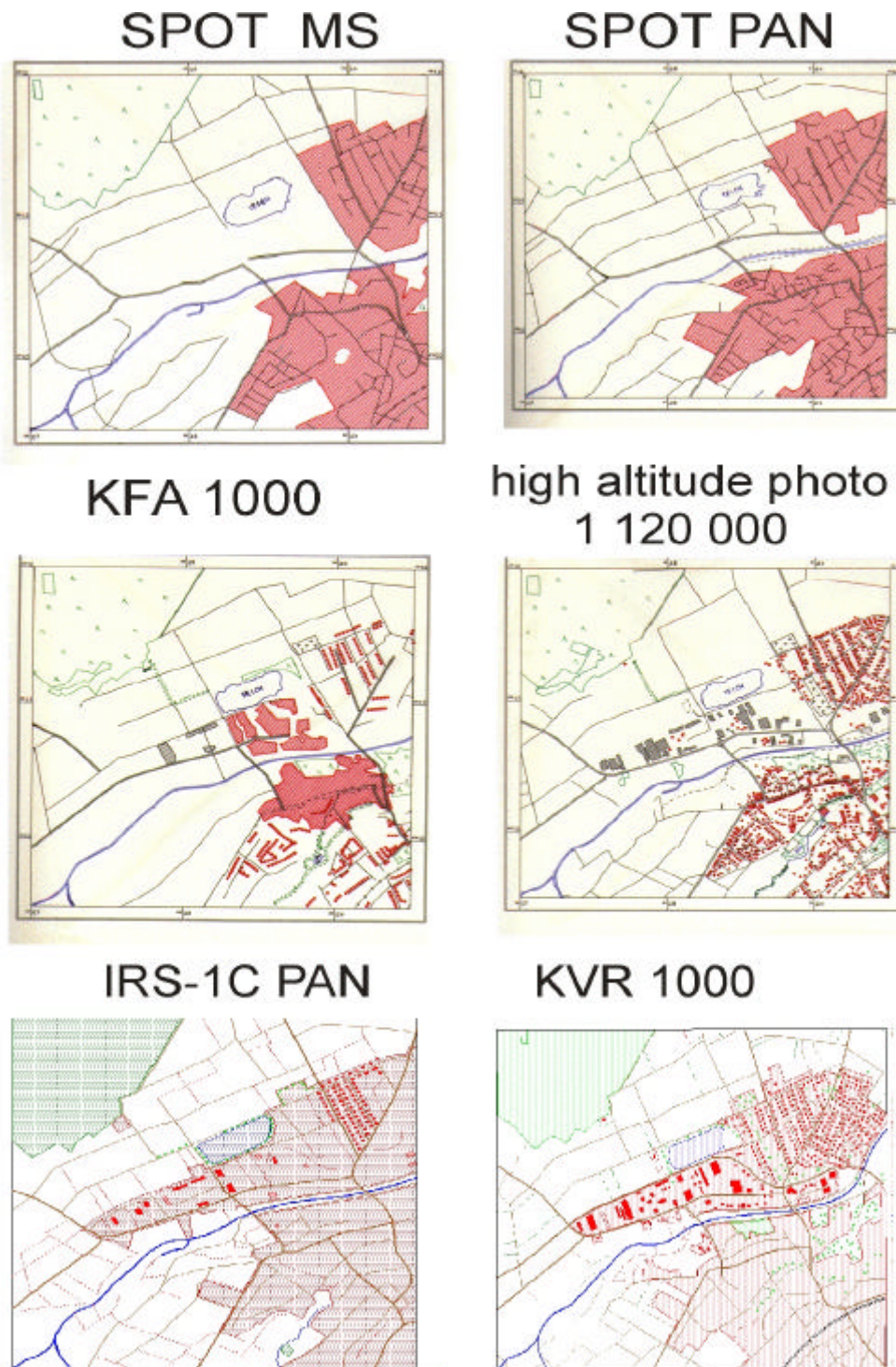


figure 7: test area of Wunstorf mapped with different space images

#### 4. Mapping of test area Göttingen

In the area of Göttingen, 100km south of Hannover, the possibility of updating ATKIS with spaceborne and airborne digital data have been checked in comparison to traditional aerial photos. The Authoritative Topographic-Cartographic Information-System (ATKIS) of the survey administration is the digital representation of the topographic maps in the scale 1 : 25 000. It is generated by digitizing the existing topographic maps, but it has to

be updated by means of photogrammetry. The usual photo scale of 1 : 12 000 corresponds to a pixel size of 15cm. This is not required for mapping in the scale 1 : 25 000, but the same images are used also for updating the maps 1 : 5000.

Beside the aerial photos, IRS-1C images and the DPA have been used. The airborne DPA was developed by the Deutsche Aerospace AG (DASA), influenced by the spaceborne sensors. The stereo module has 3 CCD lines, each with 12 000 pixel. The CCD lines do have a convergence angle of  $\pm 25^\circ$ . The field of view across flight line is  $\pm 37^\circ$ . The spectral mode has 4 CCD lines in the nadir direction ( $0.44 - 0.524\mu\text{m}$ ,  $0.52 - 0.60\mu\text{m}$ ,  $0.62 - 0.685\mu\text{m}$ ,  $0.77 - 0.89\mu\text{m}$ ) and covers with 6000 pixels the same field of view. In the case of the test area Göttingen it was used from 3.2km flying height, corresponding to a pixel size of 0.8m for the multispectral mode which has been used for mapping.

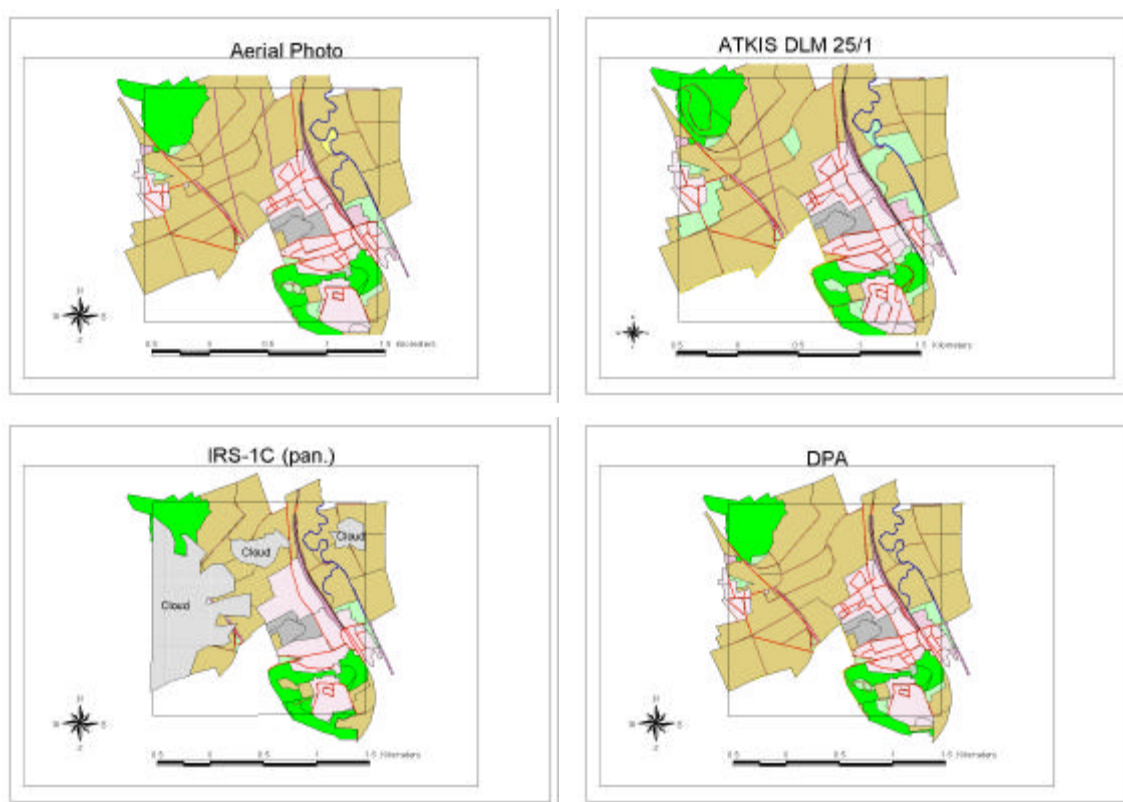


figure 8: mapping of ATKIS contents based on aerial photos, IRS-1C- and DPA-images in comparison to the original ATKIS digital landscape model 1 : 25 000

The ATKIS digital landscape model 1 : 25 000 originally is based on old existing maps and aerial photos with the scale 1 : 12 000. By this reason the whole contents could be reached with the aerial photos. In the DPA-images only the towers of a high tension power line could not be seen, so a pixel size of 0.8m is sufficient for the map scale 1 : 25 000. The IRS-1C PAN images are with 5.8m pixel size beyond the limit for the required resolution - 1.25 up to 2.5m pixel size should be available. Corresponding to this, in the densely build up areas no individual buildings could be identified, but they are also not available in the topographic maps 1 : 25 000. The mayor disadvantage of the lower resolution are the problems of the identification of streets in the densely build up areas. Most of the other parts could be identified, that means, the IRS-1C-images are useful for this scale if the mapping is supported by a field check.

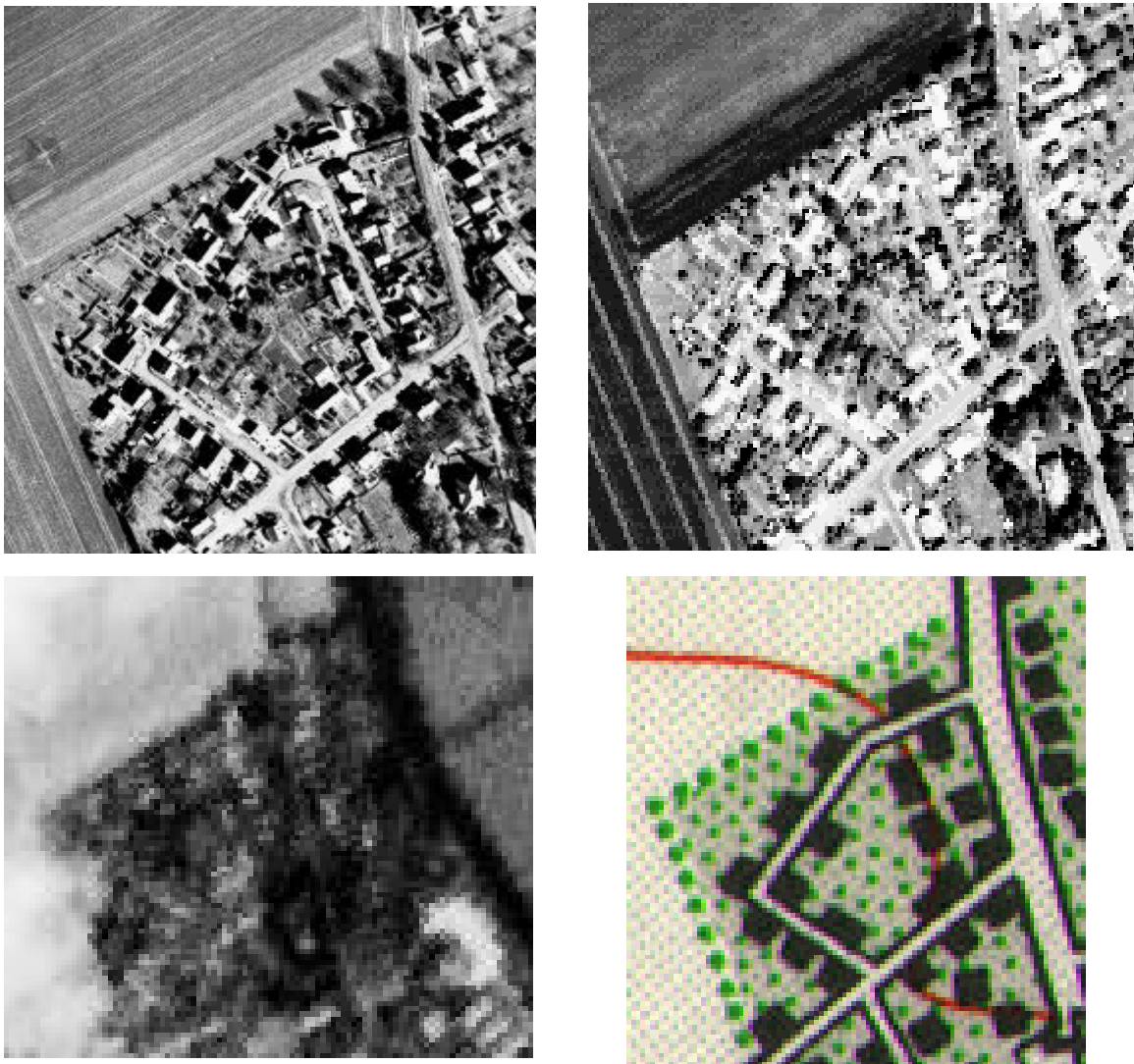


figure 9: sub area Göttingen imaged by aerial photo 1 : 12 000 (upper left), DPA (upper right), IRS-1C (lower left), topographic map 1 : 50 000 (lower right)

The different information contents of the used images is obvious in the shown images of figure 6. The very detailed information of the aerial images is not required for the topographic map 1 : 25 000 or 1 : 50 000. With 0.8m pixel size the DPA is on the same side, only for the IRS-1C-images additional information are required for mapping in this scale.

## 5. KFA3000

Images taken with the KFA3000 have been available for us only in the area of Vienna, so a direct comparison of the image contents was not possible. But also in the same area it is not so easy to compare it directly – the time of the year, in some cases also the time of the day and the atmospheric condition are different and sometimes also the area itself has been changed. So only a general tendency can be seen.



The image contents of the KFA3000 is very similar to the KVR1000, this corresponds also to the same ground resolution. The images of both cameras can be used for mapping in the scale 1 : 25 000 without any problem.



figure 10: Vienna imaged by the KFA3000

## 6. IKONOS-2

The very high resolution space sensor IKONOS-2 is operational since January 2000. With a pixel size which is in the range of 0.82m in nadir images and 1.6m for images taken at a view angle of 45° also details required for large scale mapping can be identified. In the raw images the pixel size in the orbit direction is always 0.82m, because this is only depending upon the sampling time interval, which is constant. In the direction across the orbit the pixel size can be computed by:

$$\text{pixel size across orbit} = 0.82\text{m} / \cos^2(\text{view direction})$$

So under a view direction of 45° the pixel size is 0.82m x 1.6m – corresponding to an area of 1.2m x 1.2m, or with a view angle of 25° the area covered by a pixel is 1m<sup>2</sup>.

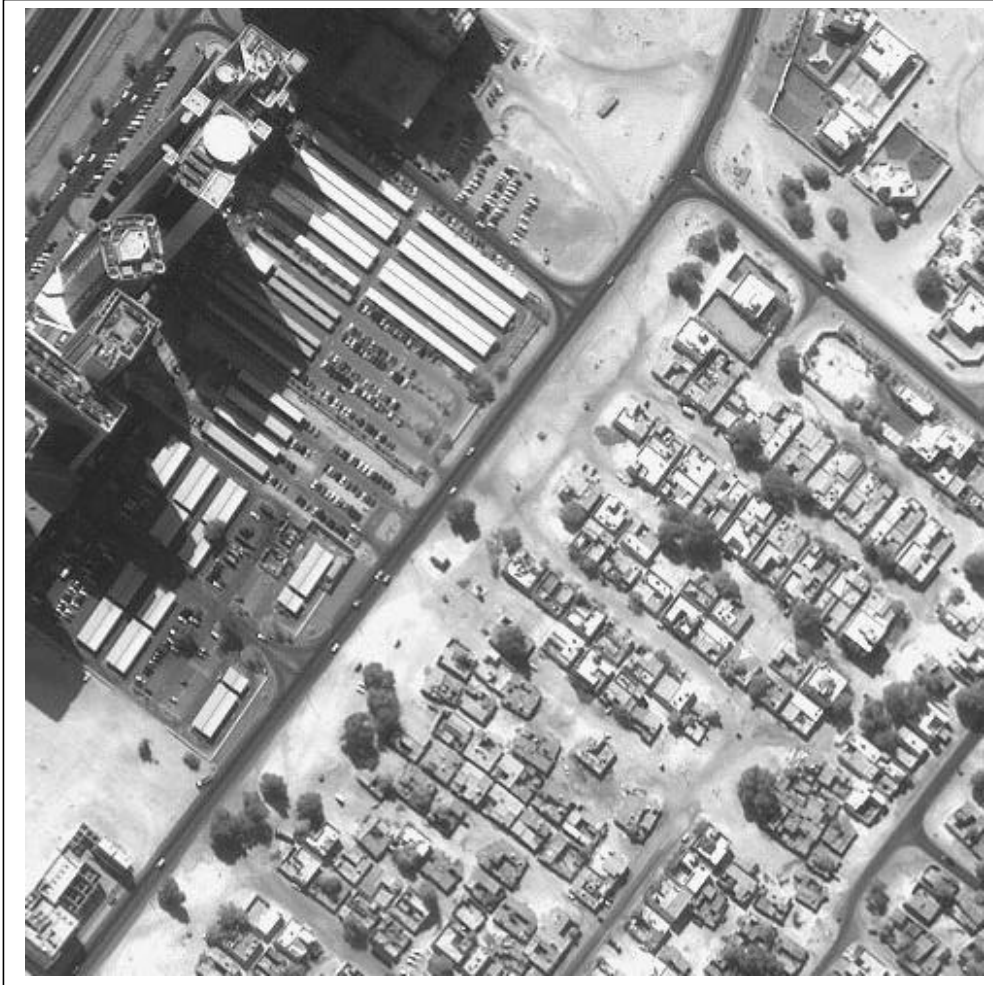
Corresponding to the rule of thumb, the pixel size of 1m allows the creation of maps with a scale between 1 : 10 000 and 1 : 20 000. A map with a scale of 1:10 000 should have an accuracy of 0.25mm x 10 000 = 2.5m. This is in the

range of the IKONOS-product "Precision Plus", that means it is not so simple to

be  
achieved

figure 11

IKONOS  
city of  
Dubai



In figure 11, the available details in a part of an IKONOS-image can be seen. It demonstrates, that the estimation of the usable map scale is correct.

## 7. Conclusion

The rule of thumb for the required pixel size in relation to the map scale of 0.05 up to 0.1mm pixel size in the map has been confirmed. The image contents is mainly depending upon the resolution. Of course the radiometric quality and the spectral information is also important, but this corresponds to the band width of 0.05 to 0.1mm pixel size. Also the stereoscopic impression is supporting the object identification and the required map contents is as different as the object structure itself. The mapping of a city in India requires a higher ground resolution than the mapping of a rural area in the United States.

The availability of actual images under economic conditions is very important, this is just now the major bottle neck. Space images are available not in any case,

but this is improving permanently, so for example the access to the Russian space images has been solved, but very often they are not actual. Only few areas are covered with high resolution stereo images – of course also taking of images can be ordered, but depending upon the weather conditions this is sometimes very time consuming and the order conditions in some cases cannot be accepted, for example nobody likes pay for images with clouds. But in general space images can be used for mapping purposes and the situation has been improved with the first very high resolution space system which will be followed by others. For the operational use, the economic conditions are important – if for example in Germany existing aerial photos are less expensive than the space images, nobody will use the space data.

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