STATUS AND TENDENCY OF SENSORS FOR MAPPING

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ABSTRACT:

The number of sensors in space usable for mapping is growing. Several new sensors are announced for the near future and several proposals are existing. Influenced by the increased availability and improved ground resolution a strong progress of the use of space images will be made very soon.
Based on the development of the space technology, line sensors for stereoscopic coverage are now available for use in aircraft. In addition also the first commercial CCD-array cameras especially designed for use in aircraft are distributed.
Not only passive imaging, also active sensors have to take into account. For special applications and especially in the tropic area Synthetic Aperture Radar has to be respected. Laser scanning from aircraft's can be an economic solution for the determination of digital height models.

1. INTRODUCTION

The Open Sky agreement of the United Nations has opened the field for the commercial use of very high resolution satellite images. Former classified data are now available for civilian use and the launch of commercial earth observation satellites is possible and announced.

The today highest resolution space images available for commercial use are still the Russian photos. The distribution problem has been solved by cooperation's with Western companies, but the photos never can be so actual like digital data. With a pixel size of 5.8m represented by IRS-1C /1D higher resolution digital space images can be used than before. Starting in 1998 digital space images with 1m-pixel shall be available.

The Synthetic Aperture Radar (SAR) sensors like RADARSAT, ERS and JERS used in space, but also airborne systems do have special functions in areas with more or less permanent cloud coverage and for specific problems. Laser scanning airborne systems are becoming more important for precise determination of digital height models. Influenced by the progress in digital photogrammetry digital sensors based on CCD-arrays and CCD-line scanner are used more often in aircraft's.

Only the systems usable for mapping and now active in space in addition to the systems prepared for launch in the near future and the new ones used in aircraft's are listed. The experimental cameras like Metric Camera, Large Format Camera and the low resolution cameras like KATE200 which are not important for up to date mapping are not included in this paper. Because of the exponential growing number of announced and proposed sensors for use in space it is difficult to give a complete overview. Not all proposed systems will survive and some will fail and most of them are or will be delayed. A. Watkins created the „CommingSoonSat" which will be launched if enough venture capital have been raised - this was exactly the situation for several proposals, but the situations seems to be now better. But nevertheless the number of launched satellites usable for mapping will be extended. Corresponding to the announcements and proposals, in the next 4 years, in the mean more than 8 earth observation satellites with high resolution shall be launched per year.

There is the tendency from national or state supported programs to purely commercial projects. So the coming up Landsat 7 is announced as the last of it's serious. But nevertheless also the commercial sensors are mainly based on state funded projects. In addition to the traditional mapping now new applications are coming up, so the Resource 21 serious is mainly based on applications in the field of precise agriculture or computer aided farming systems. Also Matra Marconi Space likes to go with the XSTAR-proposal into this market segment. This is based on the always now existing market power. Eurimage is selling now 35% of all space images in the field of agriculture, 20% in the area of oil and gas exploration and only 15% for mapping, the same percentage like for the examination of natural resources. The trend to the commercialization includes the trend to smaller, cheaper and not so heavy systems. The huge remote sensing satellites with several instruments can only be financed by a governmental organization. The continuity and easy access of the data sets also have to be guaranteed otherwise the value adding industry will not accept the systems. If the companies operating the satellites only like to sale the final products and not the original images, they will fail or they will fail in the field of mapping or they will be limited to some special niches.

2. PHOTOGRAPHIC CAMERAS USED IN SPACE

The earth observation started with photographic cameras used for national security reason. The United States of America have had the Corona project, where the film was dropped, the Sowjet Union has brought back the whole satellites for a re-use. The very high resolution camera KVR1000 together with the TK350 is used in the Komet class satellites with up to now 163 missions. The next missions are always fixed and also oriented more to the civilian use. Now also South America will be imaged - this area was unimportant during the cold war for both sides.

sensor	KFA 1000	MK4	KFA 3000	KVR 1000	TK350
f [mm]	1000	300	3000	1000	350
image size [mm]	300 x 300	180 x 180	300 x 300	180 x (180)	300 x 450
flying height [km]	220 / 350	220 / 350	220 / 350	220 / 350	220 / 350
covered area	66 / 105	132 / 210	22 / 35	40x180 64x280	200x300 310x470
ground resolut. [m/lp]	5 - 10	10 -15	2 - 5	2 - 5	10 - 15
height-base-ratio	8.2	4.2	no stereo	no stereo	1.8

table 1: technical data of photographic space cameras

Only Russia is using today photographic cameras in space. The problem of the access to the excellent data has been solved by cooperation's with Western companies. So beside other distributors, the images of the panoramic KVR1000-camera are available as digitized data with 2m pixel size and the simultaneously used TK350 with 10m pixel size on the ground as SPIN-2-data in the internet. The TK350 can be used for the determination of a digital height model which is required for the mono-plotting or orthophoto generation with the KVR1000 images because there is no stereo overlap for these.

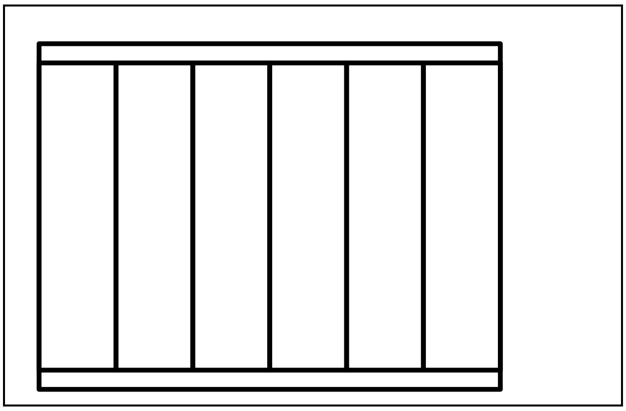

figure 1: combination of 1 TK350-photo with 6 KVR1000-photos

The KVR1000 photos can be ordered also as photographic copies. In this case they are delivered as partial copies with a size of 180mm x 180mm.

The resolution of the photos taken by the frame camera KFA3000 can be compared with the KVR1000. Also this system has no stereoscopic overlap - this is not possible for a covered area of just 22km x 22km , otherwise the imaging interval should be 1.2sec. The KFA3000 is stearable, so for orthophoto generation or mono-plotting a vertical accuracy of two times the required horizontal accuracy must be guaranteed. The KFA1000 does have a stereoscopic coverage enabling a 3-dimensional mapping, but because of the poor height to base relation the vertical accuracy is limited to approximately +/-15m.

For mapping as a rule of thumb, the ground resolution in [m/lp] should be in the range of 0.1 up to 0.2mm in the map scale, corresponding to 5m - 10m for the map scale 1 : 50 000. The range in this rule of thumb is depending upon the details which should be included in the map and the mapped area itself. Corresponding to this, the KVR1000 and also the KFA3000-images can be used for the map scale 1 : 25 000. If this shall be compared with digital data, 2 pixel are required for one line pair or the pixel size should be in the range of 0.05mm up to 0.1mm in the map scale.

There is no major problem with the use of the Russian space photos for mapping, but nevertheless, photos cannot be so actual like digital data.

3. ACTUAL DIGITAL SPACE CAMERAS

The first system used in space, especially designed for unclassified mapping purposes was SPOT 1, launched in February 1986. It was followed by SPOT 2 and 3. SPOT 1 and 2 are still active. Corresponding to above mentioned rule of thumb, the panchromatic pixel size of 10m is only valid for mapping in the scale of 1 : 100 000, but if the pixel size exceeds 5m, some important elements cannot be identified. A better resolution is now available with the German experimental MOMS-2P, the panchromatic camera of the Japanese ADEOS (active from November 1996 up to June 1997) and the panchromatic camera of IRS-1C and -1D from India.

	launch	camera	pixel	bands	swath -nadir	height/ base
SPOT 1-3	1986 1990 1993	pan multi-spectr.	10m 20m	1 3	60km	up to 1.0 cross track
MOMS-2P	1986	pan multi-spectr.	5.8m 16.5	1 4	37km 78km	1.3 in track
IRS-1C IRS-1D	1995 1997	pan LISS-III	5.8m 23.5/ 70.5 MIR	1 4	70km 142	up to 1.0 cross track
ADEOS	1996	pan multisp.	8m 16m	1 5	80km	up to o.6

table 2: technical data of active digital space systems

The well established SPOT-system is still limited by the resolution. Another disadvantage is the stereoscopic coverage only across track. That means, the corresponding stereo image can be taken only some days later and this can be disturbed by cloud coverage. Sometimes the changes in the object space are too strong to guarantee a sufficient stereoscopic impression. This problem does not exist with the MOMS-camera, 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. But the MOMS-2P is located on the Russian MIR-station and is affected by all the problems, in addition it has to share the power and time with some other projects on the MIR-platform.

The Indian Remote Sensing Satellite IRS-1C and the identical IRS-1D are operational and do have just now the highest resolution of the commercial available digital space images. In addition to the spectral channels corresponding to SPOT, there is an additional mid-IR-channel (1.55µm - 1.70µm) available with some advantages of the vegetation classification. The bands are corresponding to the Landsat bands 2, 3, 4 and 5.

The AVNIR-camera (advanced visible and near infrared) of the Japanese ADEOS-satellite with it's 5 bands in the spectral range from 0.42µm up to 0.89µm can be used also for mapping. With 8m-pixel size the resolution is located between IRS and SPOT. The satellite was lost at June 30, 1997, so the imaging was possible only during a period of 7 month, but these images are still available in the archive.

4. OPTICAL SPACE SYSTEMS UNDER PREPARATION OR ANNOUNCED

Several space sensors usable for mapping are announced for the next few years. The first are always prepared for launch, while the latest are not totally

	company or country	first launch	number of pixel	mode	pixel size (nadir)	swath [km]	pointing in-track	pointing across	height	orbit	storage
Early Bird	Earth Watch	Dec. 97	4CCD-arrays 1048 x 1080	pan multisp. 4 bands	3.2m 15m	3 x 3 15 x 15	+/-30°	+/-28°	470km	sun-synchr	500 frames
Quick Bird	Earth Watch	mid 99	27000 6700	pan multispr 4 bands 11 bit	0.82 3.28	22 22	+/-30°	+/-30°	600km	inclinat. 52	64 scenes
Ikonos	Space Imaging EOSAT	Mar. 98	13816 3454	pan multisp. 4 bands 11bit	0.82 – 2.0 3.2-8	11.3	+/-45°	+/-45°	680	sun-synchr	64Gb
Orb View 3	Orb-image	1999	8000 2000 1000	pan multisp. 4 bands hypersp 280 ban	1 / 2 4 8	8	+/-50°	+/-50°	470	sun-synchr	250-1000 scenes
EROS A	West Indian Space Ltd	1998	10000	pan	1.5	13.5	+/-45°	+/-45°	480	sun-synchr	--
EROS B	West Indian Space Ltd	1999	20000 5000	pan multisp. 4 bands	1 4	20	+/-45°	+/-45°	600	sun-synchr	--
Resours 21	Resours 21	2000	2000	multisp 5 bands	10 20 MIR	205	+/-30°	+/-40°	743	sun synchr	176 Gb
Resours TK	Russia	2000		pan multisp.	1 4	details will be published in January 1998					
IRS-P5	India	1999	12000	pan	1 /2.5	12 / 30	yes		617	sun-synchr	
IRS-P6	India	2000	4096 6000	LISS-4 3bands LISS-3 4 bands	5.8 23	24 140	 --	 --	817	Sun-synchr	
CBERS	Brazil / China	Jul 98	5600	CCD 4 bands	20	113	--	+/-32°	778	sun-synchr	--
SPOT 4	SPOT Image	begin 1998	6000 3000	pan multisp 4 bands	10 20	60	--	+/-27°	830	sun-synchr	8.5Gb
SPOT 5	SPOT Image	2002	12000 6000	pan multisp 4 bands	2.5 10 20 MIR	30 60	+/-19.2°	+/-27°	830	sun-synchr	132Gb
Clark	USA NASA	1998	4 x 1048 x 1080	Pan Multisp 3 bands	3 15	6 30	+/-30°	+/-30°	476	Sun-synchr	1.37Gb
HRST	USA Naval	2000	6000 1024 x 1024	pan hypersp	5 30	30	+/-30°	+/-30°	605	Sun-synchr	48Gb
Landsat 7	USA	Jul 98	1 16	ETM+ pan multisp 7 bands	15 30 60 TIR	185	--	--	705	sun-synchr	375Gb

table 3: technical data of announced space sensors usable for mapping

specified and may be modified, so SPOT5 originally was specified with a pixel size of 5m for the panchromatic sensor and this is now changed to 2.5m caused by the competition with other systems.

The Early Bird 1 is prepared for launch in the period of December 16 up to 20, 1997, a second, identical is under construction. The area covered by Early Bird is very limited caused by the 4 Kodak CCD-arrays with just 1048 x1080 pixel. All 4 sensors together are creating a frame. The panchromatic mode will cover the spectral range from 0.445µm up to 0.65µm, the multispectral mode will cover green, red and near infrared (see also table 4). The standalone geolocation (without control points) shall reach 150m (table 5). Early and also Quick Bird are typical commercial systems, they are much less expensive than other governmental owned satellites. Earth Watch Inc. is owned by Ball Aerospace, Hitachi Ltd, Telespazio s.p.a, CTA Space Systems, Datron Systems and MDA & Assoc. Ltd, that means it is a real international company. Ground stations for Early Bird are located in Alaska, Norway, Colorado and Italy, for Quick Bird they are located in Fairbanks, Alaska and Tromsø, Norway. The first Quick Bird shall be launched late 1998, a second shall follow early 1999.

	pan	band1	band 2	band 3	band 4	
Early Bird	0.445 - 0.65	0.49 - 0.6	0.615 - 0.67	0.79 - 0.875		
Quick Bird	0.45 - 0.90	0.45 - 0.52	0.52 - 0.60	0.63 - 0.69	0.76 - 0.90	
Ikonos	0.45 - 0.90	0.45 - 0.53	0.52 - 0.61	0.64 - 0.72	0.77 - 0.88	
OrbView 3	0.45 - 0.90	0.45 - 0.52	0.52 - 0.60	0.63 - 0.69	0.76 - 0.90	
EROS A	0.50 - 0.90	only panchromatic				
EROS B	0.50 - 0.90	?				
Resours 21 -	0.45 - 0.68	0.45-0.52	0.53-0.59	0.63-0.69	0.76-0.90	1.55-1.68
IRS P5	0.45-0.68	-				
IRS P6 LISS III LISS iV		0.52 – 0.59	0.62 – 0.68	0.77 – 0.86	LISSIV 1.57-1.70	
CBERS CCD	0.51 - 0.73	0.45 - 0.52	0.52 - 0.59	0.63 - 0.69	0.77 - 0.89	
SPOT 4	0.51 – 0.73	0.50 - 0.59	0.61 - 0.68	0.79 - 0.89	1.58 - 1.75	
Clark	0.45 – 0.80	0.50 – 0.59	0.61 – 0.68	0.79 – 0.89		
HRST	0.50 – 0.70	hyperspectral 0.40 – 2.5 with 10nm spectral resolution				

table 4: spectral bands

For Quick Bird different image products shall be available, like stereo covering 22km x 22km, strips with a swath of 22km, areas with 42km x 42km and snap shots with 22km x 22km. The area covered by Quick Bird is limited to the most populated area of the world. The inclination of 52° is not identical to the limit of the latitude because the pointing across track extends it by approximately 2°. Up to 8000 frames per day can be imaged by Early Bird. Quick Bird can use up to 65 images per orbit. Also Space Imaging EOSAT is preparing 2 satellites. Ikonos 1 shall be launched in March 1998 and Ikonos 2 in the third quarter of 1998. Like EarthWatch, EOSAT has different share holders - Lockheed Martin, E-Systems and Mitsubishi. The spectral bands of Ikonos are corresponding to the Landsat TM bands 1-4.

For commercial investors the continuity is important, by this reason, the Orbview 3A which shall be launched and operational in 1999 will be followed by Orbview 3B in 2001. The financial problems are solved, so this project should go on. Like the other companies in this field, Orbimage is not limited to mapping, the major field is seen in the field outside mapping and includes also the aspects of national security for US and other countries. The imaged object can be scanned across track, so monoscopic within one path three 76km x 73km areas can be acquired, or six areas 23km x 36km. Also 4 strips, each with a length of 1270km can be imaged in one path. A special topic is the hyperspectral channel, 280 different spectral bands can be recorded. The huge amount of data limits the area imaged by this mode. A compression is not included.

	GPS	star tracker	ground accuracy without control points horizontal	vertical
Early Bird	yes	1	ca 150m	
Quick Bird	yes	yes	23m	17m
Ikonos	yes	3	12m	8m
OrbView 3	yes	2	12m	8m
EROS A	yes	-	800m	
Resours 21	yes	yes	30m	
Clark			<100m	
HRST			17m	

table 5: announced ground accuracy achievable without control points

The West Indian Space Ltd. is a joint venture of Core Software Technology and Israeli Aircraft Industries, it is located on the Comoren Islands. The EROS A shall be launched mid of 1998 and followed by 6 EROS B-satellites, the first end of 1999 and then every 6 month up to 2002 a further satellite shall be in space. The whole system of 6 satellites will give a revisit time off nadir of half a day. Each satellite with a life time of 5 years shall cost only 50 million US$.

Resours 21 was founded by Agrium US, Boeing, Farmland Industries, GDE Systems, Pioneer Hi-Bred International and Institute of Technology Development. 4 satellites shall be launched. One of the main topics shall be the field of agriculture, by this reason 5 spectral bands including the mid infrared and no panchromatic mode is foreseen. With the whole system of satellites a sufficient revision cycle is guaranteed what is not the case for

Landsat. Also a 30m pixel size is not sufficient for the specified application.

The strong activities in the field of high resolution remote sensing satellites have been seen also by Russia. By this reason beside the existing technology, Resours TK is announced and shall be launched in 2000. The detailed specifications shall be published in January 1998. Up to now the information is limited to 1m pixel size in the panchromatic mode, 4m pixel size in the multispectral mode with 4 bands and stereo in track.

The serious of Indian Remote Sensing Satellites is continued. Beside the operational IRS-1C and -1D, usable for mapping 1 : 50 000, IRS-P5, also named Cartosat, will have a panchromatic camera with 1m and 2.5m pixel size and stereo along track. That means, it can be compared with the other sensor with very high resolution. The IRS-P6 (Resourcesat-1) will include beside the LISS-3-camera with 4 spectral bands and a pixel size of 23m (also included in IRS-1C and -1D), the LISS-4-camera with 3 spectral bands and 5.8m pixel size. The distribution of the Indian satellite data outside India is exclusively done by Space Imaging EOSAT, with a subcontract for Europe to Euromap.

A different motivation is behind the China-Brazil-Earth Resource Satellite CBERS. It is more for the internal governmental use. A data distribution for commercial applications is not yet planned. Beside the CCD-camera listed in table 3, also a IR-MSS-sensor with 80m pixel size and 160m for thermal infrared is included (4 bands: 0.50 - 1.10µm, 1.55 - 1.75µm, 2.08 - 2.35µm, 10.4 - 12.5µm) like a wide field sensor with a swath width of 890km. A second identical satellite is prepared. For CBERS 3 and 4 there is a proposal for a 5m pixel-panchromatic camera , but the realization will take at least 5 years.

SPOT 4 shall be launched in the first part of 1998, it will displace SPOT 1 and 2 with it's degraded radiometric quality. The HRV-instruments have not be changed with the exception of an additional mid infrared band which shall improve the vegetation classification. SPOT 5 is planned for the end of 2001, it is quite different from the preceding. The panchromatic mode is improved to 2.5m pixel size and the multispectral bands with the exception of the mid IR to 10m. In addition it includes in-track stereo. The data transmission will be improved by a laser link to a geo-stational communication satellite. Including SPOT4 and SPOT5, for the SPOT-system in total 3 billion US$ have been spend. On such a base a real commercial operation is not possible. But also the so called commercial systems are strongly supported by system developments, funded by governmental organizations.

In the NASA Small Spacecraft Technology Initiative (SSTI) also an Early Bird is used as Clark satellite, that means Clark is identical to Early Bird, only the storage capacity is different.

The coastal environment shall be analyzed with the Hyperspectral Remote Sensing Technology (HRST) spacecraft, which shall be launched in 2000 and be operated by the US Office of Naval Research and the US Naval Research Laboratory. In addition to the hyperspectral Ocean Imaging Spectrometer (COIS), a panchromatic sensor with 5m pixel size is included. The Optical Realtime Adaptive Spectral Identification System (ORASIS) will process and compress the data on-board. The data compression of the 200 spectral bands shall reduce the huge amount of data by the factor of 10 up to 20.

Because of the limited resolution, Landsat was not useful for mapping purposes. With the 15m pixel size in the panchromatic mode there will be a limited use for map revision with Landsat 7. Beside the additional panchromatic mode, the pixel size of the thermal infrared band will be reduced from 120m to 60m.

In Australia a project is going on to build and operate a space born hyperspectral sensor. The CSIRO Division of Mining and Exploration is coordinating the activities of a consortium including also Auspace Pty Ltd. and the Australian Centre for Remote Sensing. A feasibility study about a light weight satellite has been finished to build the ARIES-1, which shall operate in 500km height in sun synchronous mode. 32 bands of the spectral range from 0.4µm up to 2.5µm with a pixel size of 30m and a swath width of 15km shall be used together with a 10m-panchromatic sensor. The view direction can be changed +/-30° across track. A launch in late 1999 is possible.

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), developed by the Japanese MITI shall be used on NASA's EOS AM-1 platform, to be launched in 1998. Beside the Thermal Infrared (TIR) camera with a ground resolution of 90m and the SWIR for mid infrared and 30m pixel size, also a Visible and Near Infra Red (VNIR) camera with 15m pixel size shall be used. This camera has a vertical looking optic (band 1: 0.52µm – 0.60µm, band 2: 0.63µm – 0.69µm, band 3: 0.76µm – 0.86µm) and another optic inclined 24° (band 3: 0.76µm – 0.86µm). The system can be rotated, so the view direction of the inclined instrument can be for or after and also to the side. That means, it can be used for same orbit stereo imaging as well as for extensive cross-track pointing. 4000 of the 5000 pixels are used.

5. SYNTHETIC APERTURE RADAR

With ERS1 (launched 1991), ERS2 (launched 1995) operated by the European Space Agency (ESA), Radarsat 1 (launched 1995) operated by the Canadian Centre for Remote Sensing (CCRS) and JERS-1 (launched 1992) operated by National Space Development Agency of Japan (NASDA), synthetic aperture Radar (SAR) satellites are available. The JERS-1 is using the L-band, the other the shorter C-band. With the Advanced Synthetic Aperture Radar (ASAR) shall ENVISAT in 1999 guarantee the continuity of the ERS-program. The incidence angle of ERS shall be extended from 20.1° - 25.9° up to 15° - 45°. ENVISAT will also use the C-band. The pixel size of down to 10m doesn't mean the same like the identical resolution of an optical sensor because of the different reflection and the specle of Radar images. The object recognition based on the Radar images is not better than for the map scale 1 : 100 000 but several elements cannot be identified. Because of the penetration through clouds SAR does have a special function in areas with permanent cloud coverage and for time critical mapping. Special advantages of SAR are in the field of the detection of oil spills, survey of floodings and also the determination of large forest fires. Another function is the height determination which can be made in the accuracy range of +/-15m. Only in the case of interferometric Radar it can be much more accurate, but the interferomtry is disturbed by changes of the vegetation and the moisture, so with the exception of a tandem mode it can be used only in dry areas with poor vegetation. In general there are problems in mountainous areas.

6. DIGITAL AIRBORNE IMAGING SENSORS, SENSOR INTEGRATION

An usual aerial image has a resolution of approximately 40 lp/mm corresponding to 18 400 x 18 400 pixel. There are no CCD-arrays available with such a resolution. Some tests have been made with the Kodak DCS 460 with approximately 2000 x 3000 pixel. This information contents cannot be compared with an aerial image and in addition the inner orientation of the DCS 460 is not stable. With the Rolleimetric Q16 (4000 x 4000 pixel) and the Kodak MITE, metric digital camera are on the market, but the imaging interval is limited to 7 sec for the Q16. By these reasons the use of CCD-arrays in aircraft's is reduced to special cases.

The camera development for space applications has been changed for use in aircraft's. The Wide Angle Optoelectronic Stereo Scanner WAOSS of the German DLR, made for recognition of the Mars has been changed to the Wide Angle Airborne Camera WAAC.

technical data of the WAAC:

focal length: 21.7mm
field of view across track: 80°
3 CCD-lines, each with 5184 pixel
convergence angle for and after: 25°
DCT-JPEG compression
weight: 4.4kg

This digital stereo camera is now used for commercial applications in a cooperation between the DLR and Leica.

The Deutsche Aerospace AG has developed the DPA, using the same principle of a 3-line scanner, but with more pixel and spectral information. It is based on the MOMS-02-camera.

technical data of the DPA:

Stereo module:
Focal length: 80mm
3 CCD lines: 12 000 pixels/line
field of view across flight line: +/-37°
convergence angle: +/-25°
spectral range: 0.515µm – 0.78µm

Spectral module:
focal length: 40mm
4 image lines vertical: 6000 pixels/line
field of view: +/-37°
spectral range: 0.44 – 0.524µm, 0.52 – 0.60µm, 0.61 – 0.685µm, 0,77 – 0.89µm

Both cameras have been used for practical applications. Together with a positioning by kinematic differential GPS and an attitude determination by INS, the geometric problems of airborne line scanners have been solved. This does not go the field of 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. The applications in this field will grow in the near future.

The integration of line scanner cameras with GPS and INS is necessary. But in the near future the use of photographic aerial cameras will dominate. The use of kinematic differential GPS-positioning in block adjustments is growing and will become a standard procedure. In the case of blocks, the photo rotations can be determined by the over-determination even if only the projection center coordinates and no control points are given. The kinematic GPS-positioning still has problems with ambiguity errors. This can be solved by a combined use of GPS and INS in the aircraft's. A test block resulted always in an accuracy of the ground coordinates without control points better than +/-20cm for all coordinate components. (Jacobsen 1997a). If linear projects like road constructions or pipelines are handled, the block structure changes to individual flight lines. In this case the photo rotations cannot be determined just based on GPS-coordinates of the projection centers and a higher number of control points is required. The giros used up to now for practical applications are not accurate enough to determine the attitude data corresponding to the possible photogrammetric accuracy. But this may be changed with ring laser giros if the direct connection to the cameras has been solved. The giros have to be mounted on top of the cameras, otherwise the required accuracy cannot be guaranteed.

7. LASER SCANNING

The laser scanning or light detection and ranging or scanning airborne laser radar are the same. The number of different types of laser scanners is growing very fast. They are distributed under the names like: AIMS, ALTM1020, DATIS, FLI-Map, LIDAR, ScaLARS, TopEye and TopoSys. The number of different systems directly shows the economic potential of this field. The stage of development has been passed and it is a very fast growing technique. The main difference of the systems is in the field of point density and imaging capability. The determined vertical accuracy is in the range of +/-10cm to +/-20cm if it is not limited by the attitude data. So in mountainous areas the horizontal accuracy of 1m up to 2m influences the vertical component.

In some special areas the height determination by laser scanning has replaced the traditional photogrammetric survey, but the situation is different from project to project. The economic aspect is strongly depending upon the task if by other reasons photos are required or not. In addition new applications have been opened like the height determination of power lines, which was very difficult by traditional photogrammetry.

CONCLUSION

A photogrammetric break through in the use of space images can be foreseen. Over several years the commercial applications have been limited by the 10m-pixel size and the across track stereo of SPOT. The distribution of the Russian space photos with very high resolution was not acceptable. Now up to the year 2000 in total 6 systems with a pixel size of 1m or better are announced or on the way. 3 of these systems do not have a governmental background or direct support. Of course also these systems are based on former governmental developments but the operation will be totally commercial even if the main number of contracts will come from governmental organizations. The competition will show if a larger part of the mapping in future will be based on space images. It has to be more economic than the traditional way. Only for special applications the price for the images is not important. The fast distribution is a must, but this seems to be solved, because the major use of the space images will not be in the field of mapping but in the field of time critical information. The announced accuracy of geolocation up to +/-12m for the horizontal and +/-8m for the vertical component has to be proved. It requires also the knowledge of the datum and the geoid. If the accuracy can be guaranteed, this will have a strong influence to the small scale mapping.

The use of synthetic aperture radar will be limited to special applications because of the limited possibility of object identification. Only if the radar interferometry can be used without problems and limitations, this will have a strong influence to the mapping.

The use of digital cameras, especial 3-line cameras with the stereoscopic capability will grow very fast, but this will at first add more possibilities to the field of photogrammetry, it will not so much replace the traditional mapping. This will be stronger influenced by the laser scanning, which can replace the photogrammetric height determination for several applications. A sensor integration which is required for laser scanning and for the line scanner images will come also very soon into the field of traditional mapping with aerial images and will reduce the number of required control points or even will be able to eliminate the use of control points totally.

REFERENCES

Asrar, G., Reynolds, G. 1995: MTPE EOS Reference Handbook, NASA/Goddard Space Flight Center, Code 900

Branson, W. 1997: RADARSAT and its data products, tutorial Land Satellite in the next Decade, ASPRS 1997, Washington

Curtiss, O.D. 1997: The hyperspectral remote sensing technology (HRST) program, Land Satellite Information in the next decade, ASPRS, Washington 1997

Flood, M., Gutelius, B. 1997: Commercial implications of topographic terrain mapping using scanning airborne laser radar, PE&RS, April 1997, pp 327 ...

Fritz, L. 1997: Status of new commercial earth observation satellite systems, Joint workshop Sensors and Mapping from Space, Hannover, Germany

Gerull, D.B. 1997: Building, launching and operating an earth-imaging high-resolution Satellite, Land Satellite Information in the next decade, ASPRS, Washington 1997

Harris, J.K. 1997: Spaceimaging EOSAT, IKONOS product and system overview, Land Satellite Information in the next decade, ASPRS, Washington 1997

Jacobsen, K. 1995: Test of utilization of satellite Data for mapping, ISPRS WG IV/2 „International Mapping form Space“, Madras 1995

Jacobsen, K. 1997a: Block adjustment without control points, ASPRS Seattle 1997

Jacobsen, K. 1997b: IRS-1C and future remote sensing activities in India, Joint Workshop „Sensors and Mapping from Space“, Hannover 1997

Joseph, G. et al 1996a: Cameras for Indian remote sensing satellite IRS-1C, Current Science, no. 7, 1996, Indian Academy of Science, Bangalore

Joseph, G. 1996b: Remote sensing program in India: an overview, ISPRS Vienna 1996, Country report

Lohmann, P. et al 1997: Topographic mapping using the scanning laser altitude and reflectance sensor (ScaLARS), Joint Workshop „Sensors and Mapping from Space“, Hannover 1997

Müller, F. et al 1994: Digital photogrammetric assembly (DPA), point determination using airborne three-line camera imagery – practical results, ISPRS Com III, Munich 1994, Vol 30, Part 3/2

Nanz, T. 1997: Commercial remote sensing: a fad or killer products, Land Satellite Information in the next decade, ASPRS, Washington 1997

Price, R. 1977: Landsat 7: a new era for collection and distribution of land data from space, Land Satellite Information in the next decade, ASPRS, Washington 1997

Puniard, D.J. 1997: The ARIES project, a window of opportunity for Australia, Land Satellite Information in the next decade, ASPRS, Washington 1997

Satterlee, H. 1997: Resours 21, the information source for the 21st century, Land Satellite Information in the next decade, ASPRS, Washington 1997

Stoney, W.E., Bunin, S.L. 1997: Satelite and sensor data sheets, Land Satellite Information in the next decade, ASPRS, Washington 1997

Wilson, S. 1977: The “EROS” program, Land Satellite Information in the next decade, ASPRS, Washington 1997

1) http://www.digitalglobe.com/company/details.htm

2) http://crsphome.ssc.nasa.gov/ssti/CLARK/CLARK.htm

3) http://www.eurimage.it/Products/AVHRR.html

4)http://www.spaceimage.com/home/newsroom/releases/ikonos1.html

5) http://www.orbimage.com/worbview.htm

6)http://www.spot.com/anglaise/system/satel/ss_paylo.htm

7) http://www.eurimage.it/Products/RESURS_01.html

8) http://geo.arc.nasa.gov/sge/landsat/17.html

9) http://eos-am.gsfc.nasa.gov/instruments.html

10)http://hdsn.eoc.nasda.go.jp/guide/satellite/satdata/adeos2_e.html

11) www.spin-2.com

12) http://asterweb.jpl.nasa.gov/