THE STEREO CAMERA FAMILY WAOSS/WAAC FOR SPACEBORNE/AIRBORNE APPLICATIONS

Rainer Sandau, Andreas Eckardt
DLR- Institute for Space Sensor Technology
Rudower Chaussee 5 D-12489 Berlin Germany
Tel.: (xx4930) 69545530
Fax.: (xx4930) 69545532
e-mail: rainer.sandau@dlr.de

KEY WORDS: remote sensing, stereo camera, CCD- camera, CCD- line camera, CCD line scanner

ABSTRACT

The wide- angle optoelectronic stereo scanner WAOSS was developed as payload component for the Mars- 96 mission. WAOSS as well as a date interpretation algorithms are currently tested with airborne experiments. To cover a much broader range of potential applications, the more flexible wide- angle airborne camera WAAC was derived from that camera concept. After a short description of the function and the technical performance, data of both cameras experiment and application examples are shown to demonstrate the main features of the cameras: wide angle of (80°), high radiometric dynamic (11bit) and the in-track stereo capability.

1. INTRODUCTION

Since MOMS was successfully flown on the space shuttle in 1994 all the features of that camera type, the digital CCD line camera, have been extensively discussed. This type of the camera is accepted now for a central remote sensing application area.
In the DLR a miniaturised Wide- Angle Optoelectronic Stereo Scanner (WAOSS) was developed for the Russian Mars-96 mission. The test applications of this camera led to demands for a more flexible camera, more suitable for airborne imaging applications. So WAAC was developed basing on this camera concept and reusing the WAOSS modules to a wide extend.
After the short description of both camera application fields and their technical and performance characteristics, this paper concentrates on imaging examples resulting from airborne test applications of both cameras.

2. DESCRIPTION OF THE CAMERAS WAOSS AND WAAC

The Wide- Angle Optoelectronic Stereo Scanner WAOSS is a three line stereo scanner working in the pushbroom mode [1]. According to the camera design the stereo information will be generated within the image plane of one single objective by means of three CCD lines (see figure 1). Due to the movement of the satellite with the camera, each of these lines senses a certain object or area with a given time shift and under a different viewing angle. However the time shift is so small that the illumination condition may be considered constant. After reducing the amount of data by means of special compression methods, the three image strips received will be transmitted to Earth. There the data will be reconstructed and combined to form stereo images.

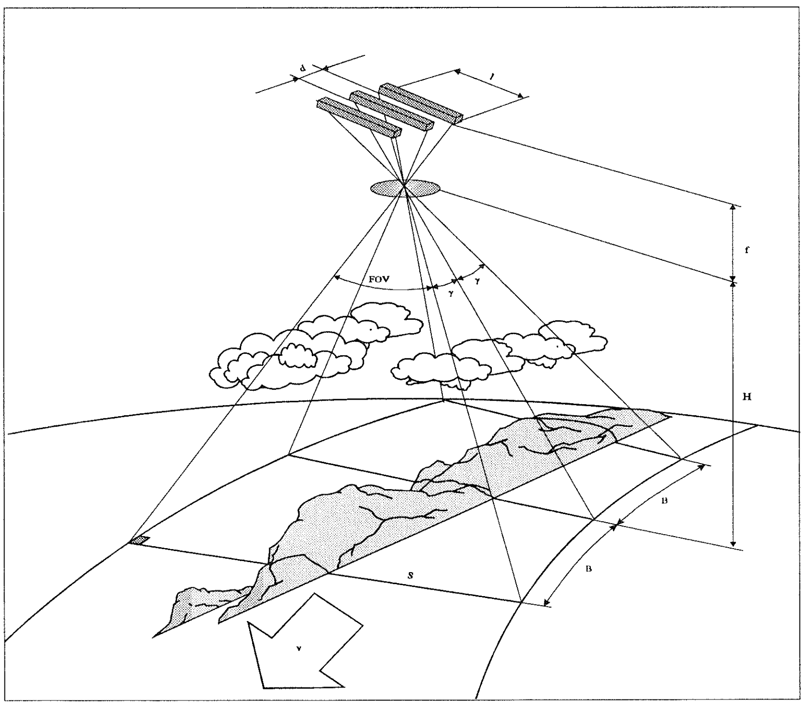

Figure 1 The three- line principle of WAOSS/WAAC

WAOSS was developed for the Russian Mars- 96 mission with DARA sponsoring taking into account its major development drivers:

- different scientific objectives like
- synoptic imaging of the weather phenomena with coarse ground resolution
- global topographical mapping with good ground resolution
- real time control of the camera parameters in the highly elliptical orbit around Mars
- severe restriction of data rates and data volumes
- High reliability for at least 2 years
- low mass, volume, and power consumption budgets

The modular design and the programmability of all essential performance features of the camera allow to adapt the camera to different scientific tasks and to different mission and spacecraft requirements rather easily.
For Earth related airborne applications of a three-line stereo camera, only the mass, volume, and power consumption restrictions are of high importance. That was the reason why the Wide Angle Airborne Camera WAAC was derived from the modular WAOSS design allowing flexible imaging conditions including high data rate and high data volume applications[2].
Table 1 shows the camera parameters of both cameras. The higher size, mass, and power consumption values of the WAOSS are mainly due to the necessity of could redundancy.
The modularity of the WAAC gives the possibility to replace modules in order to adapt WAAC to different tasks and to test novel technologies. Though, the stereo camera WAAC is anticipated to

- fulfil topographic mapping tasks
- to support the data interpretation of instruments with other wavelengths, e.g. RADAR, IR- instruments,...
- to test novel technology approaches by replacing modules and components from the optics to the external interfaces

The main advantage of the WAOSS/WAAC over conventional photographic cameras are

- wide field of view of 80° with neglectable geometric distortions over the whole range
- high radiometric dynamic covering 11bit (2048 gray levels)
- generation of digital data which allows to process the image data on digital computers and to use the data in GIS immediately.

Further advantages of this camera family are:

- the flexibility for different applications
- good performance parameters implemented in small size camera systems with low power consumption.

The camera WAOSS will be launched to Mars in November 1996. So Mars images are not available yet . But WAOSS as well as WAAC are currently tested in airborne and ground based experiments.
In the following part some example images are shown coming from airborne experiments with WAOSS and WAAC and showing the main features of these cameras:

- wide field of view (80°)
- high radiometric dynamic (11bit)
- stereo capability.

3. CAMERA APPLICATIONS

Figure 2 shows results from an airborne experiment with WAOSS. This image was taken during a flight over Berlin in the area of the radio tower and the Berlin Congress Centre in July, 1995, on board of a Do228 from an altitude of 3000m. The flight attitude dependent failures are not corrected yet. The image size is about 1800x1000 pixels. With a ground pixel size of 1mx1m, it covers an area of 1.8kmx1km.

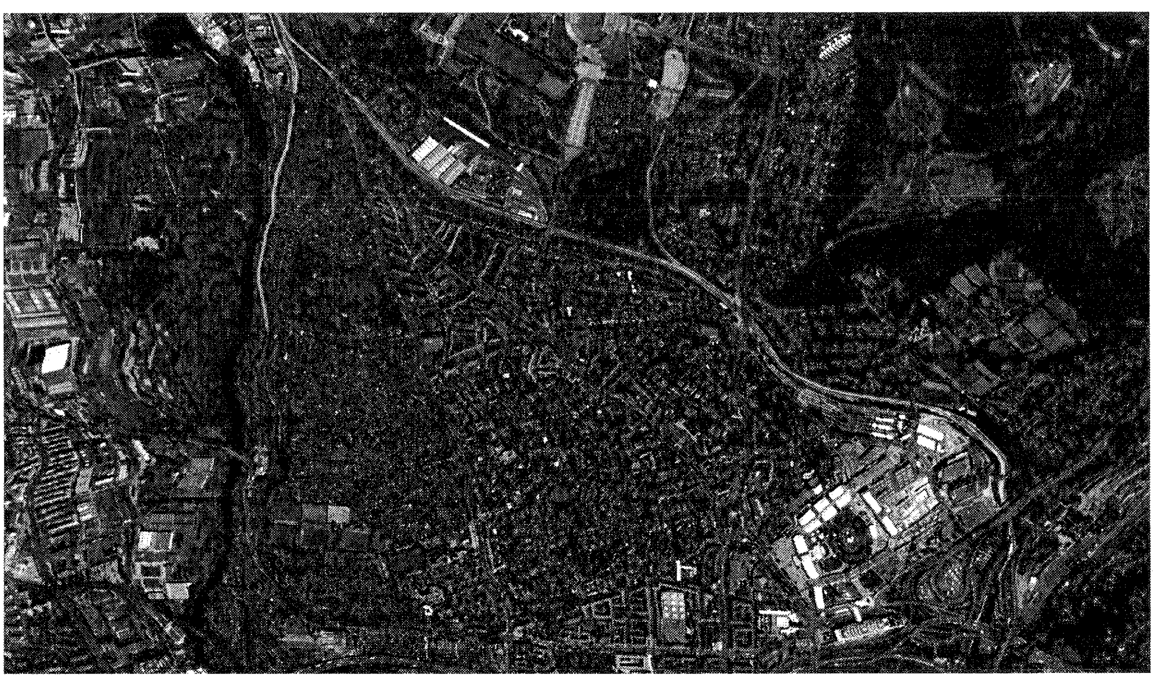

Figure 2 The WAOSS image of the area around the Berlin Congress Centre

From figure 2 one main difference between the images taken from an airborne and a spaceborne camera can be observed:
The geometric correction of the attitude dependent failures is one of the main concerns for images taken from airborne cameras. Images taken from spaceborne cameras are supposed to have far less effects coming from attitude fluctuations.
But in the actual experiment arrangement, WAOSS is mounted on a passive platform with fibre gyros to measure all three angular directions of WAOSS movements. The gyros are mounted closely to the sensors. Furthermore, the data from an GPS receiver and from the ARINC- data of the aeroplane's INS are included in the house keeping data of the camera. These data are very important for the reconstruction of the CCD- line orientation.

Figure 3 The corrected image of figure 2

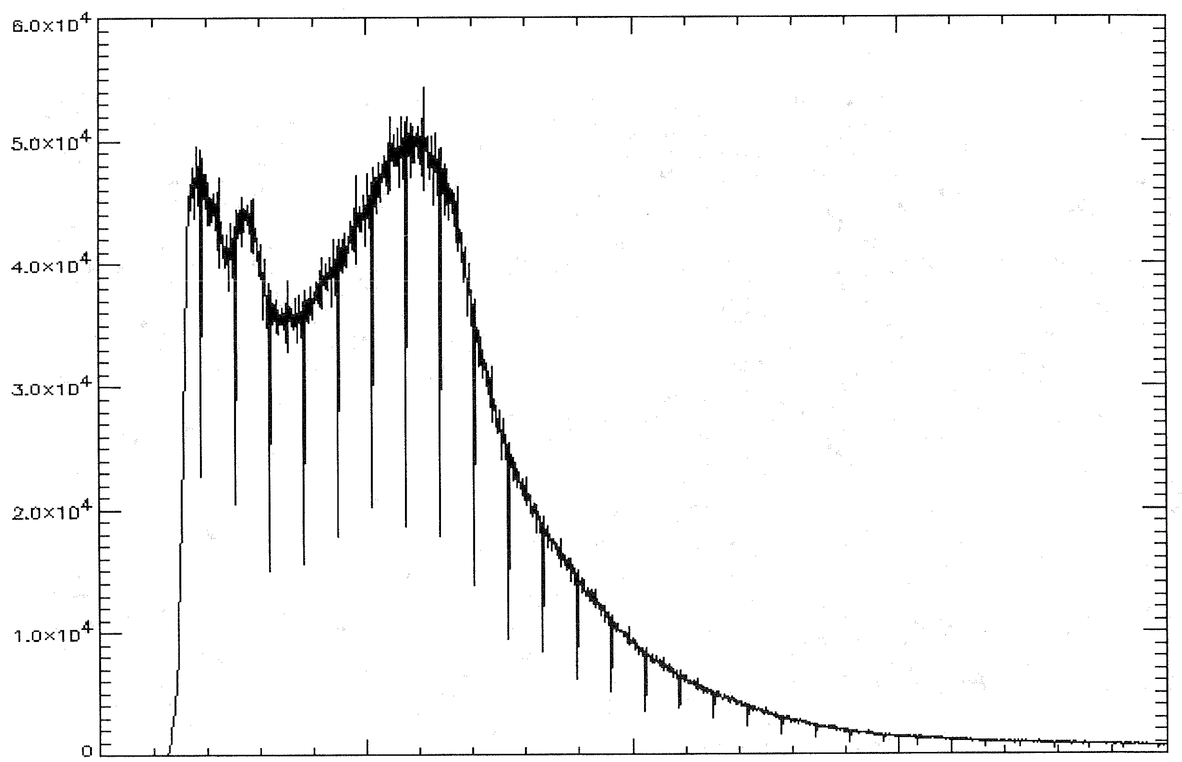

Figure 5 The histogram of figure 4

Figure 3 shows the same image after passing all procedures of flight attitude failure corrections(pitch, yaw, roll). In this image, the average compression rate was controlled to be constantly about 18 whereas the Q-factor of JPEG based compression method varied between 50 and 200.

With WAOSS's interface maximum data rate of 500kBit/s the compression is necessary. To avoid the compression noise in the reconstructed images, higher interface data rates have to be implemented which leads us to the advantage of WAAC for airborne experiments.

Figure 4 Image of an open- cut mining

Figure 4 is an image of an open coal pit taken by WAAC in October 1995. Again, the ground pixel size from a flight altitude of 3000m is about 1mx1m.

The image size is about 5kmx8,5km. For this image no compression was applied. The camera was working in the 8bit normalised mode[2]. The dark coal band and the bright clouds cause a radiometric

dynamic of eleven bit as depicted in the histogram of figure 5.
In figure 5 the effects of normalising 11bit CCD data to 8 bit in connection with an amplification factor can be well observed.

In the future the slope change detection of the overburden deposits shall be done by means of such digital stereo cameras

Figure 6 DTM of a mountain area near Ronneburg

In figure 6 the DTM from the mountain area of the Erzgebirge near Ronneburg in the south- eastern part of Germany is shown. This DTM is derived from three flight attitude corrected image strips taken by WAOSS in July 1995. By means of this image and further images changes in the overburden deposit areas of a pitchblende mine shall be detected.

	WAOSS	WAAC
Focal Length, f	21,7 mm	21,7 mm
FOV (Across the Track)	$\leq 80^0$	$\leq 80^0$
Optics	Spitmo- Russar-96	Spitmo- Russar-96
Number of CCD- Lines	3	3
Spacing of CCD's	10,1 mm	10,1 mm
Convergence Angle	25^0	25^0
IFOV (Quadratic)	$3,23 \times 10^{-4}$ rad	$3,23 \times 10^{-4}$ rad
Elements per CCD- Line	5184	5184
Elements Spacing	7 µm	7 µm
According to Orbit Data	Hn = 250 km	H = 3 km (v = 200 km/h)
Swath Width (Nadir CCD)	420 km	5,184 km
Min Ground Resolution - in Line Direction - in Trajectory Direction	 80 m 80 m	 1,0 m 1,0 m
Radiometric Resolution	8 Bit	8 Bit
Spectral Channel - Nadir - Forward,Backward	 470...670 nm 580...770 nm	 580...770 nm 470...670 nm
Data Compression Factor	2...20	2...20
Data Compression Method	DCT- JPEG	DCT- JPEG
Computer Performances	20 MIPS	20 MIPS
Output Science Datarate	100...500KBit / s	100KBit / s...24MBit / s
Physical Dimensions	L:373 x B:190 x H:218 mm	L:285 x B:190 x H:202 mm
Mass	8 kg	4,4 kg
Power	18 W	15W

Table 1

4. CONCLUSIONS

Both cameras, WAOSS and WAAC are optimised to match with the scientific requirements and interface conditions of a mission to planet Mars and the airborne applications, respectively. Nevertheless, the airborne application of WAOSS helped to matures the camera design and gave inputs for the design of the airborne camera system for Earth applications. The results obtained until now are encouraging to pursue the development and application of digital CCD- line stereo cameras.

5. ACKNOWLEDGEMENTS

WAOSS was developed by the Institute of Space Sensor Technology (WS) of the DLR under the sponsorship of DARA, the German Space Agency. The image examples have been prepared by the sensor theory group of WS (Dr. R. Reulke, Dr. M. Scheele, Mr. A. Börner, Mr. T. Terzibaschian).

6. REFERENCES

(1) Rainer Sandau, Wolfgang Bärwald, A three- line Wide- Angle CCD Camera for the Mars-96 mission
Proc.. of the ISPRS Commission I Symposium
„Primary Data Acquisition and Evaluation",
Vol.30(19994) 82-96

(2) Andreas Eckardt, The Performance of the Wide Angle Airborne Camera (WAAC)
ISPRS Intercommission Workshop Zurich 1995
Zurich, March 22-24, pp 26-29

(3) Andreas Eckardt, Wide- Angle Airborne Camera (WAAC)
OEEPE Workshop digital cameras , IGN
Paris, 28-29.9.1994