The Three-Line Stereo Camera MEOSS and its Application in Space

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1. INTRODUCTION

In 1980 the Indian Space Research Organization ISRO offered to DFVLR to fly an experiment of 10-20 kg on a Stretched ROHINI Satellite (SROSS) of the 150 kg class.

The common understanding is to fly under the constraints of the SROSS mission (Table 1) an attractive low cost experiment provided by DFVLR.

Table 1: Nominal specifications for SROSS-MEOSS Mission

Mission Parameters

circular orbit	450 km
inclination	45.56° (48.20°)
orbital period	92.8 minutes
lifetime	6-12 months
launch	1988
telemetry	S-band
data rate	10.4 Mbit
payload weight	10 kg
payload power	25 Watt for 20 minutes/day

2. THE INSTRUMENT

The main characteristics of the proposed threefold stereoscopic CCD line scan camera are:

- a single objective (monocular) imaging system for reduction of weight and adjustment efforts
- no moving mechanism
- passive cooling
- three relatively long CCD lines of 3456 pixels in one common focal plane
- one spectral band between 570 to 700 nm
- 8 bit radiometric resolution
- LANDSAT MSS compatible geometrical resolution
- correction for earth rotation by electronic shift.

The optomechanical design with a central, mechanically independent imaging unit consists of a space modification of a Zeiss Biogon objective and the focal plane containing three parallel CCD lines vertical to flight direction as shown in Fig. 1.

The central CCD line contains the optical axis and produces the nadir looking image, while the outer lines see the same parts of a scene at different angles and times (fore and aft looking images). A baffle shields the objective from straylight. To reduce deforming effects from temperature differences the central case is fabricated from Titanium. The overall weight of the camera is 6.5 kg.

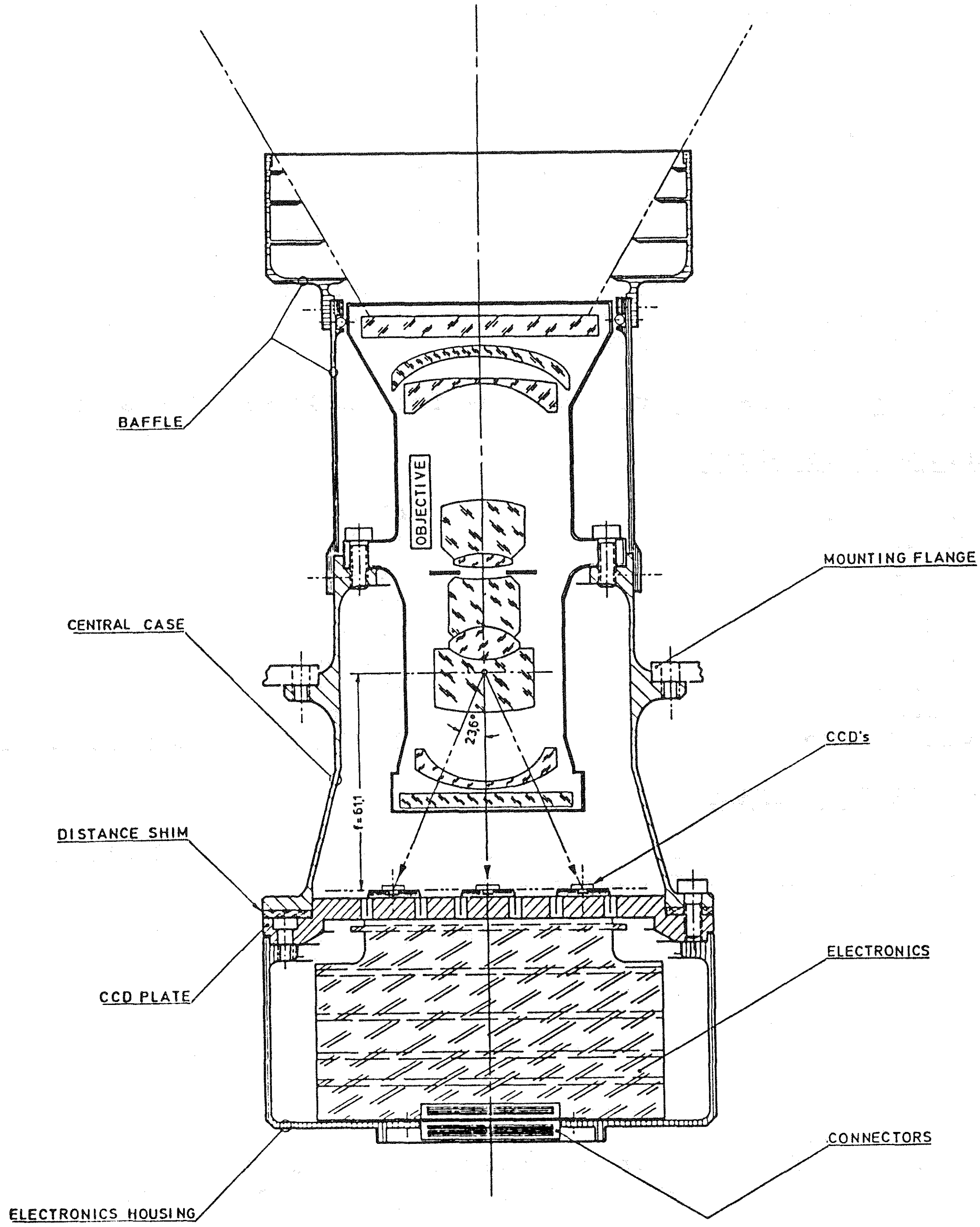


Fig. 1 Shows the vital parts of the MEOSS camera: space modified ZEISS BIOGON objective, 3 CCD's mounted in the focal plane, the electronics necessary to register and transform signals collected by the CCD's.

The instrument characteristics are summarized in

Table 2:

Camera Data:

optics	ZEISS Biogon
focal length	61.1 mm
distance of elements on CCD	Δy = 10.7 µm
number of elements on CCD	n = 3456
instantaneous field of view	IFOV = 0.01° square
distance of scanlines	d = 26.69 mm
convergence angle	ß = ± 23.60°
scanline frequency	f = 131.1 Hz
spectral channel	570-720 nm

3. MISSION

The image data reception is performed by the ISRO-NRSA LANDSAT ground station near Hyderabad and by the DFVLR ground station Weilheim and is open to other ground stations within the mission constraints.

Fig. 2 shows the ground tracks for both stations

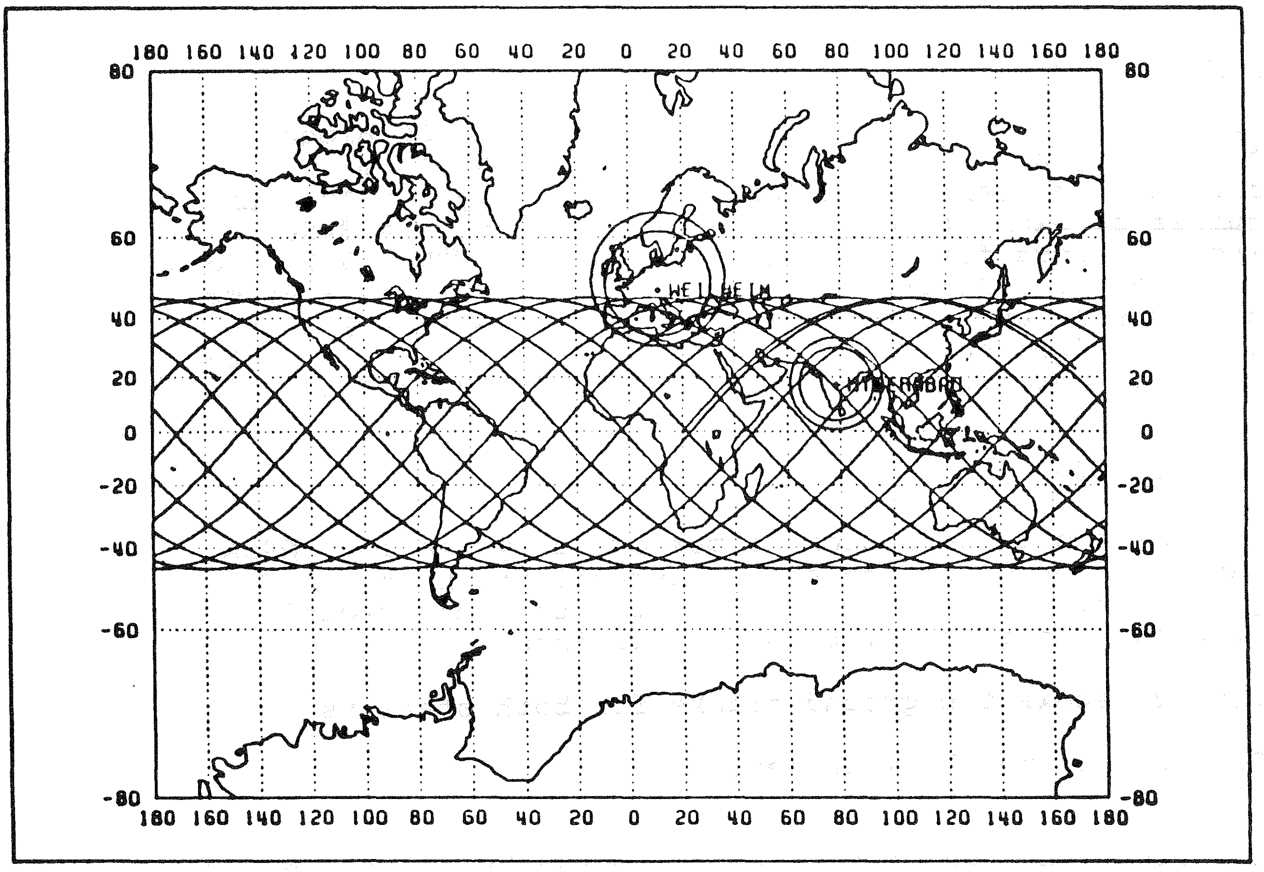
Fig. 3 for Weilheim in detail.

The received image data are determined by the following mission characteristics data.

Table 3:

Orbit Data:

height	h = 450 km
ground track velocity	V = 7.137 km/s
inclination	i = 45.60° (48.20°)
sinodal period of orbital drift	24 hours in 55.6 days
visibility range at Weilheim	1730 km at 5° elevation
No. of observable successive orbits	4 to 5



The diagram displays the ground tracks for the MEOSS-SROSS-2 mission for 1 day. An altitude H = 450 km and an inclination of 45.6 ° is assumed. Shown are the visibility circles of Weilheim and Hyderabad for 5 ° and 10 ° satellite elevation. An orbit inclination of 48.2 ° is under consideration.

Fig. 2

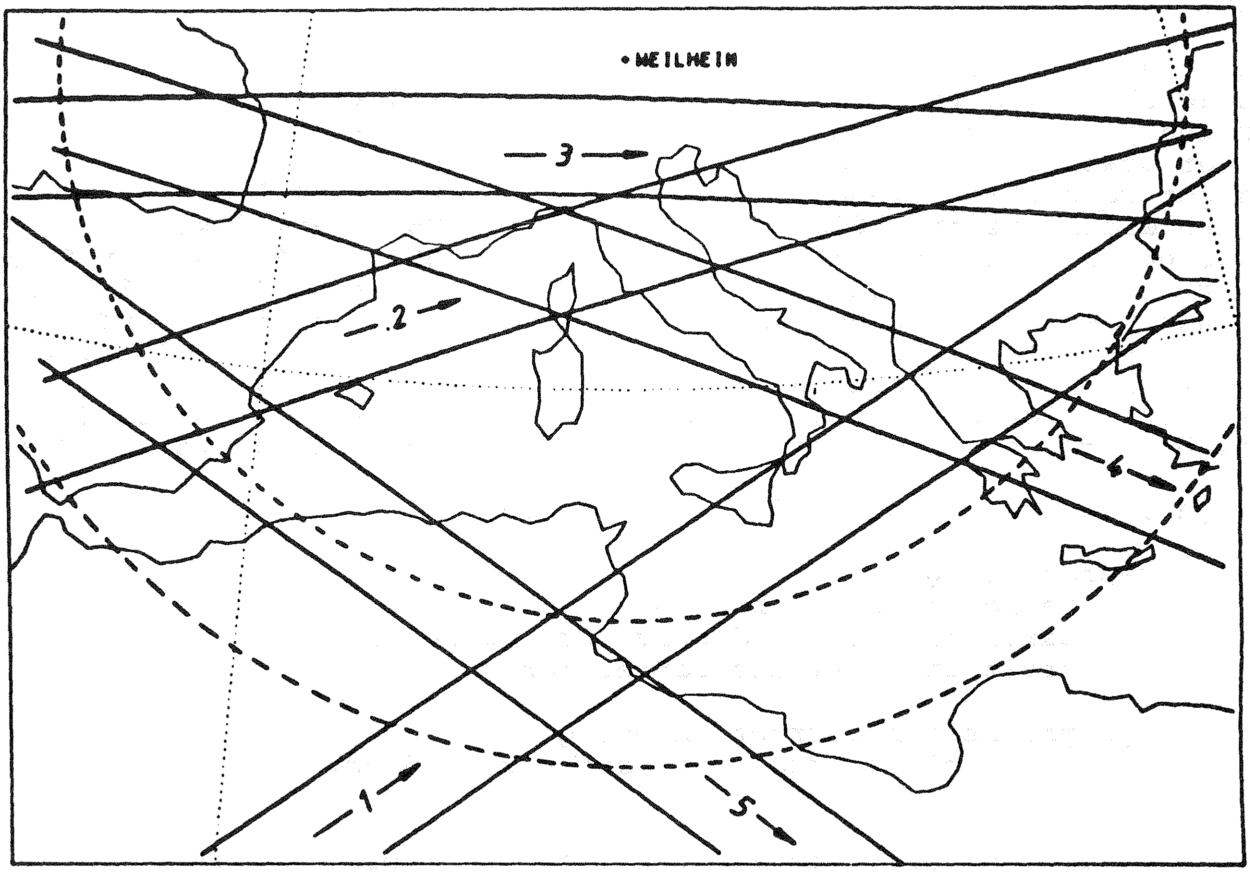


Fig. 3 Weilheim receiving station. Example for 5 consecutive orbits (numbers 1 through 5) respresenting the coverage of one day. The swath width marked by parallel lines is 255 km. Dotted lines mark the range of the station for an elevation of the satellite above the horizon of 5° respectively 10°. Because the pattern of passes is shifting 6.5° eastwards a day, full coverage of the area shown, can be achieved within 6 days.

Table 4:

Performance Data:

radiometric resolution	8 bit
selectable gain factors	1,2 and 4
ground pixel along scanline	P = 78.8 m
inter scanline distance	P = 52.0 m
height resolution element	P = 54.7 m
swath width (central CCD)	SW = 255.8 km
baselength (nadir track)	BL = 396.1 and 2x198 km
corr. time interval (nadir track)	t = 58.1 and 2x29.5 sec
ground based convergence angle	ß° = $\pm$ 25.41° and 0°
effective base to height ratio	B:H = 0.950 and 2x0.452
active pixels per scanline	n = 3237
resolution for cross track wind	Δv = 1.12 and 2.24 m/s
height error for 1 m/s along track wind	Δh = 61.1 and 122.2 m

Image data evaluation is done in two steps

- preprocessing
  - radiometric calibration
  - earth rotation and curvature correction
  - orbit and attitude correction
- high precission correction using
  - threefold stereo information redundancy
  - attitude modelling

The preprocessed data are available to all users. A high precission correction scheme is also built up and further dealt with in the next chapter under "Photogrammetric Image Correction and Evaluation".

4. SCIENTIFIC OBJECTIVES

The main goals of the MEOSS mission are

- generation of threefold stereoscopic linescan-imagery from space
- investigation of procedures for image rectification
- investigation of correlation accuracies over land and cloud fields

with the following derived products

- rectified linescan images and stereo triplets 1 : 1 000 000 scale
- orthophotos and ortho-stereo triplets 1 : 500 000 scale
- heights and cross-track velocties of cloud fields.

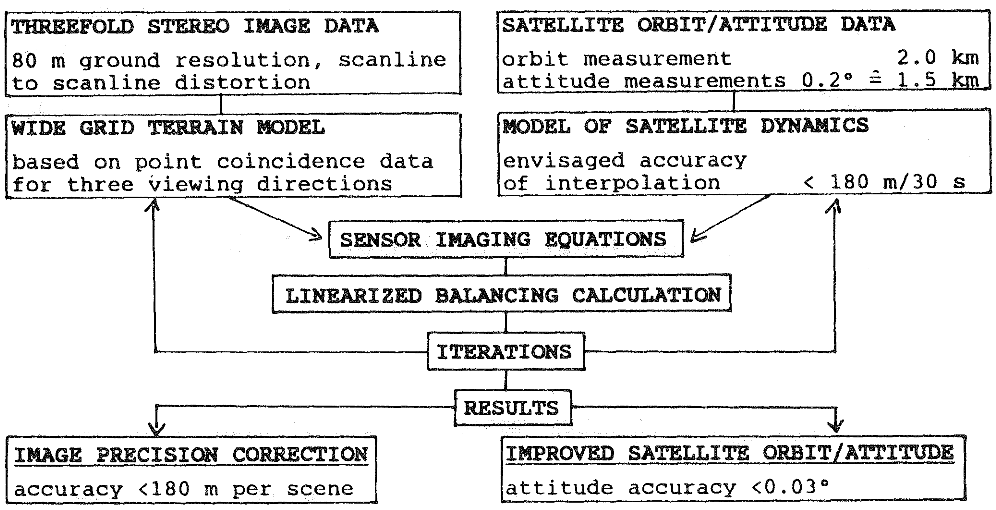
Meoss will be the first stereo scanner in space and offers the possibilities of

- basic investigation and test of different evaluation methods for threefold stereo scan systems and by this experience for the plannung of future higher resolution systems

- incorporation of orbit and attitude data of the satellite for the evaluation of the stereo information.

The program scheme to achieve these goals is indicated in Fig. 4.

Fig. 4 **MEOSS HIGH PRECISION CORRECTION SCHEME**



Geometric image correction will be based on ground control points and a large number of conjugate points, representing identical location in the three corresponding image stripes. In addition satellite orbit and attitude data are introduced. The result of these calculations involving photogrammetric collinearity equations are the position and orientation parameters of each recorded line, which can be applied to correct the image data.

In the following the type and magnitude of attitude variations of the satellite which cause a different orientation for each recorded line are given in more detail. Fig. 5 shows the attitude relevant aspects of the satellite schematically. Table 5 gives the attitude characteristics, table 6 and 7 the resulting dynamic image distortions and the static image displacement. Table 8 sumarizes the planned results of the indicated correction procedure.

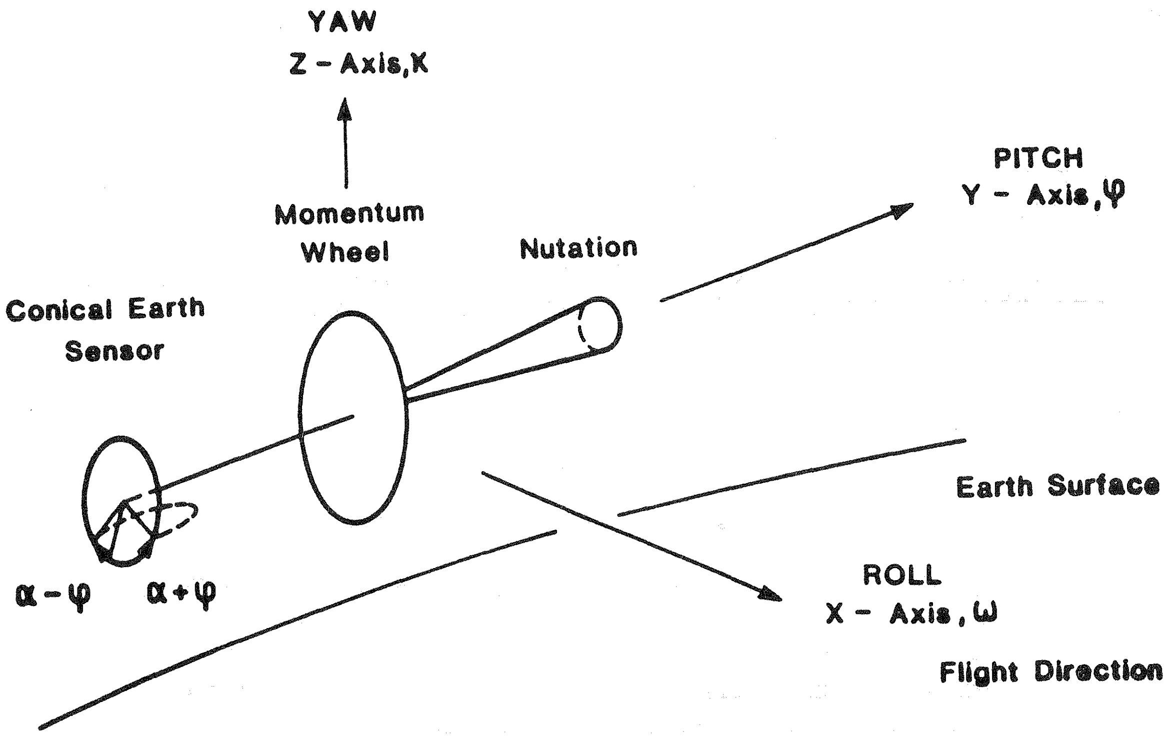


Fig. 5 Attitude Behavior of SROSS - 02 Satellite

Table 5 ATTITUDE CHARACTERISTICS OF SROSS-02 SATELLITE

	roll	pitch	yaw
Conical Scan Earth Sensor			
resolution	0.15°	0.15°	(0.4°)
Pitch Control System			
control range	---	+ 2.5° ± 0.5°	---
random drift	---	± 0.1°	---
drift periods	---	≥ 50 sec	---
drift frequencies	---	≤ $2 \cdot 10^{-2}$ Hz	---
Roll and Yaw Control System			
Control range	± 1.5°	---	± 3°
drift period	~ 5000 sec	---	~ 5000 sec
drift frequency	~ $2 \cdot 10^{-4}$ Hz	---	~. $2 \cdot 10^{-4}$ Hz
Nutation			
drift range	± 0.05°	---	± 0.03°
drift period	~ 12.5 sec	---	~ 12.5 sec
drift frequency	~ $8 \cdot 10^{-2}$ Hz	---	~ $8 \cdot 10^{-2}$ Hz

Table 6 **Dynamic Image Distortion**

Pitch random drift

± 0.1° ≙ ± 15 pixel
shift along X-axis
period > 50 sec; scene duration 29 sec

Nutation

± 0.05° ≙ ± 7 pixel
shear between Y-axis and X/Z-axis
period ~ 12.5 sec, scene duration 29 sec

Table 7 **Image Displacement**

Tracking Error
0.4 - 2 km ≙ 8 - 40 pixel
absolute position along X-axis

Earth Rotation (latitude dependent, electronically compensated)
± 8.6 km ≙ ± 110 pixel
lateral displacement
of fore and aft direction lines

Control system offset

pitch 2.5° ± 0.5° ≙ 375 ± 75 pixel
shift and scale change along X-axis

roll ± 1.5° ≙ ± 150 pixel
shift and scale change along Y-axis

yaw ± 3° ≙ ± 450 pixel
shear between X- and Y-axis

Table 8 **Correction of Image Distortion and Image Displacement**

1 MEOSS pixel

IFOV = 0,01° $\hat{=}$ P_y = 79 m; P_x = 52 m

1 MEOSS scene

swath width SW = 256 km $\hat{=}$ 3237 pixel, SW : H = 0,566

basis (length) B = ± 198 km $\hat{=}$ ± 3800 pixel, B : H = ± 0,452

Goal of correction:

better than 0,03° $\hat{=}$ 3 pixel

Data of MEOSS will be of importance for the following fields of application.

A. Cartographic Applications

Suggested activities are:

- registration of stereo images to a standard grid system
- derivation of ortho photos and ortho stereo triplets resampling procedures
- experimental derivation of topographic and orthophoto maps on scales 1:500 000 and eventually 1:250 000
- revision of topographical maps up to a scale 1:150 000.

B. Applications in Geology, Forestry, and Environmental Sciences

Suggested applications are:

- correlation of MEOSS stereo data with LANDSAT MSS, TM or SPOT multispectral data
- geolocigal mapping (lithology and structures)
- studies on angular variations of radiances; discrimination between surface and atmospheric effects
- forest inventory
- land use inventory.

In performing these tasks two features of the MEOSS mission may be of special interest:

- varying illumination (approx. 26 min. time shift per day)
- nearly 90° difference of stereoscopic viewing direction for observation from ascending and descending orbit segment at low latitudes.

C. Meteorology

The following information could be derived:

1. From MEOSS data alone

- cloud classification by 3 dimensinal observation at high resolution
- cloud-snow discrimination
- discrimination of Cirrus against diffuse background as dense cloud fields, snow covered areas and turbity patterns in water bodies
- cross track cloud velocities with 1.2 m/s resolution
- estimate of sea state from sunglint, detectable at three differently inclined scan planes
- estimation of cloud field dynamics by stereo observation from successive orbits with 93 min. time gap.

2. From combination with other data sources

- true heights of clouds and clouds displacement vectors by stereoscopy (along track cloud displacement velocity required. 1 m/s error leads to 61.1 m error in height assigment)
- optical density of clouds (radiation temperatures required).