



# United States Department of the Interior

U.S. GEOLOGICAL SURVEY  
Reston, Virginia 22092

## REPORT OF CALIBRATION of Aerial Mapping Camera

October 21, 1996

Camera type:	Zeiss RMK TOP 15*	Camera serial no.:	144123
Lens type:	Zeiss Pleogon A3/4	Lens serial no.:	143105
Nominal focal length:	153 mm	Maximum aperture:	f/4
		Test aperture:	f/4

Submitted by: Horizons, Inc.  
Rapid City, South Dakota

Reference: Letter dated October 11, 1996, from Mr. Marshall Swenson.

These measurements were made on Kodak Micro-flat glass plates, 0.25 inch thick, with spectroscopic emulsion type 157-01 Panchromatic, developed in D-19 at 68° F for 3 minutes with continuous agitation. These photographic plates were exposed on a multicollimator camera calibrator using a white light source rated at approximately 5200K.

I. Calibrated Focal Length: 152.765 mm

II. Lens Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	0	0	0	0	0	0
Decentering (um)	0	0	0	1	1	1

Symmetric radial  
distortion parameters

Decentering  
distortion parameters

Calibrated  
principal point

$$\begin{aligned} K_0 &= 0.1241 \times 10^{-4} \\ K_1 &= -0.1403 \times 10^{-8} \\ K_2 &= 0.2748 \times 10^{-13} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

$$\begin{aligned} P_1 &= 0.2070 \times 10^{-7} \\ P_2 &= 0.6219 \times 10^{-7} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

$$\begin{aligned} x_p &= -0.001 \text{ mm} \\ y_p &= -0.005 \text{ mm} \end{aligned}$$

The values and parameters for Calibrated Focal Length (CFL), Symmetric Radial Distortion ( $K_0, K_1, K_2, K_3, K_4$ ), Decentering Distortion ( $P_1, P_2, P_3, P_4$ ), and Calibrated Principal Point [point of symmetry] ( $x_p, y_p$ ) were determined through a least-squares Simultaneous Multiframe Analytical Calibration (SMAC) adjustment. The x and y-coordinate measurements utilized in the adjustment of the above parameters have a standard deviation ( $\sigma$ ) of  $\pm 3$  microns.

\* Equipped with Forward Motion Compensation

### III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 101

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	134	134	134	113	113	95	95
Tangential lines	134	134	113	95	95	80	80

The resolving power is obtained by photographing a series of test bars and examining the resultant image with appropriate magnification to find the spatial frequency of the finest pattern in which the bars can be counted with reasonable confidence. The series of patterns has spatial frequencies from 5 to 268 cycles/mm in a geometric series having a ratio of the 4th root of 2. Radial lines are parallel to a radius from the center of the field, and tangential lines are perpendicular to a radius.

### IV. Filter Parallelism

The two surfaces of the USGS TOP 15 test filter KL-F (60%) No. 142399 are within 10 seconds of being parallel. This filter, in conjunction with the internal "B" filter, was used for the calibration.

### V. Shutter Calibration

<u>Indicated exposure time</u>	<u>Effective exposure time</u>	<u>Efficiency</u>
1/100	11.00 ms = 1/90 s	71%
1/200	5.25 ms = 1/190 s	71%
1/300	3.34 ms = 1/300 s	71%
1/400	2.50 ms = 1/400 s	71%
1/500	2.00 ms = 1/500 s	71%

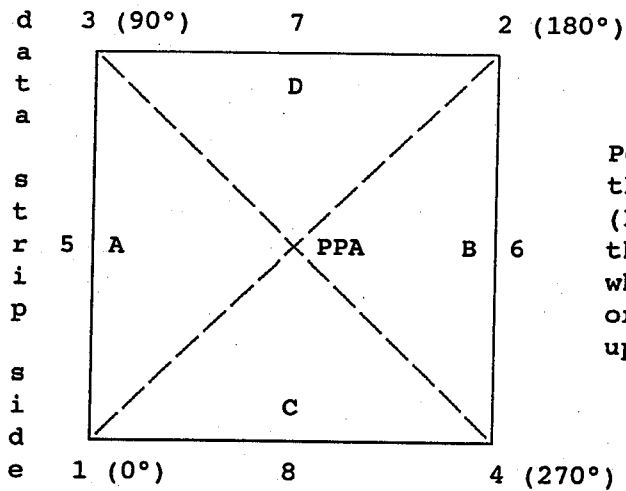
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

### VI. Magazine Platen

The platens mounted in fk 24/120 film magazine No. 111595 and T-MC No. 145764 do not depart from a true plane by more than 13 um (0.0005 in).

The platens for these film magazines are equipped with identification markers that will register "CZ278" for magazine No. 111595, and "145750" for magazine No. 145764 in the data strip area for each exposure.

VII. Principal Points and Fiducial Coordinates



Positions of all points are referenced to the principal point of autocollimation (PPA) as origin. The diagram indicates the orientation of the reference points when the camera is viewed from the back, or a contact positive with the emulsion up. The data strip is to the left.

	<u>X coordinate</u>	<u>Y coordinate</u>
Indicated principal point, corner fiducials	0.002 mm	-0.006 mm
Indicated principal point, midside fiducials	-0.001	-0.004
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) $x_p, y_p$	-0.001	-0.005

Fiducial Marks

Fiducial Mark	X coordinate	Y coordinate
1	-113.008 mm	-113.011 mm
2	113.007	112.995
3	-112.997	112.994
4	113.005	-113.011
5	-112.996	-0.009
6	113.019	0.000
7	0.004	113.002
8	-0.006	-112.994

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 319.627 mm                      3-4: 319.617 mm

Lines joining these markers intersect at an angle of 90° 00' 03"

Midside fiducials

5-6: 226.015 mm                      7-8: 225.996 mm

Lines joining these markers intersect at an angle of 89° 59' 43"

Corner fiducials (perimeter)

1-3: 226.005 mm                      2-3: 226.005 mm  
 1-4: 226.013 mm                      2-4: 226.006 mm

The method of measuring these distances is considered accurate within 0.003 mm

**Note:** For GPS applications, the nominal entrance pupil distance from the focal plane is 254 mm with a 10 mm filter thickness. Additional filter thickness will increase entrance pupil distance by 0.34 X added thickness.

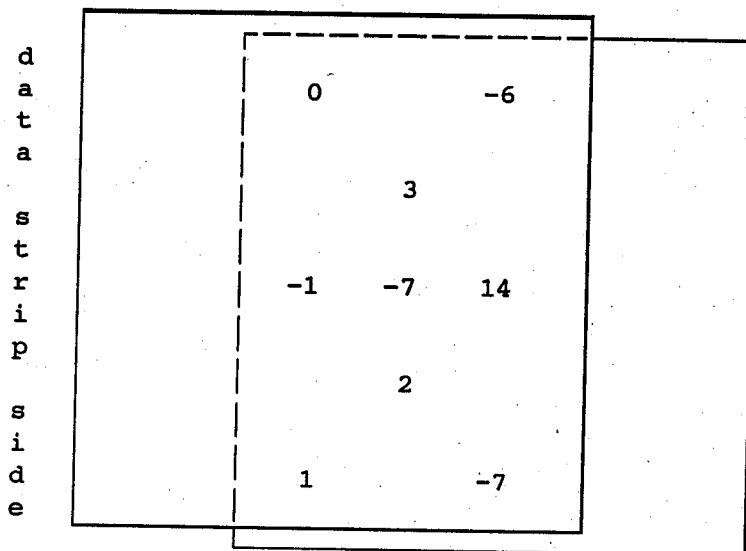
IX. Stereomodel Flatness

Magazine No.: 111595

Base/Height ratio: 0.6

Platen ID: CZ278

Maximum angle of field tested: 40°



Stereomodel  
Test point array  
(values in micrometers)

The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereomodels based on comparator measurements on contact glass (Kodak Micro-flat) diapositives made from Kodak 2405 film exposures. These measurements are considered accurate within 5 um.

X. System Resolving Power on film in cycles/mm

Area-weighted average resolution: 46

Film: Type 2405

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	57	57	48	48	48	48	48
Tangential lines	57	57	48	48	40	40	40

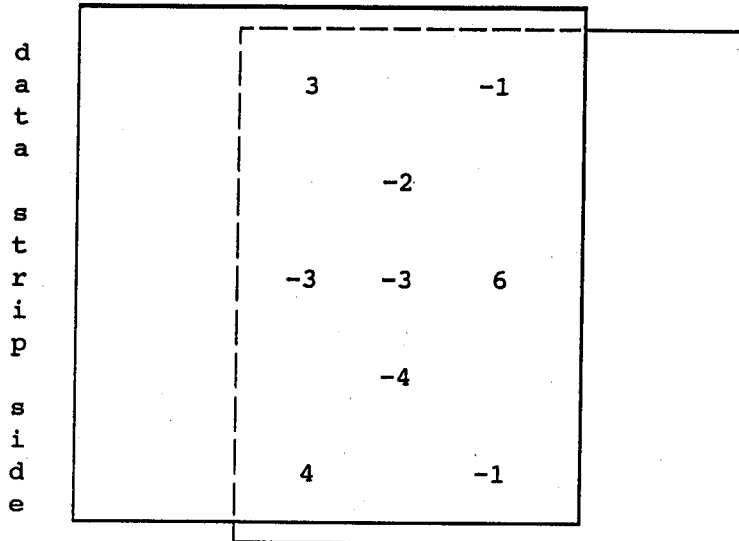
IX. Stereomodel Flatness

Magazine No.: 145764

Base/Height ratio: 0.6

Platen ID: 145750

Maximum angle of field tested: 40°



Stereomodel  
Test point array  
(values in micrometers)

The values shown on the diagram are the average departures from flatness (at negative scale) for two computer-simulated stereomodels based on comparator measurements on contact glass (Kodak Micro-flat) diapositives made from Kodak 2405 film exposures. These measurements are considered accurate within 5 um.

X. Lens/Film Resolving Power in cycles/mm

Area-weighted average resolution: 46

Film: Type 2405

Field angle:	0°	7.5°	15°	22.5°	30°	35°	40°
Radial Lines	57	57	57	48	48	48	40
Tangential lines	57	48	48	48	48	40	40

LENS/FILM DISTORTION PARAMETERS

Magazine No.: 111595

Base/Height ratio: 0.6

Platen ID: CZ278

Maximum angle of field tested: 40°

XI. Calibrated Focal Length: 152.772 mmXII. Lens/Film Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	0	-1	-1	-1	-1	1
Decentering (um)	0	1	2	3	5	7

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= 0.2343 \times 10^{-4} \\ K_1 &= -0.6556 \times 10^{-9} \\ K_2 &= -0.7928 \times 10^{-13} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= -0.3832 \times 10^{-6} \\ P_2 &= -0.1046 \times 10^{-6} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

Calibrated principal point

$$\begin{aligned} x_p &= -0.001 \text{ mm} \\ y_p &= -0.005 \text{ mm} \end{aligned}$$

The above measurements were computed from contact glass positives made from Kodak 2405 film exposed in the magazine.

The values and parameters for Calibrated Focal Length (CFL), Symmetric Radial Distortion ( $K_0, K_1, K_2, K_3, K_4$ ), Decentering Distortion ( $P_1, P_2, P_3, P_4$ ), and Calibrated Principal Point [point of symmetry] ( $x_p, y_p$ ) were determined through a least-squares Simultaneous Multiframe Analytical Calibration (SMAC) adjustment. The x and y-coordinate measurements utilized in the adjustment of the above parameters have a standard deviation ( $\sigma$ ) of  $\pm 3$  microns.

LENS/FILM DISTORTION PARAMETERS

Magazine No.: 145764

Base/Height ratio: 0.6

Platen ID: 145750

Maximum angle of field tested: 40°

XI. Calibrated Focal Length: 152.816 mmXII. Lens/Film Distortion

Field angle:	7.5°	15°	22.5°	30°	35°	40°
Symmetric radial (um)	0	0	0	0	0	0
Decentering (um)	0	0	0	0	0	1

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= -0.1291 \times 10^{-4} \\ K_1 &= 0.3455 \times 10^{-8} \\ K_2 &= -0.1717 \times 10^{-12} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= -0.3350 \times 10^{-7} \\ P_2 &= -0.1474 \times 10^{-7} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

Calibrated principal point

$$\begin{aligned} x_p &= -0.001 \text{ mm} \\ y_p &= -0.005 \text{ mm} \end{aligned}$$

The above measurements were computed from contact glass positives made from Kodak 2405 film exposed in the magazine.

The values and parameters for Calibrated Focal Length (CFL), Symmetric Radial Distortion ( $K_0, K_1, K_2, K_3, K_4$ ), Decentering Distortion ( $P_1, P_2, P_3, P_4$ ), and Calibrated Principal Point [point of symmetry] ( $x_p, y_p$ ) were determined through a least-squares Simultaneous Multiframe Analytical Calibration (SMAC) adjustment. The x and y-coordinate measurements utilized in the adjustment of the above parameters have a standard deviation ( $\sigma$ ) of  $\pm 3$  microns.

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2127, dated August 29, 1995.

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