



United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 22092

REPORT OF CALIBRATION of Aerial Mapping Camera

January 10, 1995

Camera type:	Zeiss RMK Top 15*	Camera serial no.:	141299
Lens type:	Zeiss Pleogon A3/4	Lens serial no.:	141334
Nominal focal length:	153 mm	Maximum aperture:	f/4
		Test aperture:	f/4

Submitted by: Kenney Aerial Mapping Company
Phoenix, Arizona

Reference: Carl Zeiss, Inc., purchase order No.
337-950024, dated January 11, 1995.

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: 153.966 mm

II. Lens Distortion

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

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= 0.2789 \times 10^{-5} \\ K_1 &= -0.4689 \times 10^{-8} \\ K_2 &= 0.3049 \times 10^{-12} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= -0.1661 \times 10^{-6} \\ P_2 &= -0.5452 \times 10^{-8} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

Calibrated principal point

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

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 (σ) of ± 3 microns.

* Equipped with Forward Motion Compensation

III. Resolving Power in cycles/mm

Area-weighted average resolution: 89

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	134	159	134	95	95	80	95
Tangential lines	134	134	113	80	67	67	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 KL-F (36%) No. 141519 filter accompanying this camera and the USGS TOP 15 test filter KL-F (60%) No. 142399 are within 10 seconds of being parallel. The USGS test 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	70%
1/200	5.25 ms = 1/190 s	70%
1/300	3.51 ms = 1/285 s	70%
1/400	2.75 ms = 1/365 s	70%
1/500	2.10 ms = 1/475 s	70%

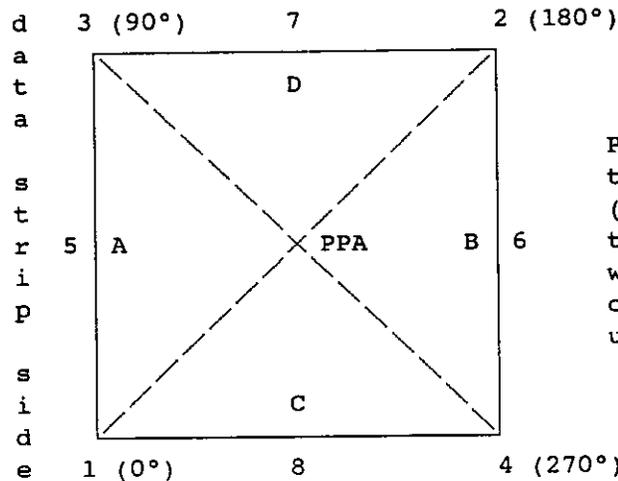
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

VI. Magazine Platen

The platen mounted in T-MC film magazine No. 137708 does not depart from a true plane by more than 13 μ m (0.0005 in).

The platen for this film magazine is equipped with an identification marker that will register "141630" 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	-0.005 mm
Indicated principal point, midside fiducials	0.005	-0.010
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	0.005	-0.005

Fiducial Marks

1	-112.988 mm	-113.004 mm
2	112.993	113.005
3	-113.003	112.985
4	113.008	-113.004
5	-112.993	-0.013
6	113.010	-0.008
7	-0.001	113.009
8	0.012	-112.992

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 319.606 mm 3-4: 319.612 mm

Lines joining these markers intersect at an angle of 89° 59' 57"

Midside fiducials

5-6: 226.003 mm 7-8: 226.001 mm

Lines joining these markers intersect at an angle of 90° 00' 08"

Corner fiducials (perimeter)

1-3: 225.990 mm 2-3: 225.996 mm

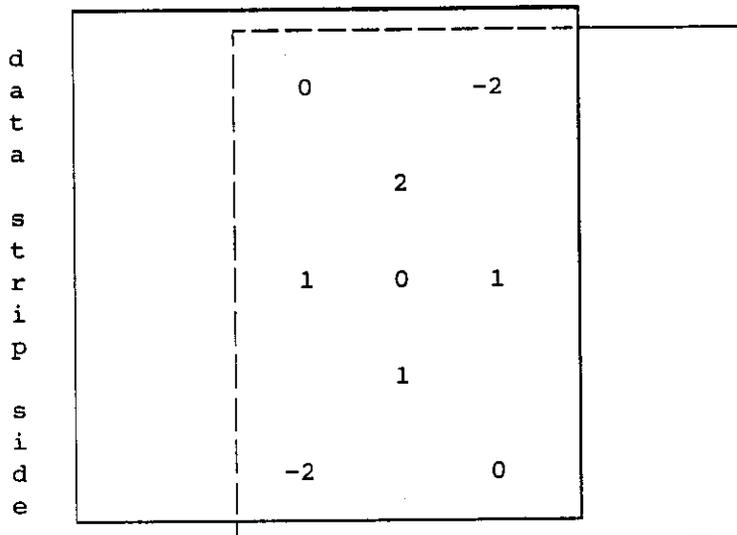
1-4: 225.996 mm 2-4: 226.009 mm

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

IX. Stereomodel Flatness

Magazine No.: 137708
 Platen ID: 141630

Base/Height ratio: 0.6
 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 μ m.

X. Lens/Film Resolving Power in cycles/mm

Area-weighted average resolution: 47

Film: Type 2405

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	67	57	57	48	48	48	48
Tangential lines	67	57	57	48	40	40	40

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/1741, dated March 20, 1992.

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 National Mapping Division



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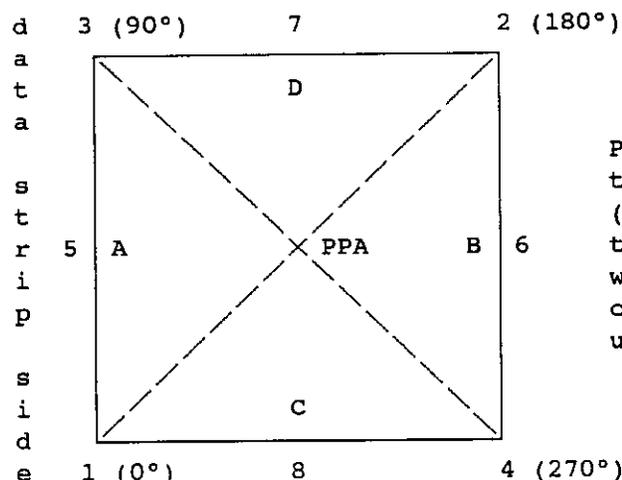
II. Radial Distortion

Field angle	\bar{D}_C	D_C for azimuth angle			
		0° A-C	90° A-D	180° B-D	270° B-C
degrees	um	um	um	um	um
7.5	0	0	0	-1	0
15	0	1	1	-1	-1
22.7	1	2	2	1	-2
30	1	3	0	3	-2
35	1	2	-1	4	-2
40	-2	2	-6	1	-3

The radial distortion is measured for each of four radii of the focal plane separated by 90° in azimuth. To minimize plotting error due to distortion, a full least-squares solution is used to determine the calibrated focal length. \bar{D}_C is the average distortion for a given field angle. Values of distortion D_C based on the calibrated focal length referred to the calibrated principal point (point of symmetry) are listed for azimuths 0°, 90°, 180° and 270°. The radial distortion is given in micrometers and indicates the radial displacement away from the center of the field. These measurements are considered accurate within 5 um.

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