



United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Reston, Virginia 20192

REPORT OF CALIBRATION of Aerial Mapping Camera

August 5, 2004

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, Inc.
Phoenix, Arizona

Reference: Z/I Imaging Corporation purchase order
No. PO002776, dated August 5, 2004.

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: 154.090 mm

II. Lens Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	-1	-1	-1	0	1	1
Decentering (um)	0	0	1	2	3	4

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= 0.3747 \times 10^{-4} \\ K_1 &= -0.5775 \times 10^{-8} \\ K_2 &= 0.1786 \times 10^{-12} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= -0.1415 \times 10^{-6} \\ P_2 &= -0.1622 \times 10^{-6} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

Calibrated principal point

$$\begin{aligned} x_p &= -0.002 \text{ mm} \\ y_p &= 0.005 \text{ mm} \end{aligned}$$

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. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 100

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

Indicated time (sec)	Rise time (μ sec)	Fall Time (μ sec)	$\frac{1}{2}$ width time (ms)	Nom. Speed (sec.)	Efficiency (%)
1/100	3763	3840	10.82	1/120	78
1/200	1878	1861	5.23	1/250	78
1/300	1250	1248	3.47	1/370	78
1/400	899	890	2.59	1/490	78
1/500	742	743	2.06	1/630	78

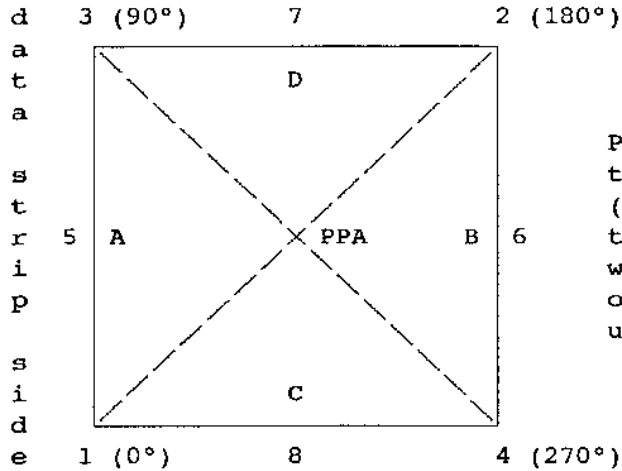
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

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	-0.010 mm	0.001 mm
Indicated principal point, midside fiducials	0.016	-0.001
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	-0.002	0.005

Fiducial Marks

1	-112.979 mm	-113.001 mm
2	112.987	113.030
3	-113.011	112.990
4	113.005	-113.001
5	-112.992	-0.011
6	113.013	0.010
7	0.009	112.983
8	0.023	-112.984

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 319.611 mm 3-4: 319.617 mm

Lines joining these markers intersect at an angle of 89° 59' 41"

Midside fiducials

5-6: 226.004 mm 7-8: 225.967 mm

Lines joining these markers intersect at an angle of 89° 59' 54"

Corner fiducials (perimeter)

1-3: 225.991 mm 2-3: 225.998 mm

1-4: 225.984 mm 2-4: 226.032 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.

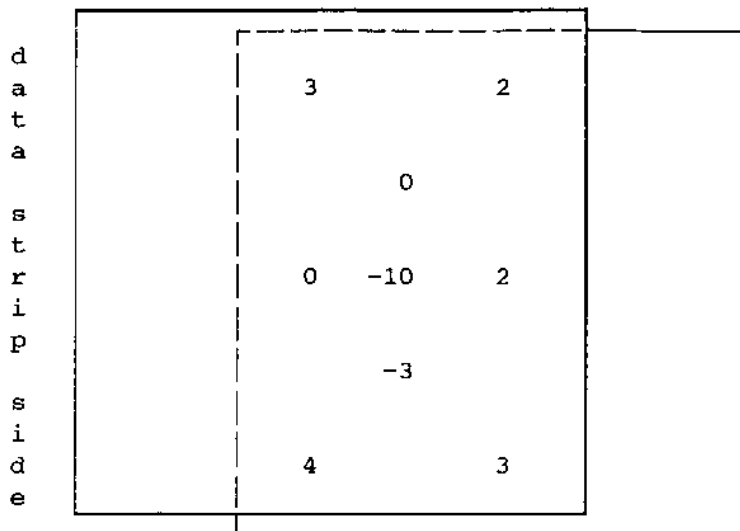
IX. Stereomodel Flatness

FMC Magazine No.: 137708

Base/Height ratio: 0.6

Platen ID: 141630

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 stereo models. The values are based on comparator measurements on Kodak 4425 copy film made from Kodak 2405 film exposures. These measurements can vary by as much as $\pm 5 \mu\text{m}$ from model to model.

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	57	48	48	48	40
Tangential lines	57	57	48	48	48	40	34

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/3011, dated February 7, 2004.

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