



# United States Department of the Interior

U.S. GEOLOGICAL SURVEY  
Reston, Virginia 20192

## REPORT OF CALIBRATION of Aerial Mapping Camera

December 12, 2001

Camera type:	Zeiss TOP 15*	Camera serial no.:	145844
Lens type:	Zeiss Pleogon A3/4	Lens serial no.:	145891
Nominal focal length:	153 mm	Maximum aperture:	f/4
		Test aperture:	f/4

Submitted by: Midwest Aerial Photography  
Galloway, Ohio

Reference: Letter of authorization, signed by Ms.  
Jeannie Radford, dated December 10, 2001.

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: 153.000 mm

### II. Lens Distortion

Field angle:	7.5°	15°	22.7°	30°	35°	40°
Symmetric radial (um)	-1	-1	0	2	2	-2
Decentering (um)	0	1	1	2	4	5

#### Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= 0.3746 \times 10^{-4} \\ K_1 &= -0.1217 \times 10^{-7} \\ K_2 &= 0.6494 \times 10^{-12} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

#### Decentering distortion parameters

$$\begin{aligned} P_1 &= -0.3092 \times 10^{-6} \\ P_2 &= 0.6082 \times 10^{-7} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

#### Calibrated principal point

$$\begin{aligned} x_p &= 0.008 \text{ mm} \\ y_p &= -0.008 \text{ mm} \end{aligned}$$

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: 102

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	134	134	134	113	113	95	95
Tangential lines	134	113	113	113	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 Zeiss TOP 15 KL-F (36%) filter No. 150025, 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

Indicated time (sec)	Rise time ( $\mu$ sec)	Fall Time ( $\mu$ sec)	$\frac{1}{2}$ width time (ms)	Nom. Speed (sec.)	Efficiency (%)
1/100	4094	4049	11.00	1/120	76
1/200	2016	2016	5.22	1/250	76
1/300	1321	1306	3.48	1/380	76
1/400	950	967	2.53	1/520	76
1/500	755	770	2.03	1/640	76

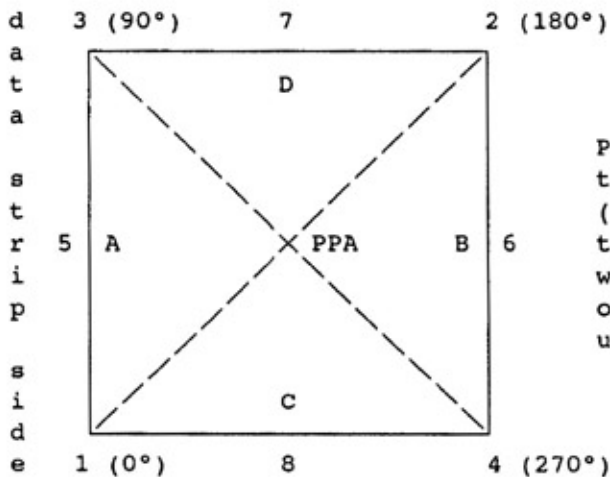
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

### VI. Magazine Platen

The platen mounted in T-MC film magazine No. 145759 does not depart from a true plane by more than 13  $\mu$ m (0.0005 in).

The platen for this film magazine is equipped with an identification marker that will register "144862" 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	0.023 mm	0.004 mm
Indicated principal point, midside fiducials	0.019	0.002
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) $x_p, y_p$	0.008	-0.008

Fiducial Marks

1	-112.980 mm	-112.990 mm
2	113.021	112.993
3	-112.977	113.006
4	113.015	-112.990
5	-112.985	0.011
6	113.031	-0.007
7	0.021	113.001
8	0.016	-112.988

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 319.600 mm                      3-4: 319.604 mm

Lines joining these markers intersect at an angle of 90° 00' 06"

Midside fiducials

5-6: 226.016 mm                      7-8: 225.989 mm

Lines joining these markers intersect at an angle of 90° 00' 12"

Corner fiducials (perimeter)

1-3: 225.996 mm                      2-3: 225.998 mm

1-4: 225.995 mm                      2-4: 225.983 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.

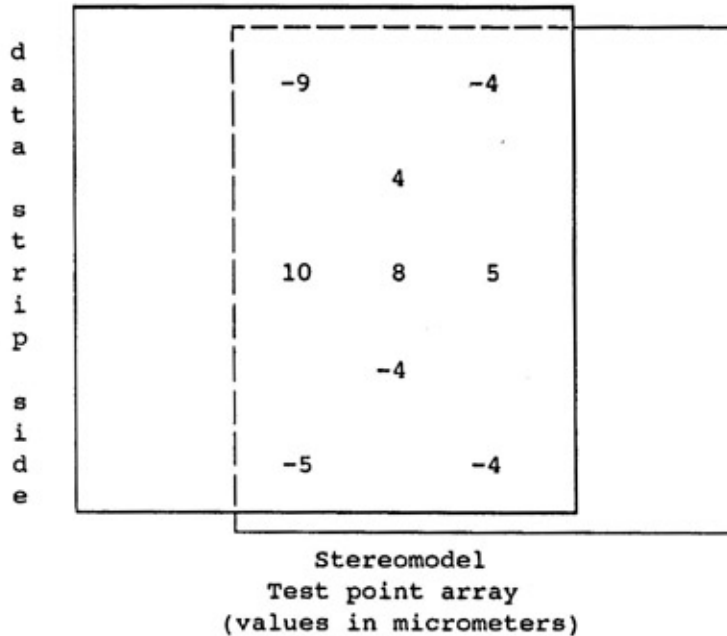
IX. Stereomodel Flatness

FMC Magazine No.: 145759

Base/Height ratio: 0.6

Platen ID: 144862

Maximum angle of field tested: 40°



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 contact glass (Kodak Micro-flat) diapositives 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: 50

Film: Type 2405

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

LENS/FILM DISTORTION PARAMETERS

FMC Magazine No.: 145759

Base/Height ratio: 0.6

Platen ID: 144862

Maximum angle of field tested: 40°

XI. Calibrated Focal Length: 152.980 mmXII. Lens/Film Distortion

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

Symmetric radial distortion parameters

$$\begin{aligned} K_0 &= -0.9696 \times 10^{-4} \\ K_1 &= 0.1276 \times 10^{-7} \\ K_2 &= -0.3230 \times 10^{-12} \\ K_3 &= 0.0000 \\ K_4 &= 0.0000 \end{aligned}$$

Decentering distortion parameters

$$\begin{aligned} P_1 &= -0.1008 \times 10^{-6} \\ P_2 &= -0.1742 \times 10^{-7} \\ P_3 &= 0.0000 \\ P_4 &= 0.0000 \end{aligned}$$

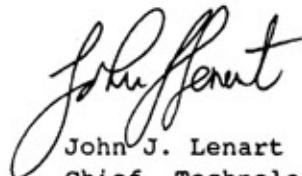
Calibrated principal point

$$\begin{aligned} x_p &= 0.008 \text{ mm} \\ y_p &= -0.008 \text{ mm} \end{aligned}$$

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/2795, dated November 1, 2001.



John J. Lenart  
Chief, Technology Operations Section  
National Mapping Division