United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION
of Aerial Mapping Camera

March 26, 2015

Camera type:	Zeiss RMK Top 15*	**Camera serial no.:**	151979
Lens type:	Zeiss Pleogon A3/4	**Lens serial no.:**	152092
Nominal focal Length:	153 mm	**Maximum aperture:**	f/4
		Test aperture:	f/4

Submitted by: Aerocon Photogrammetric Services, Inc.
Willoughby, OH

Reference:

These measurements were made on Agfa glass plates, 0.19 inch thick, with spectroscopic emulsion type APX 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: 153.174 mm

II.   Lens Distortion

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

Symmetric radial distortion	Decentering distortion	Calibrated principal point
K_0 = -0.6871E-04	P_1 = 0.4803E-07	x_p = 0.001 mm
K_1 = 0.6479E-08	P_2 = 0.4957E-07	y_p = 0.009 mm
K_2 = -0.6876E-13	P_3 = 0.0000	
K_3 = 0.0000	P_4 = 0.0000	
K_4 = 0.0000		

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: 105

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	113	113	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 and KL-F (36%) filter No. 151502 are within 10 seconds of being parallel. The USGS TOP 15 filter, in conjunction with the internal "B" filter, was used for the calibration.
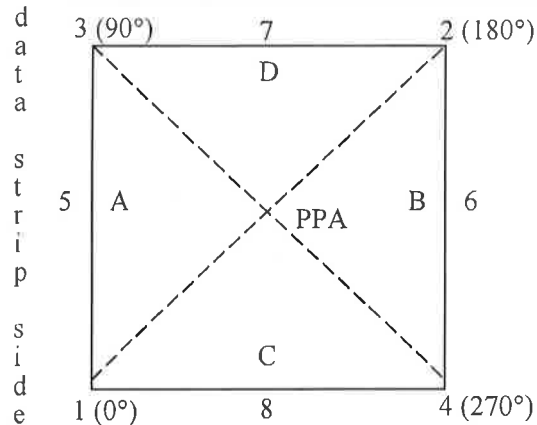
V.   Shutter Calibration

Indicated Time (sec)	Rise Time (μ sec)	Fall Time (μ	½ Width Time (ms)	Nom. Speed (sec)	Efficiency (%)
1/100	3437	3444	10.94	1/110	80
1/200	1888	1778	5.31	1/240	78
1/300	1259	1264	3.44	1/380	77
1/400	923	894	2.58	1/500	78
1/500	731	739	2.08	1/620	78

The effective exposure times were determined with the lens at aperature f/4. The method is considered accurate within 3 percent. The technique used is described in International Standard ISO 516:1999(E).

VI.   Magazine Platen

The platen mounted in Zeiss T-MC film magazine No. 151621 does not depart from a true plane by more than 13 μm (0.0005 in).

The platen for this film magazine is equipped with an identification marker that will register "151808" in the data strip area for each exposure.

VII. Principal Point and Fiducial Mark Coordinates

```
d
a     3 (90°)        7           2 (180°)
t
a              D
s
t     5  A              B   6
r              ×
i              PPA
p
s
i              C
d
e     1 (0°)        8           4 (270°)
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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.

	X coordinate (mm)	Y coordinate (mm)
Indicated principal point, corner fiducials	0.016	0.002
Indicated principal point, midside fiducials	0.008	-0.004
Principal point of autocollimation (PPA)	0.000	0.000
Calibrated principal point (point of symmetry)	0.001	0.009

Fiducial Marks		
1	-112.990	-113.001
2	113.014	112.997
3	-112.975	112.991
4	113.021	-113.001
5	-112.988	-0.003
6	113.016	-0.006
7	0.016	112.992
8	0.001	-113.045

VIII. Distances Between Fiducial marks

Corner fiducials (diagonals)	1-2:	319.613 mm	3-4:	319.604 mm

Lines joining these markers intersect at an angle o 90° 00' 04"

Midside fiducials	5-6:	226.005 mm	7-8:	226.037 mm

Lines joining these markers intersect at an angle o 89° 59' 49"

Corner fiducials (perimeter)	1-3:	225.993 mm	2-3:	225.989 mm
	1-4:	226.011 mm	2-4:	225.998 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 254mm 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: 151621

Platen ID: 151808

Base/Height ratio: 0.6

Maximum angle of field tested: 40 °

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d  ┌─────────────────────────────┐
a  │     ┌╌╌╌╌╌╌╌╌╌╌╌╌╌╌╌┐        │
t  │     ┆   5        -6 ┆        │
a  │     ┆               ┆        │
   │     ┆       -3      ┆        │
s  │     ┆               ┆        │
t  │     ┆   9   -7    3 ┆        │
r  │     ┆               ┆        │
i  │     ┆        1      ┆        │
p  │     ┆               ┆        │
   │     ┆  -10        7 ┆        │
s  │     └╌╌╌╌╌╌╌╌╌╌╌╌╌╌╌┘        │
i  └─────────────────────────────┘
d
e
```
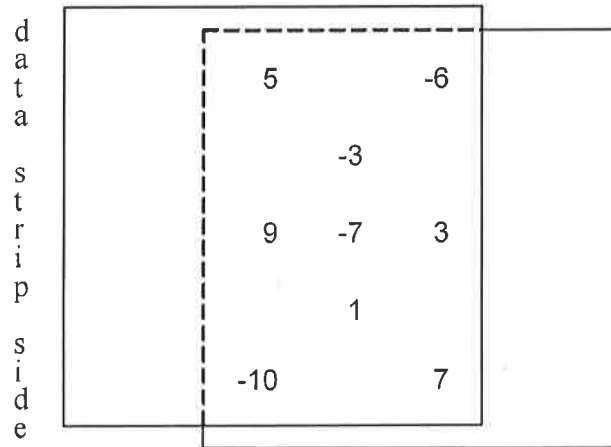
Stereomodel Test Point Array
(values in micrometers)

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 Agfa Avitone P3p copy film made from Agfa Aviphot Pan 200 film exposures. These measurements are considered accurate to within 5 μm.

X.   System Resolving Power on film in cycles/mm

Area-weighted average resolution: 49   **Film:** Pan 200

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

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/3589, dated February 17, 2012.

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Climate and Land Use Change