United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION   June 20, 2001
of Aerial Mapping Camera

Camera type: Wild RC20*   Camera serial no.: 5116
Lens type: Wild Universal Aviogon A4-F   Lens serial no.:   13150
Nominal focal length: 153 mm   Maximum aperture: f/4
                                     Test aperture: f/4

Submitted by: Air Photographics, Inc.
                Martinsburg, West Virginia

Reference: Air Photographics, Inc. purchase
                order No. 0701, dated June 20, 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: 152.816 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	0	1	1	2

Symmetric radial distortion parameters	Decentering distortion parameters	Calibrated principal point
$K_0 = 0.4646 \times 10^{-4}$	$P_1 = -0.9453 \times 10^{-7}$	$x_p = 0.003$ mm
$K_1 = -0.9108 \times 10^{-8}$	$P_2 = -0.2916 \times 10^{-7}$	$y_p = -0.004$ mm
$K_2 = 0.3563 \times 10^{-12}$	$P_3 = 0.0000$	
$K_3 = 0.0000$	$P_4 = 0.0000$	
$K_4 = 0.0000$		

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: 89

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	95	95	113	95	95	95	67
Tangential lines	95	80	95	95	95	80	67

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 Wild 525 No. 6707 filter accompanying this camera are within 10 seconds of being parallel. This filter was used for the calibration.

V. Shutter Calibration

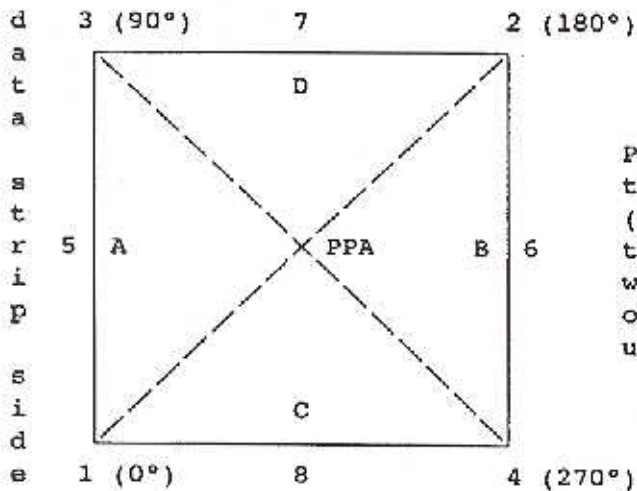| Indicated time (sec)	Rise time (μ sec)	Fall Time (μ sec)	½ width time (ms)	Nom. Speed (sec.)	Efficiency (%)
1/125	1750	1758	8.20	1/140	87
1/250	882	875	4.19	1/270	87
1/500	450	447	2.14	1/540	87
1/1000	233	228	1.07	1/1080	87

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. Film Platen

The film platen mounted in Wild RC20 drive unit No. 5116-515 does not depart from a true plane by more than 13 um (0.0005 in).

This camera is equipped with a platen identification marker that will register "515" in the data strip area for each exposure.

VII. Principal Points and Fiducial Coordinates

```
d    3 (90°)          7              2 (180°)
a
t       ┌─────────────────────────────────┐
a       │ ╲              D              ╱  │
        │   ╲                         ╱    │
s       │     ╲                     ╱      │
t       │       ╲                 ╱        │
r    5  │ A       ╳ PPA              B │ 6
i       │       ╱                 ╲        │
p       │     ╱                     ╲      │
        │   ╱                         ╲    │
s       │ ╱              C              ╲  │
i       └─────────────────────────────────┘
d
e    1 (0°)           8              4 (270°)
```

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	Y coordinate
Indicated principal point, corner fiducials	−0.010 mm	0.005 mm
Indicated principal point, midside fiducials	−0.009	0.004
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	0.003	−0.004

Fiducial Marks

	X coordinate	Y coordinate
1	−106.010 mm	−105.997 mm
2	105.988	106.007
3	−106.004	106.001
4	105.991	−105.997
5	−110.011	0.000
6	109.980	0.009
7	−0.008	110.001
8	−0.010	−110.005

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)
    1-2: 299.815 mm   3-4: 299.808 mm
Lines joining these markers intersect at an angle of 89° 59' 56"

Midside fiducials
    5-6: 219.992 mm   7-8: 220.006 mm
Lines joining these markers intersect at an angle of 89° 59' 49"

Corner fiducials (perimeter)
    1-3: 211.998 mm   2-3: 211.993 mm
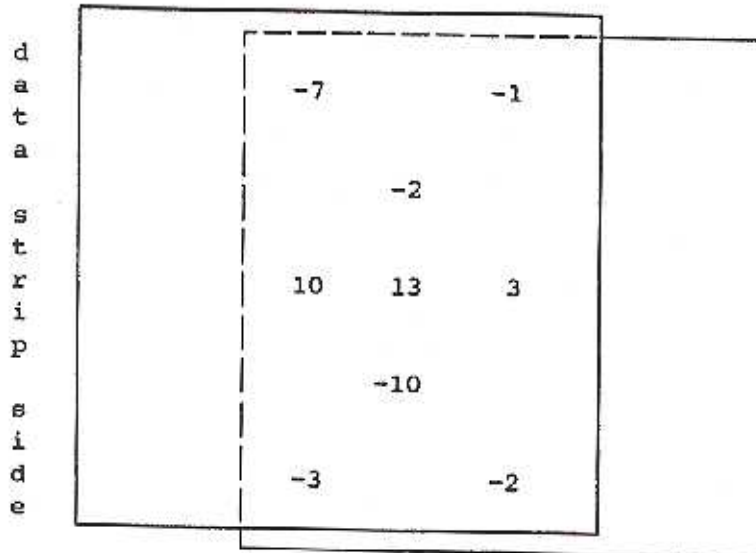   1-4: 212.001 mm   2-4: 212.004 mm

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 282 mm.

IX. Stereomodel Flatness

FMC Drive Unit No.: 5116-515   Base/Height ratio: 0.6

Platen ID: 515   Maximum angle of field tested: 40°


```
d
a
t      -7            -1
a
s
t          -2
r
i   10    13     3
p
s
i          -10
d
e   -3            -2
```

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 contact glass (Kodak Micro-flat) diaposi-tives made from Kodak 2405 film exposures. These measurements can vary by as much as ± 5 μm from model to model.

X. System Resolving Power on film in cycles/mm

Area-weighted average resolution: 43   Film: Type 2405

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

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2449, dated June 10, 1998.

Christoph T. Larson

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

Conversion of SMAC Distortion Parameters to Distortion Offsets
==

Input Parameters

Calibrated focal length	: 152.816 mm
Radial distortion K0	: 0.4646e-4
Radial distortion K1	: -0.9108e-8
Radial distortion K2	: 0.3563e-12
Radial distortion K3	: 0.0000
Radial distortion K4	: 0.0000
Decentering distortion P1	: -0.9453e-7
Decentering distortion P2	: -0.2916e-7
Decentering distortion P3	: 0.0000
Decentering distortion P4	: 0.0000
Calibrated principal point, Xp	: 0.003 mm
Calibrated principal point, Yp	: -0.004 mm

Radial and tangential distortion offsets
----

rad	mean	0 degrees		90 degrees		180 degrees		270 degrees	
10	-0.5	-0.5	0.0	-0.5	-0.0	-0.4	-0.0	-0.4	0.0
20	-0.9	-1.0	0.0	-0.9	-0.0	-0.8	-0.0	-0.8	0.0
30	-1.2	-1.4	0.0	-1.3	-0.1	-0.9	-0.0	-1.0	0.1
40	-1.3	-1.7	0.1	-1.5	-0.1	-0.9	-0.1	-1.1	0.1
50	-1.3	-2.0	0.1	-1.6	-0.2	-0.6	-0.1	-0.9	0.2
60	-1.1	-2.0	0.2	-1.6	-0.3	-0.2	-0.2	-0.6	0.3
70	-0.7	-2.0	0.2	-1.4	-0.4	0.6	-0.2	-0.0	0.4
80	-0.2	-1.9	0.3	-1.1	-0.6	1.5	-0.3	0.7	0.6
90	0.4	-1.8	0.4	-0.8	-0.7	2.5	-0.4	1.5	0.7
100	0.9	-1.7	0.5	-0.5	-0.9	3.5	-0.5	2.3	0.9
110	1.3	-1.9	0.6	-0.4	-1.1	4.4	-0.6	3.0	1.1
120	1.3	-2.5	0.7	-0.7	-1.3	5.1	-0.7	3.3	1.3
130	0.7	-3.7	0.8	-1.6	-1.5	5.2	-0.8	3.1	1.5
140	-0.7	-5.8	0.9	-3.4	-1.7	4.5	-0.9	2.0	1.7
150	-3.3	-9.2	1.0	-6.4	-2.0	2.6	-1.0	-0.2	2.0

rad	: radius in mm
mean	: mean radial distortion in micron
nnn degrees	: radial and tangential distortion in micron for the four semi-diagonals with nnn the orientation angle as used in USGS calibration reports.

MSU input values

Principal Distance	: 152.816
Principal Point of Autocollimation	: 0.000 0.000
Point of Best Symmetry	: 0.003 -0.004
Distortion interval	: 10 mm

16 radial distortion values in micron for radii
of 10, 20 .. 160 mm plus a terminating zero:

```
  -0.5  -0.9  -1.2  -1.3  -1.3  -1.1  -0.7  -0.2
   0.4   0.9   1.3   1.3   0.7  -0.7  -3.3  -7.5   0.0
```