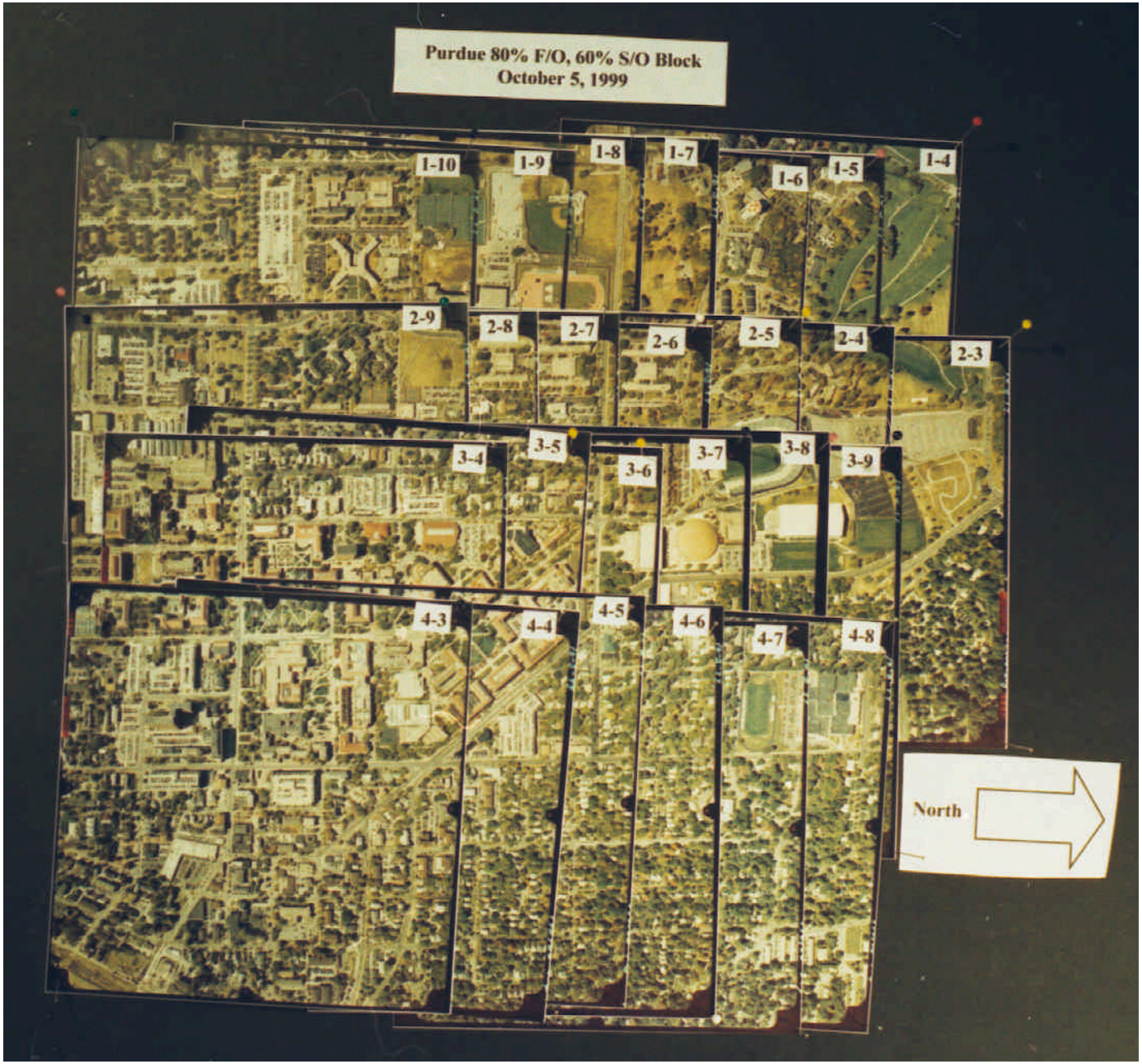
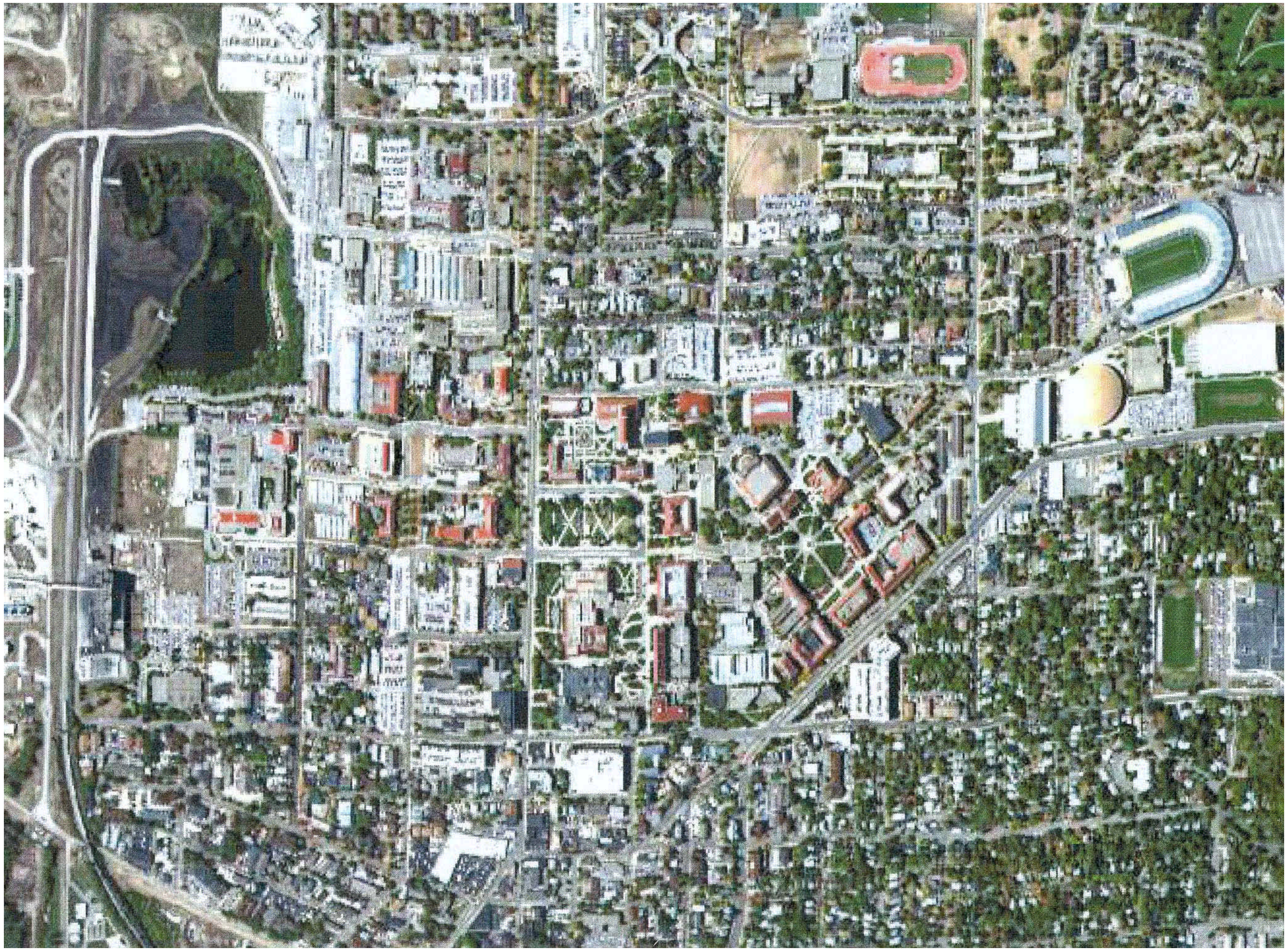


Index Mosaic of 1999 Purdue Block: 80% Forward Overlap and 60% Side Overlap (usual is 60/30 !) – Many trees show that October is not best time.

HYMAP Data, Summer 1999



Tying Block to Reference Coordinate System

- GPS in the aircraft. Exposure events are never synchronized with position determination, so we record time and interpolate. Still requires block adjustment!

- GPS/INS in the aircraft. Modern systems *almost* eliminate the need for block adjustment, but *not quite* ! At least for conventional mapping. Requires big investment by aerial photography vendor.

- Control Points. Low cost (investment). High cost (labor). Can be *signalized* (painted targets) or natural, *photo-ID* points. Targets require planning and logistics, photo-ID not.

- Any combination of the above.

Constraining the Block Adjustment

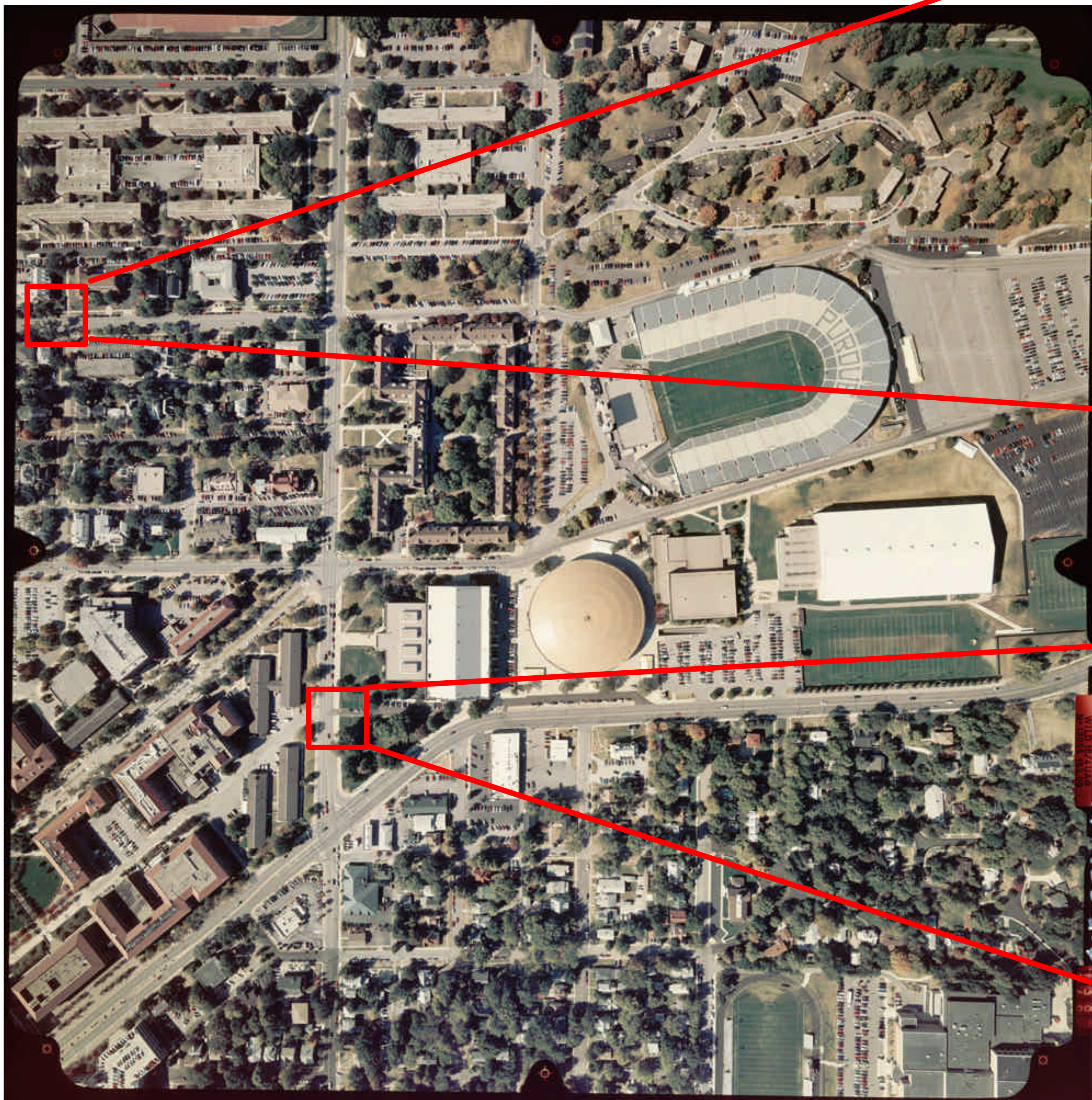
- The reference system can be arbitrary (i.e. fix seven parameters: position of one camera (3), attitude of one camera (3), scale (1).
- Arbitrary system can also be enforced by *free network* or *inner constraints*. Instead of arbitrarily selecting seven parameters to fix, we spread seven constraints over many parameters.
- Fixed constraints: parameter gets no correction
- Weighted constraints: small corrections governed by weight
- Unified least squares (see CE605): *everything* is an observation, its role is determined by *a priori* sigma or weight.

Photo 2-4

STNE

MACK

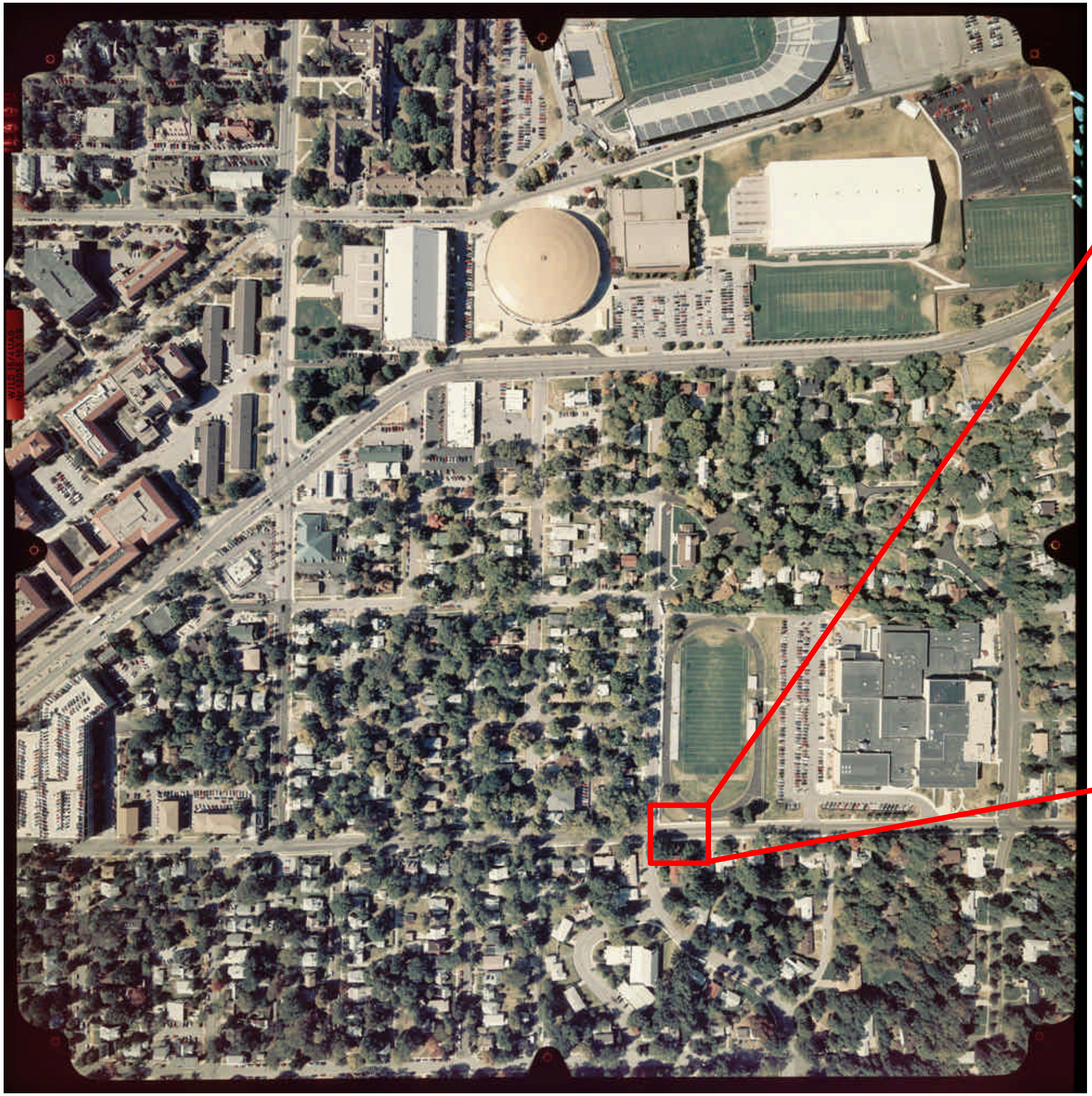
Photo 2-4

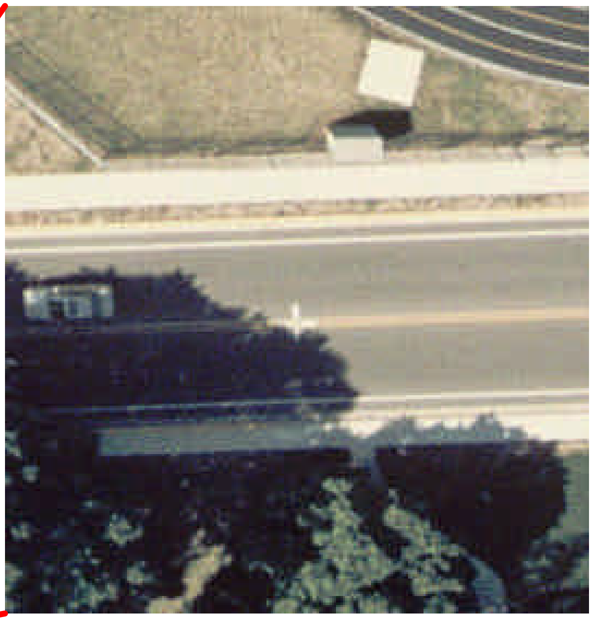


PH12

T19

Photo 3-9





HISC

Photo 1-7

BBLL

(painted cross)

Photo 2-9

LILY

Photo 3-4

CHEM

PH11

Photo 3-4

FOOD

UNION

Control Point Coordinates

(Ind. State Plane West, meters; Height above MSL)

Name	East	North	Height
STNE	914033.105	575906.022	205.029
MACK	914240.575	575735.100	193.806
BBLL	913565.598	575312.949	188.413
LILY	913918.320	574521.670	189.121
UNION	914669.074	574627.642	187.221
FOOD	914259.905	574429.529	188.090
T019	914270.793	575432.323	191.420
PH11	914684.629	575022.082	186.935
CHEM	914390.023	574830.733	188.652
PH12	913928.634	575198.475	189.874
HISC	914661.357	575767.410	192.104

GPS Survey of Control Points

Point PH12 at Fifth & Russell Streets

Point BBLL off of Stadium Ave. between track & baseball field

Point MACK in parking lot off of Northwestern Ave., next to Mackey Arena

Ibrahim Aly downloading data from Ashtech receiver and processing

Pass Point Selection

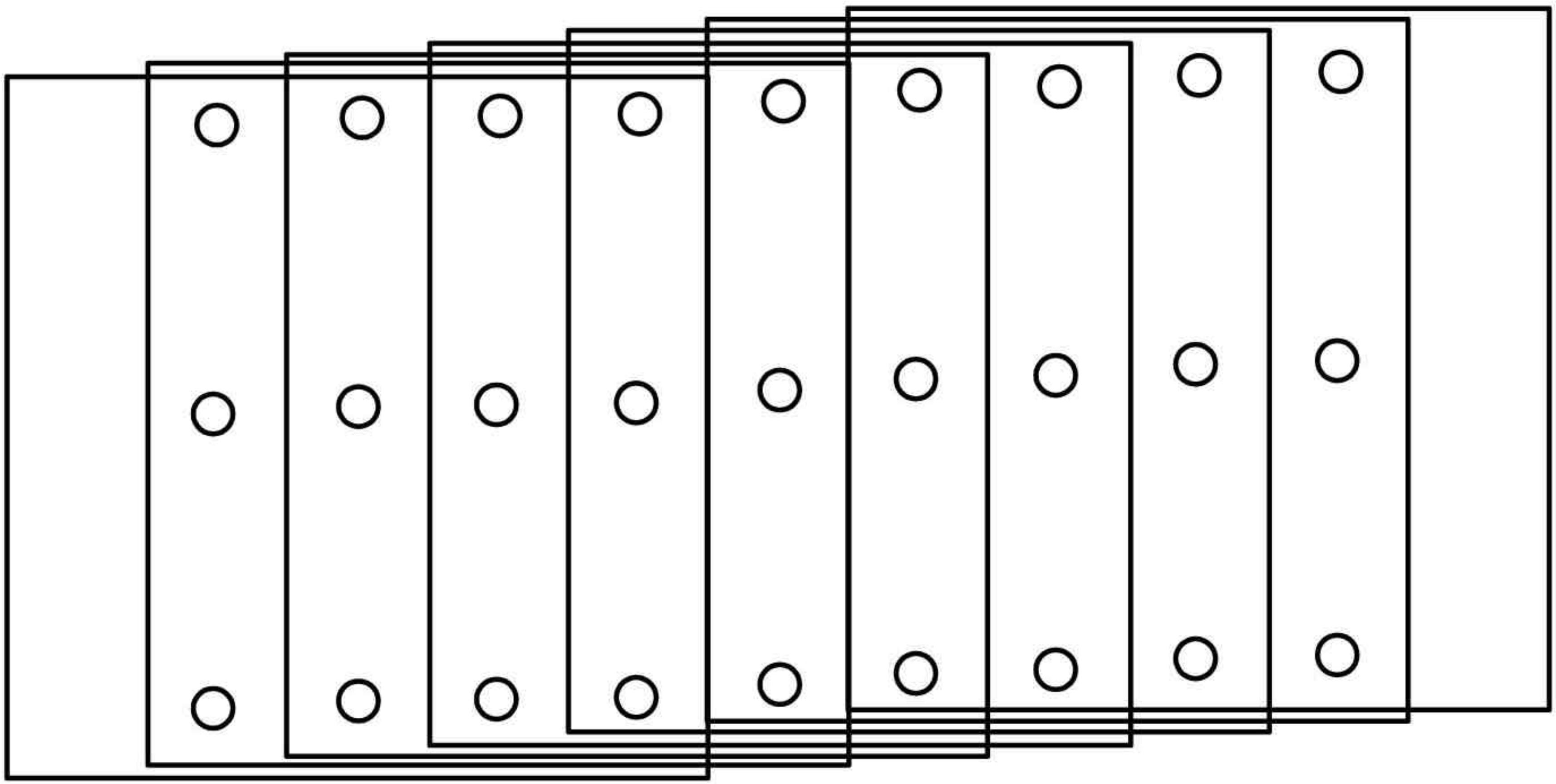
•Points in the block are of two kinds: control points (few) and pass points, or tie points (many).

•Pass points provide geometric strength and make a rigid, and redundant, structure from the block. Control points tie this structure to a reference coordinate system.

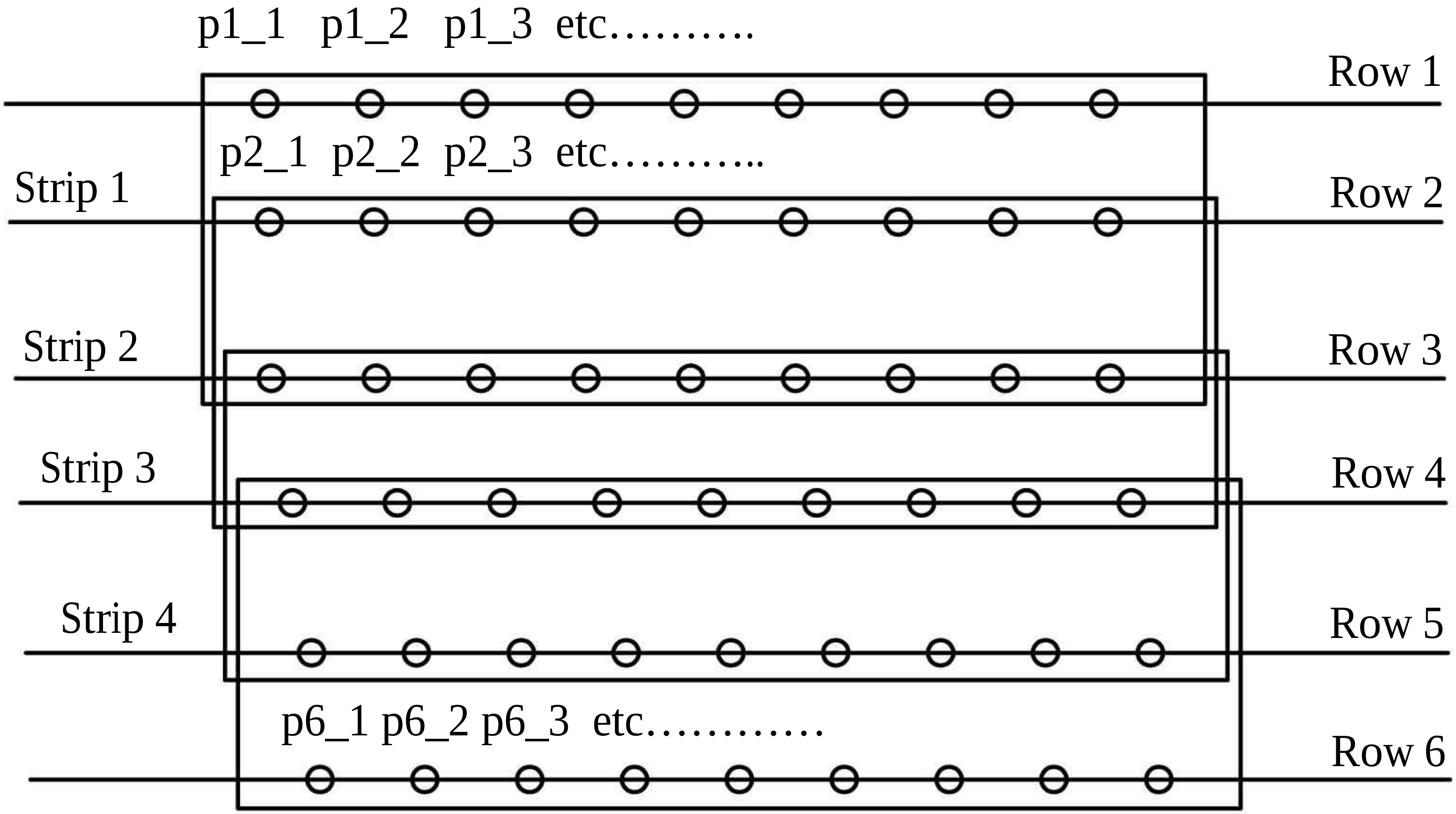
•High powered programs allow the user to select a pattern and the program will select pass points from lists of *interest points.* We will do, initially, manual selection.

•If well defined they can be measured monoscopically (one image at a time). If not well defined, they must be marked, transferred, and measured in a *stereo* mode.

With this pass point layout for a single strip, interior photos will have 15 pass points each. Try for ideal location, but move or omit if no well defined points can be found. Overlapping strips should share pass points. Note that 80% forward overlap is not common – usually 60%.



Notice how adjacent strips share pass points – so the selection must be done cooperatively between strips. Let's agree on a point ID convention:



United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION
of Aerial Mapping Camera

December 18, 1998

Camera type: Wild RC10
Lens type: Wild Universal Aviogon /4
Nominal focal length: 153 mm

Camera serial no.: 1394
Lens serial no.: 13055
Maximum aperture: f/4
Test aperture: f/4

Submitted by: Dickerson Aerial Surveys, Inc.
Lafayette, Indiana

Reference: Letter dated December 14, 1998, from Mr. John D. Dickerson.

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: 153.077 mm

II. Lens Distortion

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

Symmetric radial distortion parameters

$K_0 = 0.6142 \times 10^{-4}$
$K_1 = -0.1179 \times 10^{-7}$
$K_2 = 0.4519 \times 10^{-12}$
$K_3 = 0.0000$
$K_4 = 0.0000$

Decentering distortion parameters

$P_1 = -0.1235 \times 10^{-7}$
$P_2 = 0.9974 \times 10^{-7}$
$P_3 = 0.0000$
$P_4 = 0.0000$

Calibrated principal point

$x_p = 0.005$ mm
$y_p = -0.004$ mm

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.

III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 80

Field angle:	0°	7.5°	15°	22.7°	30°	35°	40°
Radial Lines	113	113	80	57	95	95	67
Tangential lines	113	113	80	67	80	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 No. 7419, the 500 Pan No. 4006, and the 525 No. 7415 filters accompanying this camera are within 10 seconds of being parallel. The 525 filter was used for the calibration.

V. Shutter Calibration

Indicated exposure time	Effective exposure time	Efficiency
1/200	5.50 ms = 1/180 s	81%
1/400	2.63 ms = 1/380 s	81%
1/600	1.75 ms = 1/570 s	81%
1/800	1.31 ms = 1/760 s	81%
1/1000	1.05 ms = 1/950 s	81%

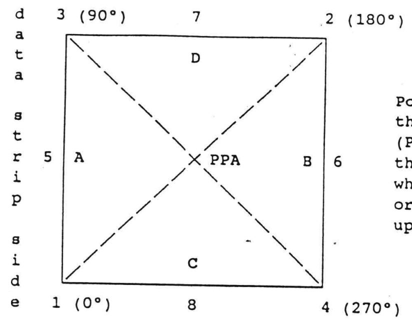
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

VI. Film Platen

The film platen mounted in Wild RC10 drive unit No. 1394-68 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 "68" 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.

	X coordinate	Y coordinate
Indicated principal point, corner fiducials	0.003 mm	-0.001 mm
Indicated principal point, midside fiducials	0.004	-0.001
Principal point of autocollimation (PPA)	0.0	0.0
Calibrated principal point (pt. of sym.) x_p, y_p	0.005	-0.004
Fiducial Marks		
1	-106.006 mm	-106.003 mm
2	106.003	105.993
3	-105.991	105.999
4	105.998	-106.003
5	-110.002	-0.002
6	110.042	-0.001
7	0.004	109.988
8	0.003	-110.025

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 299.817 mm   3-4: 299.807 mm

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

Midside fiducials

5-6: 220.044 mm   7-8: 220.013 mm

Lines joining these markers intersect at an angle of 89° 59' 58"

Corner fiducials (perimeter)

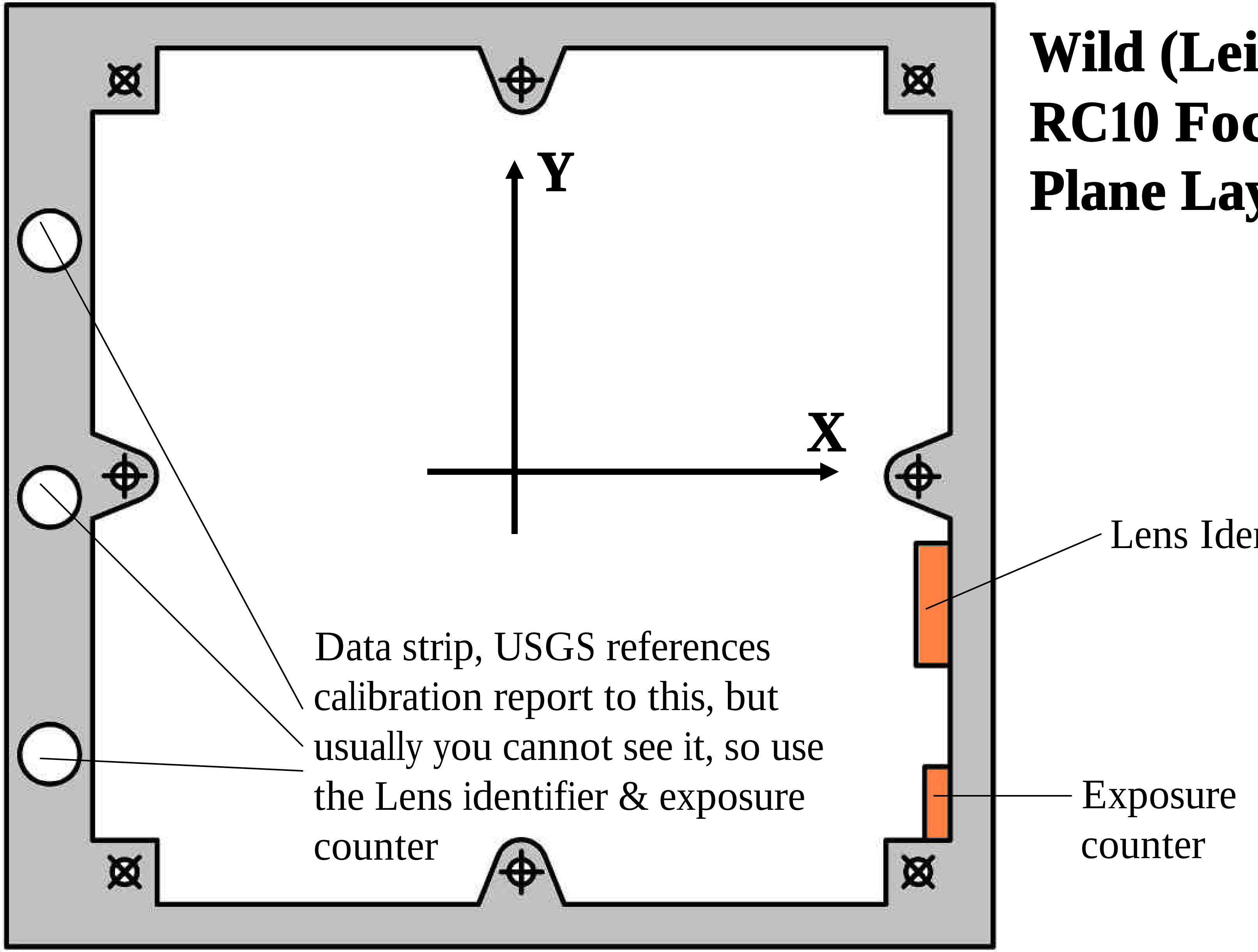
1-3: 212.002 mm   2-3: 211.994 mm

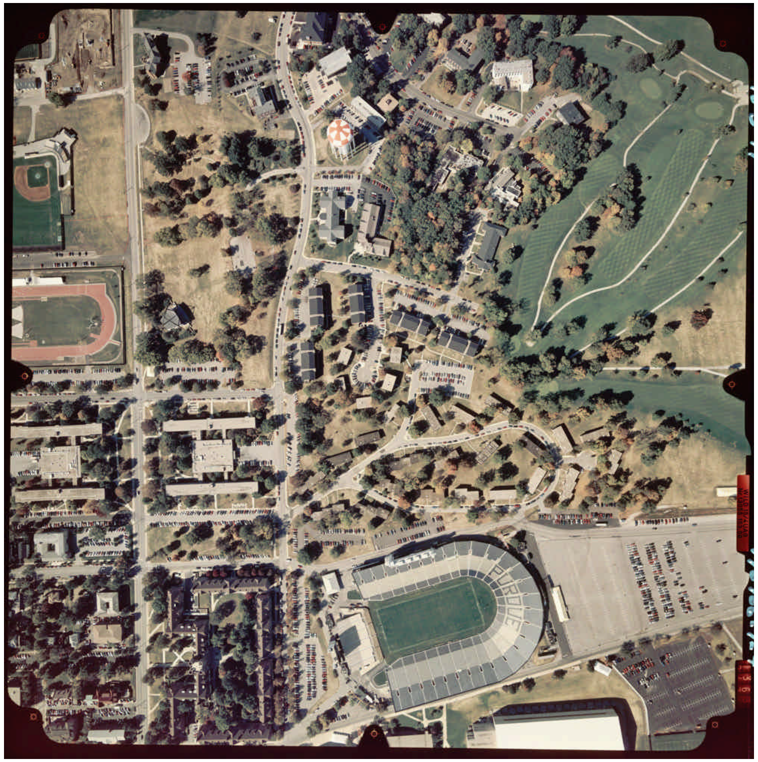
1-4: 212.004 mm   2-4: 211.996 mm

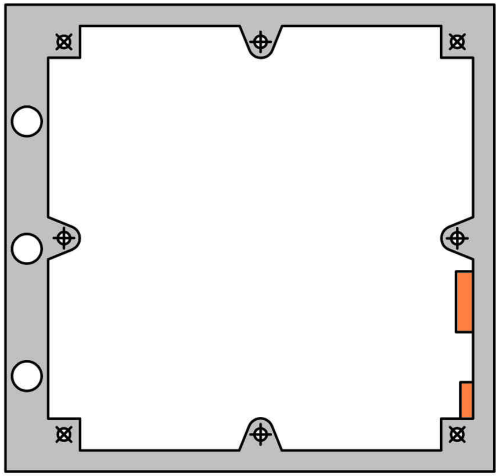
The method of measuring these distances is considered accurate within 0.003 mm

Note: For GPS applications, the nominal entrance pupil distance from the focal plane is 282 mm.

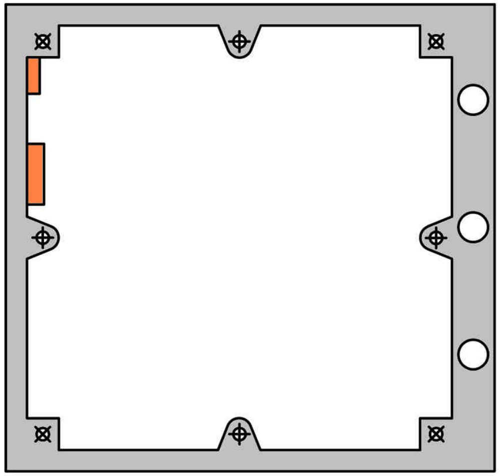
Wild (Leica) RC10 Focal Plane Layout





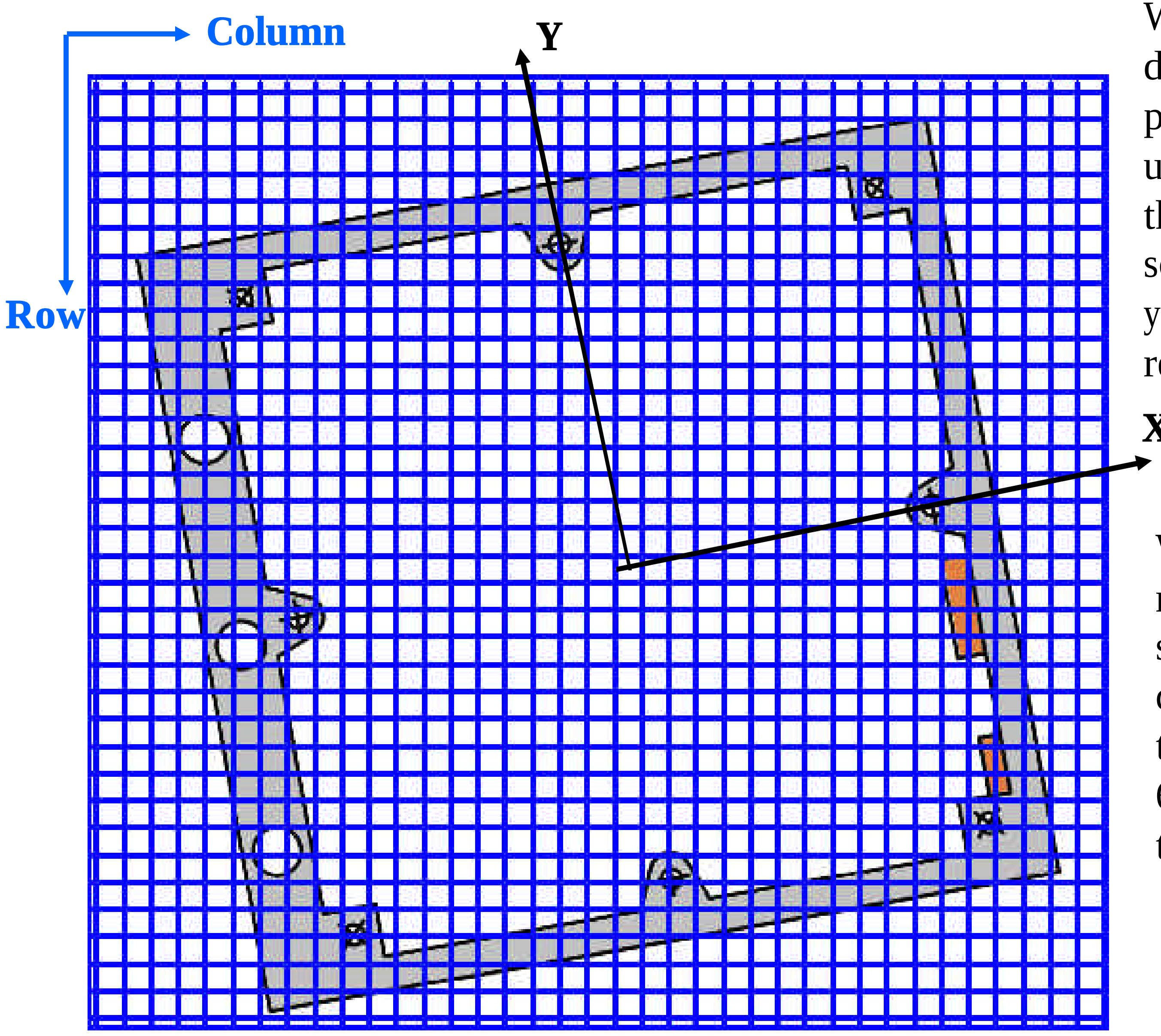


1-4



4-3

When you transform measured fiducials to calibrated values – you must assign correctly the measurements and the calibrated values.



When you scan and digitize a hardcopy photograph, there is usually no way to align the photo (x,y) and the scan (r,c) axes – even if you could – there is no real advantage.

We compensate for the misaligned coordinate systems by a 2D coordinate transformation, often a 6-parameter transformation.

Coordinate Transformations to relate measurement (r,c) and image (x,y) coordinate systems

Write equations at fiducial marks or reseau marks or any other fixed points which are known or observed in *both* systems. Solve for parameters with those equations – then apply at all other measured points.

4 - parameter, nonlinear

$$\begin{bmatrix} r \\ c \end{bmatrix} = l \begin{bmatrix} \cos q & \sin q \\ -\sin q & \cos q \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_1 \\ t_2 \end{bmatrix}$$

4 - parameter, linear

$$\begin{bmatrix} r \\ c \end{bmatrix} = \begin{bmatrix} a & b \\ -b & a \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} c \\ d \end{bmatrix}$$

6 - parameter, affine, nonlinear

$$\begin{bmatrix} r \\ c \end{bmatrix} = \begin{bmatrix} \cos q & \sin q \\ -\sin q & \cos q \end{bmatrix} \begin{bmatrix} 1 & 0 \\ a & 1 \end{bmatrix} \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} t_1 \\ t_2 \end{bmatrix}$$

6 - parameter, affine, linear

$$\begin{bmatrix} r \\ c \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ x \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$

8 - parameter, nonlinear

$$r = \frac{a_1 x + b_1 y + c_1}{a_0 x + b_0 y + 1}$$

$$c = \frac{a_2 x + b_2 y + c_2}{a_0 x + b_0 y + 1}$$

Atmospheric Refraction

$$\Delta d = k \tan a$$

$$k = \frac{2410H}{H^2 - 6H + 250} - \frac{2410h}{h^2 - 6h + 250}\left(\frac{h}{H}\right)$$