APPROXIMATE FARM SURVEYS FROM VERTICAL AERIAL PHOTOGRAPHS

BY
EARL CHURCH
ASSOCIATE PROFESSOR OF PHOTOGRAMMETRY, SYRACUSE UNIVERSITY

A PROBLEM IN AERIAL PHOTOGRAMMETRY WHICH APPEARS TO BE OF SPECIAL INTEREST AT THIS TIME IS THE DETERMINATION OF FARM ACREAGES AND THE PRODUCTION OF FARM MAPS. THE METHOD WHICH HAS BEEN MOST WIDELY USED IS A SIMPLE ONE, CONSISTING MERELY OF A DETERMINATION OF AN APPROXIMATE SCALE FOR A PHOTOGRAPH (SOMETIMES CALLED THE "SCALE-CHECK PROBLEM"), A DETERMINATION OF THE AREA OF THE PROPERTY ON THE PHOTOGRAPH, AND A MULTIPLICATION OF THIS AREA BY THE SQUARE OF THE LINEAR SCALE FACTOR, OR SOME SLIGHT VARIATIONS OF THIS PROCEDURE.

IN OUR WORK AT SYRACUSE UNIVERSITY WE HAVE DEVELOPED A SIMPLE SOLUTION OF THIS LITTLE PROBLEM INTRODUCING ONE OR TWO OF THE SIMPLER PRINCIPLES OF PHOTOGRAMMETRY, WHICH MAY BE OF SOME INTEREST. WE HAVE HESITATED TO PUBLISH ANY REPORTS ON THIS WORK BEFORE THIS TIME ON ACCOUNT OF THE SIMPLICITY OF THE PROBLEM ITSELF AND ON ACCOUNT OF THE FACT THAT NO PRINCIPLES ARE INVOLVED WHICH ARE NOT UNIVERSALLY KNOWN, HOWEVER, IN ORDER TO SHOW OUR METHOD OF TAKING ELEVATIONS INTO ACCOUNT THEREBY OBTAINING VERY INTERESTING AND SATISFACTORY RESULTS IN THIS WORK, THIS DISCUSSION IS PRESENTED TOGETHER WITH AN ILLUSTRATIVE PROBLEM.

1. Image Displacements in a Vertical Photograph Caused by Topographic Relief

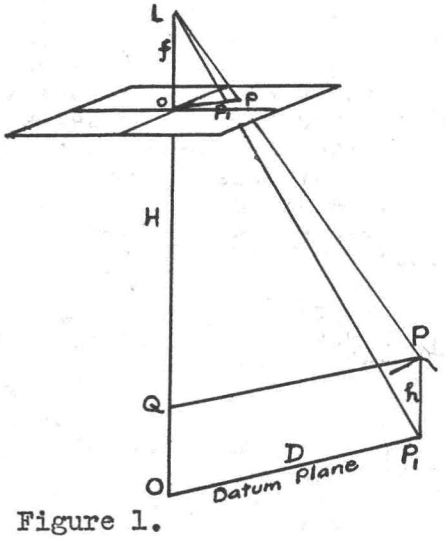

Figure 1.

FIGURE 1 ILLUSTRATES THE WELL KNOWN PRINCIPLE THAT IN A TRULY VERTICAL PHOTOGRAPH THE IMAGE DISPLACEMENTS CAUSED BY TOPOGRAPHIC RELIEF RADIATE FROM THE PRINCIPAL POINT. THIS OF COURSE IS THE FUNDAMENTAL PRINCIPLE OF RADIAL PLOTTING USING PRINCIPAL POINT RAYS. THE POINT P HAS ITS IMAGE AT p, WHEREAS THE POINT P_1 AT SEA LEVEL OR AT THE DATUM PLANE VERTICALLY BENEATH P WOULD HAVE ITS IMAGE AT p_1. THE POINT P_1 OBVIOUSLY LIES ON THE LINE OP. THE IMAGE DISPLACEMENT MENTIONED IS PP_1.

IN THE FIGURE, LO = H, THE ELEVATION OF THE EXPOSURE STATION; Lo = f, THE EFFECTIVE FOCAL LENGTH OF THE AERIAL CAMERA; P_1P = h, THE ELEVATION OF THE GROUND POINT P; op = d, THE DISTANCE FROM THE PRINCIPAL POINT TO THE ACTUAL IMAGE; $op_1 = d_1$, THE DISTANCE FROM THE PRINCIPAL POINT TO THE FICTITIOUS IMAGE OF P_1; OP_1 = D, A HORIZONTAL GROUND DISTANCE; D - D_1 = THE DESIRED IMAGE DISPLACEMENT.

LET US DRAW THE HORIZONTAL LINE PQ. THEN WE HAVE TWO PAIRS OF SIMILAR TRIANGLES, Lop_1 AND LOP_1, AND Lop AND LQP. FROM THESE

$$d_1/D = f/H \quad \text{AND} \quad d/D = f/(H-h).$$

THEN

$$D - D_1 = \frac{fD}{H - h} - \frac{fD}{H}$$

$$= fD\left(\frac{1}{(H - h} - \frac{1}{H}\right)$$

$$= \frac{fDh}{H(H - h)}$$

$$D - D_1 = \frac{fD}{H} \times \frac{h}{H - h}$$

$$D - D_1 = \frac{fD}{H - h} \times \frac{h}{H}$$

THAT IS, THE DISPLACEMENT

$$D - D_1 = D_1 \times \frac{H}{H - H}$$

OF

$$D - D_1 = D \times \frac{H}{H}$$

THUS, IF WE HAVE THE DISTANCE D = OP ON A PHOTOGRAPH FROM THE PRINCIPAL POINT TO AN IMAGE P, AND WE WISH TO FIND THE DISTANCE TO A FICTITIOUS IMAGE P_1 OF A POINT P_1 AT DATUM ELEVATION VERTICALLY BENEATH P, WE MOVE THE IMAGE INWARD TOWARD O BY THE DISTANCE D x H/H. OR, IF WE HAVE MAP POSITIONS OF O AND P PLOTTED TO SOME KNOWN SCALE, WHICH IN REALITY AMOUNTS TO HAVING THE LINE $D = OP_1$ PLOTTED ON PAPER TO THE SCALE, AND WE WISH TO FIND WHERE THE OUTER POINT SHOULD BE MOVED TO PLACE IT INTO THE POSITION CORRESPONDING TO THE IMAGE OF P ON A PHOTOGRAPH EXPOSED FROM AN ALTITUDE H SUCH THAT F/H EQUALS THE MAP SCALE, WE EXTEND THE PLOTTED LINE OUTWARD FROM O BY AN AMOUNT EQUAL TO THE MAP DISTANCE OP_1 MULTIPLIED BY H/(H-H).

THE SECOND STATEMENT OF THIS PRINCIPLE IS USED IN THE RECTIFICATION OF AERIAL PHOTOGRAPHS. THE FIRST STATEMENT SHOWS HOW THE PRINCIPLE APPLIES DIRECTLY TO THE PROBLEM IN HAND.

II. Scale

STRICTLY SPEAKING, AN AERIAL PHOTOGRAPH, EVEN A TRULY VERTICAL ONE, OF GROUND WHICH IS NOT FLAT, CAN HAVE NO EXPLICIT SCALE. FOR A VERTICAL PHOTOGRAPH EXPOSED FROM AN ALTITUDE H WITH A CAMERA WHOSE EFFECTIVE FOCAL LENGTH IS F, IF THE GROUND WERE ALL LEVEL AT SEA LEVEL OR THE DATUM ELEVATION, THE SCALE WOULD BE CONSTANT AND EQUAL TO F/H. FOR A VERTICAL PHOTOGRAPH OF LEVEL GROUND AT SOME ELEVATION H OTHER THAN ZERO, THE SCALE WOULD BE CONSTANT AND EQUAL TO F/(H - H). FOR A VERTICAL PHOTOGRAPH OF GROUND WITH TOPOGRAPHIC RELIEF, IF TWO POINTS HAPPEN TO LIE AT EQUAL ELEVATIONS H, THEN THE SCALE FOR THIS PARTICULAR LINE IS D/D = F/(H - H), USING THE SYMBOLS D FOR THE PHOTOGRAPHIC DISTANCE BETWEEN THE IMAGES AND D FOR THE GROUND DISTANCE BETWEEN THE POINTS. IF THE TWO POINTS LIE AT UNEQUAL ELEVATIONS H_1 AND H_2, THE SCALE FOR THIS LINE D/D MAY BE TAKEN AS APPROXIMATELY EQUAL TO $F/(H - H_M)$, WHERE H_M IS THE AVERAGE OF H_1 AND H_2.

INASMUCH AS IN ACTUAL PRACTICE TOPOGRAPHIC RELIEF IS INVARIABLY ENCOUNTERED, THE PROBLEM OF DETERMINING THE "SCALE" OF A VERTICAL PHOTOGRAPH ASSUMES CONSIDERABLE AMBIGUITY. DOES DETERMINING THE SCALE MEAN FINDING F/H, THE VALUE THE SCALE WOULD HAVE IF THE TERRAIN WERE ALL AT DATUM ELEVATION? OR DOES IT MEAN DETERMINING F/(H - H) WHERE H IS SOME ESTIMATED AVERAGE ELEVATION OF THE ENTIRE TERRAIN IN THE PHOTOGRAPH? UNDOUBTEDLY THE BEST WAY TO CONSIDER THIS SO-CALLED "SCALE-CHECK PROBLEM", IS TO REGARD AS THE DESIRED ANSWER TO THE PROBLEM THE ELEVATION H OF THE EXPOSURE STATION. THEN IF ONE WISHES TO USE SOME RATIO AS THE "SCALE" OF THE PHOTOGRAPH, A DANGEROUS PROCEDURE IF RESULTS OF ANY PRECISION ARE DESIRED, HE SHOULD USE F/(H - H) AND ASSUME THE RESPONSIBILITY OF ADOPTING SOME SATISFACTORY MEAN VALUE FOR H FOR THE ENTIRE TERRAIN OR FOR INDIVIDUAL LINES.

III. Precise Determination of Distances from Vertical Photographs

SUPPOSE THAT BY SOME SOLUTION OF THE "SCALE-CHECK PROBLEM" SUCH AS THAT GIVEN IN THE NEXT PARAGRAPH, THE ELEVATION H OF THE EXPOSURE STATION HAS BEEN DETERMINED FOR A VERTICAL PHOTOGRAPH. SUPPOSE THAT IT IS DESIRED TO FIND THE HORIZONTAL DISTANCE BETWEEN TWO GROUND POINTS A AND B WHOSE IMAGES APPEAR AT A AND B ON THE PHOTOGRAPH.

IN ORDER TO TAKE INTO ACCOUNT THE TOPOGRAPHIC RELIEF IT IS NECESSARY TO KNOW THE ELEVATIONS OF A AND B. THESE MAY BE DETERMINED BY MEANS OF PRECISE BAROMETERS ACCURATELY ENOUGH TO GIVE VERY GOOD RESULTS FOR THE HORIZONTAL DISTANCE TO BE DETERMINED. LET US CALL THE ELEVATIONS OF THE TWO POINTS H_A AND H_B RESPECTIVELY.

THE MOST CONVENIENT WAY TO MAKE THE MEASUREMENTS ON THE PHOTOGRAPH IS NOT TO MEASURE DIRECTLY THE LENGTH OF AB, BUT RATHER TO MEASURE THE RECTANGULAR

COORDINATES OF A AND B WITH RESPECT TO ANY CONVENIENT PAIR OF RECTANGULAR AXES WHICH MAY OR MAY NOT BE THE GEOMETRIC AXES OF THE PHOTOGRAPH BUT WHICH AT LEAST HAVE THEIR ORIGIN AT THE PRINCIPAL POINT. THESE MEASUREMENTS MAY BE MADE WITH A COMPARATOR UPON GLASS PLATES IF SUCH AN INSTRUMENT IS AVAILABLE, OR THEY MAY BE MADE UPON PAPER PRINTS WITH A LINEAR SCALE. THE ACCURACY OF THE RESULTS WILL OF COURSE DEPEND UPON THE ACCURACY WITH WHICH THESE MEASUREMENTS ARE MADE. LET US CALL THE PHOTOGRAPHIC COORDINATES OF A AND B (x_A, y_A) AND (x_B, y_B).

FIRST LET US FIND THE COORDINATES OF THE FICTITIOUS IMAGES A' AND B', OF GROUND POINTS SITUATED VERTICALLY BENEATH A AND B AT SEA LEVEL OR ON THE DATUM PLANE FROM WHICH H IS MEASURED. IT IS TO BE NOTED THAT A' AND B' LIE ON THE LINES OA AND OB RESPECTIVELY, AND THAT THE DISPLACEMENTS OF A AND B TOWARD O TO GIVE A' AND B' ARE THE DISPLACEMENTS FOR TOPOGRAPHIC RELIEF DISCUSSED IN PARAGRAPH 1. IT IS NOT NECESSARY TO MAKE THESE DISPLACED IMAGES ON THE PHOTOGRAPH. WE SIMPLY COMPUTE THEIR COORDINATES FROM

$$x'_A = x_A \left(1 - \frac{H_A}{H}\right) \qquad x'_B = x_B \left(1 - \frac{H_B}{H}\right)$$

$$y'_A = y_A \left(1 - \frac{H_A}{H}\right) \qquad y'_B = y_B \left(1 - \frac{H_B}{H}\right)$$

A FEW SIMPLE OPERATIONS ON A CALCULATING MACHINE GIVE THESE COORDINATES. IT WILL BE NOTED THAT MULTIPLICATION OF BOTH x_A AND y_A BY THE SAME RATIO TO GIVE x'_A AND y'_A INSURES THAT A' IS SITUATED ON THE LINE OA.

SECOND, LET US FIND THE LENGTH OF A'B'. THIS IS FOUND FROM THE COORDINATES WITHOUT ACTUALLY MARKING THESE FICTITIOUS IMAGES. WITH A CALCULATING MACHINE THIS DISTANCE, CALLED D', CAN BE FOUND READILY FROM

$$D' = \sqrt{(x'_A - x'_B)^2 + (y'_A - y'_B)^2}$$

THIRD, THE CORRECT HORIZONTAL GROUND DISTANCE D WHICH IS DESIRED, IS GIVEN DIRECTLY BY

$$D = D' \frac{H}{F}.$$

THIS DISTANCE IS CORRECT REGARDLESS OF THE HEIGHTS OF A AND B OR OF ANY DIFFERENCE IN HEIGHT BETWEEN A AND B.

IV. The Scale-Check Problem.

ACCORDING TO THE FOREGOING DISCUSSION, THE "SCALE-CHECK PROBLEM" AMOUNTS TO FINDING THE ALTITUDE H OF THE EXPOSURE STATION OF A VERTICAL PHOTOGRAPH, WHEN THERE ARE KNOWN THE HORIZONTAL DISTANCE D BETWEEN THE TWO GROUND POINTS A AND B WHOSE IMAGES A AND B APPEAR IN THE PHOTOGRAPH, AND THE GROUND ELEVATIONS H_A AND H_B OF THE TWO POINTS A AND B RESPECTIVELY.

FIRST LET US MEASURE ON THE PHOTOGRAPH THE COORDINATES OF THE IMAGES A AND B, WITH RESPECT TO GEOMETRIC AXES OF THE PHOTOGRAPH OR ANY OTHER CONVENIENT PAIR OF RECTANGULAR AXES WHOSE ORIGIN IS THE PRINCIPAL POINT OF THE PHOTOGRAPH. WE WILL CALL THESE COORDINATES (x_A, y_A) AND (x_B, y_B).

SECOND, LET US FIND THE PHOTOGRAPHIC DISTANCE D BETWEEN A AND B FROM THESE COORDINATES USING THE FORMULA

$$D = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2}.$$

THIRD, AN APPROXIMATE VALUE (H) OF THE ALTITUDE OF THE EXPOSURE STATION CAN BE DETERMINED BY FINDING

$$(H) - H_M = \frac{FD}{D}$$

AND THEN ADDING H_M, THE AVERAGE OF THE ALTITUDES H_A AND H_B, AS SHOWN IN PARAGRAPH 2.

FOURTH, WITH THIS APPROXIMATE VALUE (H) FOR THE ALTITUDE OF THE EXPOSURE STATION, DISPLACE A AND B TOWARD THE PRINCIPAL POINT BY THE AMOUNTS OF THE IMAGE DISPLACEMENT CAUSED BY TOPOGRAPHIC RELIEF, AS DISCUSSED IN PARAGRAPH 1. THE DISPLACED FICTITIOUS IMAGES A' AND B' ARE NOT MARKED, BUT THEIR COORDINATES ARE GIVEN BY

$$x'_A = x_A \left(1 - \frac{H_A}{(H)}\right) \qquad x'_B = x_B \left(1 - \frac{H_B}{(H)}\right)$$

$$y'_A = y_A \left(1 - \frac{H_A}{(H)}\right) \qquad y'_B = y_B \left(1 - \frac{H_B}{(H)}\right)$$

FIFTH, FIND THE PHOTOGRAPHIC DISTANCE D' BETWEEN THE FICTITIOUS IMAGES A' AND B' FROM

$$D' = \sqrt{(x'_A - x'_B)^2 + (y'_A - y'_B)^2}.$$

SIXTH, FIND THE CORRECT VALUE OF H FROM

$$H = F\frac{D}{D'}$$

FINALLY, INVESTIGATE TO SEE THAT THIS FINAL VALUE OF H DOES NOT CHANGE THE COORDINATES (x'_A, y'_A) AND (x'_B, y'_B) WHICH WERE CALCULATED FROM THE APPROXIMATE VALUE OF H. THESE COORDINATES ARE SELDOM ALTERED EXCEPT IN CASE OF AN EXTREMELY GREAT DIFFERENCE BETWEEN THE ALTITUDES OF THE GROUND POINTS A AND B. HOWEVER IF THEY ARE CHANGED SLIGHTLY A SECOND CALCULATION OF THE FINAL VALUE OF H MAY BE NECESSARY.

V. Progressing with the Scale-Check Problem in a Strip of Vertical Photographs without Measuring Additional Ground Distances Beyond the First Photograph

IT IS POSSIBLE TO SOLVE THE SCALE-CHECK PROBLEM THROUGHOUT A STRIP OF VERTICAL PHOTOGRAPHS WITHOUT MEASURING ANY GROUND DISTANCES EXCEPT THE ONE FOR THE INITIAL PHOTOGRAPH IN THE STRIP. TO DO THIS, HOWEVER, IT IS NECESSARY TO KNOW THE GROUND ELEVATIONS OF THE POINTS USED. VERY SATISFACTORY RESULTS CAN BE OBTAINED USING ELEVATIONS DETERMINED WITH SENSITIVE BAROMETERS, AND THE SUBSTITUTION OF THIS SIMPLE PROCEDURE FOR THE WORK OF MEASURING SCALE-CHECK LINES REPRESENTS A GREAT SAVING IN THE FIELD WORK.

LET US SUPPOSE THAT THE SCALE-CHECK PROBLEM HAS BEEN CARRIED OUT FOR THE FIRST PHOTOGRAPH IN THE USUAL WAY. THEN SUPPOSE THAT ELEVATIONS ARE KNOWN FOR TWO POINTS WHOSE IMAGES APPEAR IN THE OVERLAP BETWEEN THIS PHOTOGRAPH AND THE SUCCEEDING ONE. THE INTERVISIBILITY OF THESE POINTS ON THE GROUND HAS NO BEARING ON THE PROBLEM, FOR THE ONLY FIELD WORK NECESSARY IS TO DETERMINE THE ELEVATIONS OF THE POINTS WITH THE BAROMETER. BY USING THE ELEVATIONS OF THESE TWO POINTS AND FOLLOWING THE METHOD OF PARAGRAPH 3, THE HORIZONTAL GROUND DISTANCE BETWEEN THESE POINTS CAN BE QUICKLY CALCULATED. THEN THE NECESSARY DATA ARE AVAILABLE FOR THE SCALE-CHECK PROBLEM FOR THE SECOND PHOTOGRAPH.

THEORETICALLY THIS CAN BE CARRIED ON INDEFINITELY. THE ONLY SOURCE OF TROUBLE WITH THIS PROCEDURE IS ENCOUNTERING A BADLY TILTED PHOTOGRAPH IN THE STRIP. INASMUCH AS TILTS ARE BOUND TO OCCUR IN PRACTICE, IT WOULD NOT BE ADVISABLE TO CARRY THE SCALE-CHECKING THROUGH A VERY LONG STRIP WITHOUT MEASURING AN OCCASIONAL GROUND DISTANCE FOR VERIFYING THE WORK.

VI. The Farm Survey

THE METHOD TO BE DESCRIBED FOR MAKING A SURVEY OF A FARM BY MEANS OF MEASUREMENTS ON VERTICAL PHOTOGRAPHS, INVOLVES THE USE OF THE ELEVATIONS OF THE FARM CORNERS, WHICH AGAIN MAY BE DETERMINED ON THE GROUND BY MEANS OF SENSITIVE BAROMETERS.

THE FIRST STEP IN THE PROCESS IS TO SCALE-CHECK THE PHOTOGRAPH UPON WHICH THE VERTICES OF THE FARM APPEAR. THIS CAN BE DONE BY MEANS OF A DIRECT MEASUREMENT OF A DISTANCE ON THE GROUND AS IN PARAGRAPH 4, OR BY AN INDIRECT DETERMINATION OF A GROUND DISTANCE IN THE PROGRESSIVE METHOD OF PARAGRAPH 5. IN EITHER CASE THIS DETERMINES H, THE ALTITUDE OF THE EXPOSURE STATION.

Determining the Lengths of the Farm Boundaries

THE SECOND STEP IS TO MEASURE ON THE PHOTOGRAPH THE COORDINATES OF THE FARM CORNERS, BASED UPON THE GEOMETRIC AXES OF THE PHOTOGRAPH OR UPON ANY CONVENIENT PAIR OF RECTANGULAR AXES HAVING THEIR ORIGIN AT THE PRINCIPAL POINT OF THE PHOTOGRAPH.

THIRD, DISPLACE THE IMAGES OF THE FARM CORNERS TOWARD THE PRINCIPAL POINT

TO OBTAIN THE FICTITIOUS IMAGES OF GROUND POINTS VERTICALLY BENEATH THE FARM CORNERS AT SEA LEVEL OR IN THE DATUM PLANE. THIS DISPLACEMENT INVOLVES NO MARKING OF THE POINTS, BUT MERELY THE REDUCTION OF THE COORDINATES OF EACH CORNER BY MULTIPLYING THEM BY THE FACTOR $(1 - h/H)$ AS BEFORE IN PARAGRAPHS 1 AND 3.

FOURTH, USING THESE REDUCED COORDINATES, WE FIND THE PHOTOGRAPHIC LENGTHS OF THE VARIOUS SIDES OF THE FARM BY THE EXPRESSION

$$D' = \sqrt{(x'_A - x'_B)^2 + (y'_A - y'_B)^2}$$

AS IN PARAGRAPH 3.

THEN, FIFTH, FIND THE LENGTHS OF THE SIDES OF THE FARM BY USING THE RELATION

$$D = D' \frac{H}{F}$$

DATA FOR A MAP OF THE FARM

SIXTH, IF A MAP OF THE FARM IS DESIRED, MULTIPLY ALL OF THE REDUCED PHOTOGRAPHIC COORDINATES OF THE VERTICES BY H/F. THIS GIVES ACTUAL GROUND COORDINATES OF THE FARM CORNERS.

SEVENTH, FROM THESE GROUND COORDINATES THE FARM CORNERS CAN BE PLOTTED QUICKLY ON COORDINATE PAPER TO ANY SCALE DESIRED, GIVING AN EXCELLENT MAP OF THE FARM. THE FACT THAT THE ORIGIN FOR THESE COORDINATES REPRESENTS NOTHING IN PARTICULAR WITH RESPECT TO THE FARM CORNERS, HAS NO BEARING ON THE MAP ITSELF.

DETERMINING THE AREA OF THE FARM

EIGHTH, IF THE AREA OF THE FARM IS DESIRED, THE MOST ACCURATE METHOD IS NOT TO USE A PLANIMETER, BUT RATHER TO USE THE GROUND COORDINATES OF THE VERTICES FOUND IN THE SIXTH STEP AND TO FIND THE AREA WITH A CALCULATING MACHINE BY THE USUAL ANALYTICAL GEOMETRY METHOD FOR FINDING THE AREA OF A POLYGON. THIS AREA IN SQUARE FEET IS QUICKLY REDUCED TO ACRES BY DIVIDING BY 43560.

DETERMINING THE BEARINGS OF THE BOUNDARIES

IF THE BEARINGS OF THE FARM BOUNDARIES ARE ALSO DESIRED, FINDING THEM INVOLVES THE GROUND DETERMINATION OF THE AZIMUTH OF THE CONTROL LINE USED IN THE SCALE-CHECK PROBLEM. THIS CAN BE DONE BY ANY OF THE WELL KNOWN METHODS OF PRACTICAL ASTRONOMY.

AFTER THE PHOTOGRAPHIC COORDINATES OF THE EXTREMITIES OF THE SCALE-CHECK LINE HAVE BEEN REDUCED FOR TOPOGRAPHIC RELIEF, THE PHOTOGRAPHIC DIRECTION OF THE RESULTING FICTITIOUS LINE CAN BE DETERMINED. THE MOST CONVENIENT WAY TO FIND $\tan^{-1} (x'_A - x'_B)/(y'_A - y'_B)$ AND ASSIGN THE ANGLE TO THE PROPER QUADRANT ACCORDING TO THE RELATIVE POSITIONS OF THE POINTS ON THE PHOTOGRAPH SO THAT THIS DIRECTION WILL BE MEASURED CLOCKWISE FROM THE POSITIVE Y-AXIS OF THE PHOTOGRAPH. THEN IF WE SUBTRACT THIS PHOTOGRAPHIC DIRECTION FROM THE GROUND AZIMUTH OF THE LINE, WE HAVE A CONSTANT VALUE CALLED K IN THE SPECIMEN COMPUTATIONS TO FOLLOW, WHICH CAN BE ADDED TO THE PHOTOGRAPHIC DIRECTION OF ANY LINE BETWEEN IMAGES DISPLACED FOR TOPOGRAPHIC RELIEF TO GIVE THE GROUND AZIMUTH OF THE CORRESPONDING LINE.

THEN USING THE REDUCED COORDINATES FOR, SAY, TWO ADJACENT FARM CORNERS FROM STEP 3 ABOVE, ONE CAN FIND THE PHOTOGRAPHIC DIRECTION OF THE FARM BOUNDARY JOINING THESE CORNERS BY FINDING $\tan^{-1} (x'_A - x'_B)/(y'_A - y'_B)$ AND PLACING THE ANGLE IN THE PROPER QUADRANT TO GIVE A PHOTOGRAPHIC DIRECTION MEASURED CLOCKWISE FROM THE POSITIVE Y-AXIS. THEN ADDING THE CONSTANT K DETERMINED FROM THE SCALE-CHECK LINE WILL GIVE THE CORRECT GROUND AZIMUTH OF THE FARM BOUNDARY. THIS CAN BE DONE VERY READILY FOR EACH BOUNDARY OF THE FARM.

PERHAPS IN THIS CONNECTION IT SHOULD BE MENTIONED THAT IN CASE PROGRESSIVE SCALE-CHECKING IS CARRIED OUT AS DESCRIBED IN PARAGRAPH 5, IT IS A VERY SIMPLE MATTER TO CARRY THE AZIMUTHS FORWARD AS WELL AS THE LENGTHS, WITHOUT DETERMINING ADDITIONAL AZIMUTHS ON THE GROUND.

SCALE-CHECK PROBLEM (See Paragraph 4).

Photo #V. $f = 184.030$ mm.

Ground Control Data:

	X	Y	H	
B	53494.25 ft.	204838.52 ft.	1007.02 ft.	D = BC
C	50115.73	203110.35	1038.66	= 3794.85 ft.
	3378.52	1728.17	1022.85 = H_M	

Photo Measurements:

B	- 51.00 mm.	+ 12.21 mm.
C	- 20.17	- 52.70
	30.83	64.91

$d = 71.86$ mm.

$$(H) - H_M = \frac{184.030 \times 3794.85}{71.86} = 9718 \text{ ft.}$$

1023 ft. = H_M
10741 ft. = (H)

Reduced Coordinates:

	H/H'	x	y
B	.09375	- 46.22 mm.	+ 11.07 mm.
C	.09670	- 18.22	- 47.60
		28.00	58.67

$d' = 65.01$ mm.

$$H = \frac{184.030 \times 3794.85}{65.01} = 10742 \text{ ft.}$$

PROGRESSING WITH SCALE-CHECK PROBLEM FROM PHOTO V TO PHOTO VI WITHOUT ADDITIONAL LENGTH MEASUREMENT ON THE GROUND (See Paragraph 5).

Determination of Length of a Scale-Check Line for Photo VI by Measurement on Photo V: (See Paragraph 3)

Coordinates on Photo V:

	x	y	H (Barometer)	H/H	Reduced Coordinates x'	Reduced Coordinates y'
A_{VI}	+ 29.62 mm.	+ 48.84 mm.	$1084\frac{1}{2}$	.10095	+ 26.63 mm.	+ 43.91 mm.
D_{VI}	+ 34.80	- 11.82	$1085\frac{1}{2}$	.10105	+ 31.28	- 10.63
					4.65	54.54

$d' = 54.74$ mm.

$$D = \frac{54.74 \times 10742}{184.030} = 3195 \text{ ft.}$$

Scale-Check Problem for Photo VI: (See Paragraph 4)

Photo #VI. $f = 183.957$ mm. $D = 3195$ ft.

Photo Coordinates:

	X	Y	H (Barometer)
A_{VI}	- 5.66 mm.	+ 36.13 mm.	$1084\frac{1}{2}$ ft.
B_{VI}	- 3.40	- 24.39	$1085\frac{1}{2}$
	2.26	60.52	1085 ft. = H_M

$d = 60.56$ mm.

$$(H) - H_M = \frac{183.957 \times 3195}{60.56} = 9706 \text{ ft.}$$

1085 ft. = H_M
10791 ft. = (H)

Reduced Coordinates:

	H/H	x	y
A_{VI}	.10050	- 5.09 mm.	+ 32.50 mm.
D_{VI}	.10059	- 3.06	- 21.94
		2.03	54.44

$d' = 54.48$ mm.

$$H = \frac{183.957 \times 3195}{54.48} = 10789 \text{ FT.}$$

FARM SURVEY (SEE PARAGRAPH 6)

(STEP 1) MEASUREMENTS ON PHOTO VI — f = 183.957 MM. H = 10789 FT. SCALE AT DATUM PLANE: 1 MM. = H/f = 58.6518 FT.

(STEPS 2 & 3)	CORNER	PHOTO COORDINATES x	PHOTO COORDINATES y	H (BAROMETER)	REDUCED COORDINATES H/H	x'	y'
	I	+ 55.64 MM.	+ 3.40 MM.	1062 FT.	.09843	+ 50.16	+ 3.07
	II	+ 55.32	- 12.05	1051	.09741	+ 49.93	- 10.88
	III	+ 46.30	- 12.10	1060	.09824	+ 41.75	- 10.91
	IV	+ 46.19	- 16.28	1046½	.09699	+ 41.71	- 14.70
	V	+ 31.30	- 16.02	1048	.09713	+ 28.26	- 14.46
	VI	+ 31.37	+ 3.30	1058½	.09811	+ 28.29	+ 2.98

(STEPS 4 & 5) BOUNDARY LINE	Δx'	Δy'	D'	D	
I-II	0.23 MM.	13.95 MM.	13.95 MM.	818 FT.	
II-III	8.18	0.03	8.18	480	
III-IV	0.04	3.79	3.79	222	
IV-V	13.45	0.24	13.45	789	DIMENSIONS
V-VI	0.03	17.44	17.44	1023	
VI-I	21.87	0.09	21.87	1283	

(STEP 6) GROUND COORDINATES FOR PLOTTING MAP (REDUCED PHOTO COORDINATES MULTIPLIED BY 58.6518)

CORNER	X	Y
I	+ 2942 FT.	+ 180 FT.
II	+ 2928	- 638
III	+ 2449	- 640
IV	+ 2446	- 862
V	+ 1657	- 848
VI	+ 1659	+ 175
(I	+ 2942	+ 180)

(STEP 8) AREA OF THE FARM

7347567
4921178
2) 2426389
1213194 SQ.FT.

$$\frac{1213194}{43560} = 27.85 \text{ ACRES.}$$

PROGRESSING WITH AZIMUTHS

		REDUCED x'	REDUCED y'
PHOTO V	B	- 46.22	+ 11.07
	C	- 18.22	- 47.60
		28.00	58.67

TAN = .47725
PHOTO DIRECTION OF BC = 154° 29.2'

GROUND AZIMUTH OF BC (FROM CONTROL) = 242° 54.6'
PHOTO DIRECTION OF BC = 154 29.2
K_V = 88 25.4

		x'	y'
PHOTO V	A_{VI}	+ 26.63	+ 43.91
	D_{VI}	+ 31.28	- 10.63
		4.65	54.54

TAN = .08526
PHOTO DIRECTION OF $A_{VI}D_{VI}$ = 175° 07.6'

PHOTO DIRECTION OF $A_{VI}D_{VI}$ = 175° 07.6'
K_V = 88 25.4
GROUND AZIMUTH OF $A_{VI}D_{VI}$ = 263 33.0

PHOTO VI

A_{VI}	- 5.09	+ 32.50
D_{VI}	- 3.06	- 21.94
	2.03	54.44

TAN = .03729
PHOTO DIRECTION OF $A_{VI}D_{VI}$ = 177° 51.8'

GROUND AZIMUTH OF $A_{VI}D_{VI}$ = 263° 33.0'
PHOTO DIRECTION OF $A_{VI}D_{VI}$ = 177 51.8
K_{VI} = 85 41.2

DETERMINING BEARINGS OF FARM BOUNDARIES

LINE	$\Delta x'/\Delta y'$ TAN	PHOTO DIRECTION	GROUND AZIMUTH (BY ADDING 85°41'.2)
I-II	.01648	180° 56.7'	266° 38'
II-III	1/.00367	269 47.4	355 29
III-IV	.01055	180 36.2	266 17
IV-V	1/.01784	271 01.3	356 42
V-VI	.00172	0 05.9	85 47
VI-I	1/.00412	89 45.8	175 27

COMPARISON OF THE PHOTOGRAMMETRIC SURVEY AND THE GROUND SURVEY OF THE FARM

LINE	PHOTOGRAMMETRIC SURVEY AZIMUTH	PHOTOGRAMMETRIC SURVEY LENGTH	GROUND SURVEY AZIMUTH	GROUND SURVEY LENGTH	DISCREPANCY AZIMUTH	DISCREPANCY LENGTH
I-II	266° 38'	818 FT.	266° 25'	825 FT.	-0° 13'	+ 7 FT.
II-III	355 29	480	356 45	473	+1 16	- 7
III-IV	266 17	222	269 56	221	+3 39	- 1
IV-V	356 42	789	356 26	789	-0 16	0
V-VI	85 47	1023	85 39	1026	-0 08	+ 3
VI-I	175 27	1283	175 40	1289	+0 13	+ 6
	AREA = 27.85 ACRES		AREA = 28.02 ACRES		0.17 ACRE	

ALTHOUGH TWO OF THE BOUNDARY LINES SHOW RATHER LARGE DISCREPANCIES IN AZIMUTH BETWEEN THE PHOTOGRAMMETRIC AND THE GROUND SURVEYS, THIS IS NOT AT ALL SURPRISING BECAUSE THE BOUNDARY LINES IN QUESTION ARE VERY SHORT. IN ALL CASES WHERE THE BOUNDARY LINES HAVE ANY CONSIDERABLE LENGTHS THE AGREEMENT IN AZIMUTH IS GOOD. THE ERROR OF 0.17 ACRE IN THE PHOTOGRAMMETRIC DETERMINATION OF THE AREA REPRESENTS BUT LITTLE OVER ONE-HALF OF ONE PERCENT.

IT IS BELIEVED THAT THIS QUICK AND CHEAP METHOD FOR MAKING SURVEYS OF MANY FARMS WILL PROVE RATHER USEFUL IN MODERN ECONOMIC PROJECTS.

MODERN MAPS FOR COLOMBIA BY AERIAL METHODS

BY

R. H. LASCHE

REPRINTED FROM FAIRCHILD AVIATION NEWS

"HE'LL SPREAD OUT THAT COSTLY, ORNATE, LYING AND DEFICIENT MAP THAT THE OFICINA DE LONGITUDES OF BOGOTA DREW UP, AND AFTER MUCH SEARCHING HE'LL SAY: 'THERE ARE NO SUCH RIVERS HERE.' AND QUITE SATISFIED, HE'LL CONTINUE ENTRENCHED IN HIS IGNORANCE, BECAUSE THIS POOR COUNTRY ISN'T KNOWN BY ITS OWN SONS, NOT EVEN BY ITS GEOGRAPHERS."

THESE WORDS FROM JOSE EUSTASIO RIVERA'S BOOK, "THE VORTEX," APTLY DESCRIBE A CONDITION WHICH, UNTIL RECENTLY, HAD EXISTED IN COLOMBIA SINCE ITS BEGINNING--A CONDITION WHICH STILL EXISTED UPON MY ARRIVAL THERE LESS THAN THREE YEARS AGO.

ALMOST EVERY MODERN NATION KNOWS WHAT RIVERS, MOUNTAINS AND LANDMARKS LIE WITHIN ITS BORDERS--BUT IN COLOMBIA THE VERY NATURE OF THE TERRAIN ITSELF KEPT THESE THINGS A HIDDEN SECRET. THE COLOMBIAN GOVERNMENT HAD RECOGNIZED FOR MANY YEARS THE NECESSITY FOR ACCURATE AND DETAILED MAPS BUT INSURMOUNTABLE OBSTACLES STOOD IN THE WAY OF ORDINARY GROUND SURVEY METHODS OF MAPPING. VAST AREAS OF THE COUNTRY CONSIST OF FLAT PLAINS WHICH SWELTER UNDER A BLAZING