An Analysis of Stereotriangulation for Highway Engineering Mapping

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•THE TEXAS Highway Department has developed a procedure to use stereotriangulation for the procurement of intermediate control data for photogrammetric mapping. A Zeiss C-8 Stereoplanigraph is used for the stereobridges. Electrotapes (electronic distance measuring instruments) and other high-order surveying equipment are used for the primary ground control traverses. All data are adjusted by electronic computers for which special programs have been designed.

A research project was initiated to determine the feasibility of this method for obtaining supplemental or intermediate ground control for large-scale photogrammetric mapping to be used for engineering purposes. From an evaluation of the data obtained, information such as accuracies to be expected, limitations of adaptability, and economics were to be determined.

Ninety percent of all photogrammetric projects mapped by the Texas Highway Department are developed to a horizontal scale of 1 in. = 40 ft with vertical data shown by 1-ft contour lines and spot elevations to the nearest 0.1 ft. All planimetric features of the finished map sheets must be within 1.0 ft of their true horizontal position and that 90 percent of all contours must be within one-half the contour interval, in this case 0.5. The remaining 10 percent may approach the maximum deviation of one contour interval. Spot elevations may deviate a maximum of 0.30 ft.

To meet these rigid requirements, the basic ground control data must be very accurate. Ground control on such a photogrammetric project consists of a primary control traverse with points varying distances apart, depending on terrain and desired measurement spacing, but averaging about ½ mi apart, with secondary or intermediate control points approximately 300 ft apart to insure at least two points per stereomodel. These primary and secondary control points are paneled before photography with crosses having legs 4 ft long and 6 in. wide for easy photo identification. The primary field control traverses must meet at least second-order distance and angular closure requirements. The intermediate field control for stereo-model scaling must meet third-order accuracy requirements. The criteria used by the Texas Highway Department for second- and third-order accuracies are given in Table 1.

An Electrotape field party established by the Photogrammetry Section of the Highway Design Division is made available to all District and Resident Engineer Offices located throughout the state to work in cooperation with their field personnel to develop primary control traverse data. This field party does not attempt to establish the intermediate control from which the photogrammetric mapping is accomplished because the volume of work and the physical size of the state make it unfeasible.

The establishing of the intermediate ground control points is expensive and has been a major difficulty in the development of control data. There are several reasons for this difficulty. Most District field parties have previous commitments such as construction projects which make it impossible to obtain this control in time to meet the mapping schedule, and in many cases, the areas to be mapped for highway engineering are inaccessible because of weather, terrain, vegetation, or uncooperative landowners. With these difficulties in intermediate ground control repeatedly encountered, the possibility of utilizing stereotriangulation merited a research program to determine feasible methods and techniques.

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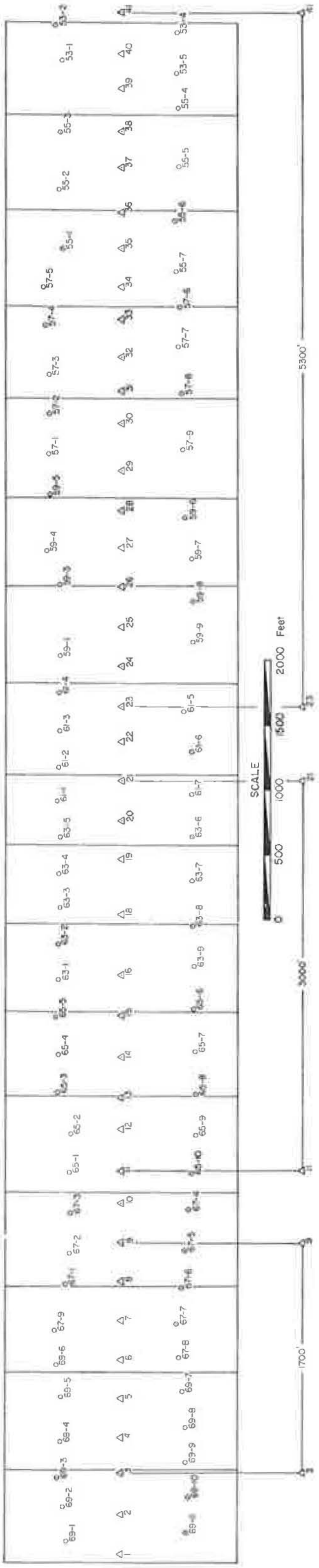

Figure 1. Control layout of stereotriangulation research area.

TABLE 1
ACCURACY CRITERIA

Order of Accuracy	Horizontal Dist. [a]	Horizontal Angles (sec)			Vertical Dist. (ft)
		Traverse Lines	Triangle Closure		
			Avg.	Max.	
2nd	1:10,000	$10\sqrt{N}$	3	5	$0.035\sqrt{M}$
3rd	1:5,000	$30\sqrt{N}$	5	10	$0.050\sqrt{M}$

[a]N = No. of angles between tangents of traverse.
[b]M = length of level circuit in miles.

An area approximately 2.7 mi long along I-35 north of Austin, Texas, was selected for the test area. Field control was established on this project (Fig. 1) similar to any other project designed to be mapped at 1 in. = 40 ft with a 1-ft contour interval. The only exception was that the Highway Design Division Electrotape field party, with its highly trained personnel and high-accuracy surveying equipment, established all the ground control including the intermediate control points. The traverse was run throughout the length of the project establishing primary control points at intervals of 1,700, 3,000, and 5,300 ft. The angles were measured with a 10-sec Kern theodolite and each angle was turned a minimum of 8 times. This basic traverse closed well within the tolerances of second-order specifications. Intermediate control points were chained in at distances varying from 270 to 330 ft. A total of 41 centerline points were established. Each of the intermediate points was slightly offset at varying distances from the tangent line between the primary control points. These deviations from tangent were induced to reduce any stereo operator "adjustments" for alignment. These centerline points were paneled with white crosses having legs 4 ft long and 6 in. wide.

The feasibility of vertical stereobridging was also studied. Wing points were placed throughout the length of the project and marked with panels of the same dimensions as those of the centerline. The wing points were located approximately 400 ft on either side of the centerline and were spaced approximately 300 ft apart, thus insuring enough for each stereo-model. A total of 76 wing points were paneled. Elevations were established on the centerline panels and wing point panels using a Kern level (Fig. 1).

After paneling and establishment of the ground control, a contract was awarded to a prequalified photogrammetric contractor to photograph the area following the Standard Specifications for Photography prepared by the Texas Highway Department. Specifically, the area had to be photographed with a "distortion-free" aerial camera having a 6-in. focal length producing a 9- by 9-in. aerial negative. The scale of the photography was required to be 1 in. - 200 ft, with an allowable 10 percent deviation. The negatives were to be of excellent image quality in all respects, and no negatives could have tilt exceeding 3 deg and accumulative tilt between successive negatives could not exceed 4 deg. The negatives were required to have an overlap between 55 and 65 percent. The photography received met these requirements in all respects.

Two qualified photogrammetric contractors having "first-order" stereoplotting equipment were selected to develop stereotriangulation data of the test area. The contractors had two different models of first-order plotters: a Galileo Santoni Model IV Stereocartograph and a Wild A-5 Autograph. Zeiss C-5 and C-8 Stereoplanigraphs were later incorporated into the study.

This research was initiated to determine the acceptability of stereobridged control for use in the development of photogrammetric maps. Also, data for stereobridging from Kelsh-type stereoplotters were to be compared with those obtained from the contracted stereoplotters. A skeleton control data tabulation sheet (Table 2) and a set of photography of the test area indicating the location of the vertical control points listed on the skeleton control sheet were furnished each of the photogrammetric contractors and the Texas Highway Department Kelsh operator. Also, the contractors were furnished the aerial negatives of the photographic flight for making diapositive plates adaptable to their equipment.

TABLE 2

SKELETON CONTROL DATA SHEET, I-35 STEREOBRIDGE PROJECT

Point	Elevation	Coordinates		Point	Elevation	Point	Elevation
		X	Y				
1	642.36	44,980.8	25,880.86	69-1	645.52	61-2	705.62
2	644.27	45,243.02	26,036.70	69-2	647.06	61-3	714.60
3	646.06	45,518.52	26,189.51	69-3	648.25	61-4	718.64
4	650.41			69-4		61-5	731.80
5	658.93			69-5		61-6	730.22
6	664.87			69-6		61-7	
7	666.04			69-7		59-1	
8	661.49			69-8		59-2	
9	654.95	47,007.80	27,052.03	69-9	641.66	59-3	
10	652.47	47,273.54	27,198.95	69-10	641.19	59-4	
11	656.27	47,487.65	27,328.88	69-11	641.18	59-5	
12	668.55			69-12	637.72	59-6	
13	674.35			67-1		59-7	
14	681.44			67-2	667.58	59-8	
15	689.33			67-3	658.58	59-9	
16	697.08			67-4	650.89	57-1	
17	703.98			67-5	647.61	57-2	
18	706.31			67-6	658.03	57-3	
19	708.32			67-7		57-4	
20	709.95			67-8		57-5	
21	710.31	50,092.70	28,820.72	67-9		57-6	
22	713.89	50,348.75	28,973.24	65-1		57-7	
23	723.13	50,589.56	29,106.15	65-2		57-8	
24				65-3		57-9	
25				65-4		55-1	
26	745.68			65-5		55-2	
27				65-6		55-3	735.94
28				65-7		55-4	740.30
29	735.52			65-8		55-5	
30				65-9		55-6	
31				65-10	660.34	53-1	725.71
32	728.40			63-1		53-2	715.42
33				63-2		53-3	709.28
34				63-3		53-4	719.23
35	710.67			63-4		53-5	730.62
36				63-5			
37				63-6			
38	737.55			63-7			
39				63-8			
40				63-9			
41	737.38	55,222.26	31,775.55	61-1			

TABLE 3

UNADJUSTED KELSH-TYPE PLOTTER TABULATION[a]

Point	Two-Projector Kelsh			Three-Projector Kelsh			K & E M-2 Stereoplotter		
	X	Y	Z	X	Y	Z	X	Y	Z
				(a) Centerline Points					
1				Control furnished					
2									
3									
4	-1.0	-1.2		+0.4	-0.3		+0.4	-0.4	
5	-1.3	-1.6		+0.4	-0.4		+0.1	-0.7	
6	-1.5	-2.0		+0.5	-0.6		+0.3	-0.8	
7	-1.5	-2.6		+0.6	-0.1		+0.2	-0.4	
8	-1.5	-3.2		+0.6	-1.5		-0.3	-0.7	
9				Avg. (1 through 8)					
10	1.360	2.120		0.500	0.580		0.260	0.600	
11									
12				Panel destroyed					
13	-0.4	-1.1		+0.2	-0.1		-0.2	-0.2	
14	+0.5	-1.8		+0.3	+0.1		-0.3	-0.2	
15	+0.8	-2.0		+0.4	+0.4		-0.5	0.0	
16	+0.9	-2.6		+0.1	+0.5		-0.5	+0.5	
17				Panel destroyed					
18	+1.8	-3.2		-0.6	+0.5		-1.6	+1.5	
19	+2.2	-3.1		-1.0	+1.2		-2.0	+2.0	
20	+2.9	-3.1		-1.3	+1.9		-2.1	+2.2	
21				Avg. (12 through 20)					
22	1.35	2.41		0.55	0.67		1.02	0.94	
24	Data incomplete			-0.7	-0.6	+0.9	-0.6	-0.5	0.0
25				-0.4	-0.8	+1.3	-0.5	-0.6	+0.3
26				-0.6	-0.6	+1.7	-0.9	-0.5	+0.6
27				-0.9	-0.9	+2.7	-1.2	-0.4	+0.5
28				-1.4	-0.8	+4.0	-1.5	-0.2	+1.0
29				-2.6	-1.6	+4.2	-2.2	-0.7	+1.1
30				-2.7	-0.4	+4.5	-2.3	+0.4	+1.3
31				-3.1	-0.6	+4.7	-2.5	+0.6	+2.2
32				-3.8	-1.8	+5.0	-2.6	-0.5	+3.3
33				-4.8	-1.8	+6.6	-2.4	-0.2	+4.0
34				-3.9	-2.4	+7.0	-2.4	-0.2	+4.3
35				-4.9	-2.9	+7.7	-2.8	-0.3	+5.5
36				-5.0	-3.3	+8.5	-2.9	-0.2	+7.1
37				-6.6	-3.0	+8.0	-4.0	+0.7	+9.5
38				-7.0	-4.0	+8.5	-4.0	0.0	+9.9
				-8.2	-5.6	+9.1	-4.6	-0.8	+10.8
				-9.2	-5.4	+9.8	-4.9	-1.2	+11.8
				-10.0	-6.1	+10.6	-4.6	-0.7	+12.7
Avg.				(4.228)	(2.367)	(5.822)	(2.606)	(0.483)	(4.772)
				(b) Vertical Wing Points[b]					
69-1									
69-2									
69-3									
69-4		-0.1			-0.2			-0.0	
69-5		-0.4			-0.3			-0.2	
69-6		0			-0.1			+0.1	
69-7		+0.3			+0.4			+0.3	
69-8		+0.2			+0.1			+0.1	
69-9									
69-10									
69-11									
69-12									
67-1		-0.2			-0.1			-0.1	
67-2									
67-3									
67-4									
67-5									
67-6									
67-7		-0.3			-0.1			-0.3	
67-8		+0.1			+0.2			0	
67-9		+0.4			+0.4			+0.3	
65-1		0.0			-0.1			+0.2	
65-2		+0.5			+0.2			+0.6	
65-3		+0.3			+0.2			+0.8	
65-4		-0.4			-0.3			-0.1	
65-5		+0.2			+0.1			+0.6	
65-6		+1.1			+1.4			+0.6	
65-7		+1.3			+0.7			0.0	
65-8		+1.0			+1.3			+0.7	
65-9		+0.9			+1.0			+0.3	
65-10		-0.6			-0.8			-1.4	
63-1		-0.2			-0.1			+0.1	
63-2		-0.7			0.0			+0.2	
63-3		-0.3			-0.1			+0.5	
63-4		-0.1			+0.2			+0.8	
63-5		+0.3			0.0			+0.9	
63-6		+1.1			+1.3			+0.4	
63-7		+0.9			+0.8			-0.1	
63-8		+4			+0.8			+0.2	
63-9		+0.6			+0.8			+0.1	
61-1		+0.1			-0.3			+0.9	
61-2									
61-3									
61-4									
61-5									
61-6									
61-7		+0.6			+0.4			-0.5	
Avg.		(0.437)			(0.430)			(0.380)	

[a]Area of centerline vertical control only.

[b]Wing point data in area of no centerline control is erratic; average errors and pattern are given in Table 4.

This skeleton control consisted of at least three horizontal and nine vertical control points at various distances throughout the length of the project. The initial model was fully controlled with additional horizontal and vertical control furnished at distances approximately 1,700, 3,000, and 5,300 ft apart. The primary reasoning for the varying control distances was to determine the capabilities of control extension on Kelsh-type stereoplotters. The stereobridge on the first-order equipment was set up similarly, with three different length bridges required. Vertical control was furnished throughout the 1,700- and 3,000-ft control gaps on the centerline panels, and every 1,000 ft thereafter. The differential control spacing was to assist in determining a preferred distance between the basic control points on a normal mapping project with a scale of 1 in. = 40 ft.

The test area was set up on a two-projector Kelsh plotter, a three-projector Kelsh plotter, and a three-projector K & E M-2 stereoplotter. All three bridging tests were run by the same operator to minimize the effect of operator techniques on the data differences obtained. The operator had no access to the known control data until all three bridges were completed.

The basic procedure used on all Kelsh-type bridging was simple control extension. The operator was provided a manuscript having all the furnished horizontal control points plotted by coordinates. The initial model was oriented as precisely as possible by the operator to the known horizontal and vertical control. This control was extended and tied to the next controlled model, which was set up and extended likewise until all three uncontrolled areas were spanned. As the operator tied one model to the next, all panel points were dropped on the furnished manuscript and elevations of each panel were noted. On completion of this bridge, the coordinates and elevations of the dropped points were manually taken off the manuscript and written in their appropriate blanks on the control skeleton sheets. A comparison of differences of the X, Y, and Z coordinate positions of these Kelsh-type stereobridges indicated what accumulative errors and patterns of errors might be expected (Table 3).

As indicated in Table 3, the three-projector plotters gave slightly better results. All three instruments had excellent results in the shorter bridges and some of the errors noted could be attributed to the manner in which the coordinates were manually obtained using an engineer's scale. However, no error greater than ½ ft was obtained. Therefore, this factor carried little weight in the evaluation.

This test indicated the necessity for abundant centerline vertical control. Level bubbles were utilized in the area where no centerline vertical control was furnished; however, the results were very unsatisfactory (Table 3). Deviations from the known control points obtained from the stereobridges on the three Kelsh-type stereoplotters were plotted to evaluate a possible pattern of deviation for adjustments. These tests indicated fair systematic error patterns for the horizontal control but very little for the vertical control, minimizing the amount of confidence to be placed on using this control for high-order accuracy photogrammetric mapping. This does not rule out using control data obtained by Kelsh-type stereobridging for areas not exceeding a three-model bridge between known horizontal and wing point vertical control, and having at least one centerline vertical control point per model. This control gap could be increased considerably with abundant centerline vertical control, providing the expected resultant map accuracies were relaxed accordingly. The extent of the use of Kelsh-type equipment for extending control would have to be governed by the intended use of the maps to be derived from this control.

Additional research on different techniques is hoped for in the immediate future, especially in the area of duplication of models on the three-projector plotters in conjunction with an adjustment computer program similar to the one now being used with stereotriangulation. This duplication of models technique was attempted, but without any graphic or computer adjustments. The initial results were similar to those obtained by the normal tie-in control extensions given in Table 3; however, the additional research in this area appears to be merited, and evaluation of existing data is being continued at this time.

Each of the contractors processing the test area on first-order stereoplotters was required to submit a synopsis and to complete the skeleton control sheet, whereon the X, Y, and Z coordinates of known panels on the project were furnished. The synopsis should contain information on the equipment used, procedure, and difficulties encountered. As stated earlier, the stereoplotting equipment employed was a Galileo Santoni Model IV Stereocartograph and a Wild A-5 Autograph. Both contractors used computer programs and their respective bridging procedures were very similar. The project was bridged by approximately scaling the initial model to the known control furnished and tying in each successive model without disturbing the previous model setting. Machine adjustments of BY, BZ, Swing, Tip, and Tilt were used in joining the successive models. Machine coordinates were established for all vertical and horizontal panel points throughout the length of the project.

The machine X, Y, and Z coordinates of the known and unknown control points were keypunched along with the true X, Y, and Z coordinates of the known vertical and horizontal control points for the computer input data. These cards were run through the computer using a program adapted to adjust and transform all machine coordinates to the basic datum coordinates furnished. These coordinate data were printed on a readout sheet supplying X, Y, and Z ground coordinates of all panels throughout the length of the project.

Difficulties encountered by the contractors as stated in their synopsis included excessive swing in the initial model, as evidenced by lack of BY movement to complete the bridge, adjusted for on subsequent bridge; excessive BZ movement, indicating climbing of aircraft in photography acquisition, adjusted for on subsequent bridges; and the possibility of excessive distortion in two isolated models, as evidenced by having to cross tilt the successive model to tie it to the previous model.

The completed skeleton control data sheets were received from the contractors with the required synopses. The initial data received for the Santoni stereotriangulation were analyzed, the field coordinates for the computer input were reversed, and the program was rerun. The revised data are referenced throughout this paper.

The data obtained by the stereobridges using the first-order stereoplotters were superior to the results obtained on Kelsh-type equipment. The data obtained on the variable lengths of stereobridges requested indicated little significant differences; however, no bridge was of sufficient length to provide conclusive results. The deviations of the coordinates obtained by stereotriangulation on the first-order plotters were similar, both horizontally and vertically, to the data obtained on the three-pro-

TABLE 4

FIRST-ORDER AND AVERAGE KELSH STEREOBRIDGE TABULATION DATA

Point	Kelsh (Unadjusted)			Santoni			A-5			C-5			C-8		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
(a) Centerline Points															
1	Control furnished			-0.1	-0.1	-0.2	-0.1	-0.1	-0.5	+0.3	+0.2	+0.1	+0.1	+0.1	-0.1
2				0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	+0.1	+0.1	-0.2	0.0	-0.1
3				0.0	+0.2	0.0	+0.3	+0.2	+0.2	-0.3	-0.4	0.0	0.0	0.0	0.0
4	+0.4	-0.3		-0.1	-0.1	+0.6	+0.3	-0.2	+0.5	0.0	-0.4	+1.1	-0.1	-0.4	-0.2
5	+0.3	-0.5		-0.2	-0.5	+0.6	-0.1	-0.2	+0.7	-0.5	-0.3	0.0	-0.3	-0.4	0.0
6	+0.3	-0.7		0.0	-0.3	0.0	-0.1	-0.1	+0.2	-0.4	-0.4	-0.2	-0.2	-0.1	-0.2
7	-0.4	-0.2		+0.3	+0.2	+0.1	+0.1	0.0	+0.5	-0.3	-0.2	-0.1	0.0	0.0	+0.1
8	-0.4	-1.2		-0.1	+0.1	0.0	0.0	-0.2	+0.1	-0.1	+0.4	-0.1	-0.1	-0.2	-0.4
9	Avg. (1 through 8)			+0.2	-0.2	+0.1	-0.1	+0.2	+0.1	-0.2	-0.2	+0.2	+0.1	+0.2	+0.2
10				-0.3	0.0	-0.1	-0.1	-0.3	-0.1	+0.2	-0.4	+0.5	+0.2	-0.3	+0.5
11	0.36	0.6		-0.1	+0.1	-0.6	-0.1	0.0	-0.5	0.0	-0.2	-0.3	+0.3	+0.1	+0.1
12								Panel destroyed							
13	-0.2	-0.12		-0.2	+0.3	-1.0	-0.2	+0.2	-0.4	+0.1	+0.3	+0.5	+0.1	+0.2	+0.4
14	-0.3	-0.13		0.0	+0.1	-0.4	+0.1	+0.2	-0.3	+0.4	+0.3	+0.3	+0.3	+0.4	+0.4
15	-0.4	-0.2		-0.1	+0.1	-0.7	-0.2	+0.1	-0.5	+0.4	+0.2	+0.2	+0.1	+0.4	0.0
16	-0.3	+0.5		-0.2	+0.1	-0.8	-0.2	+0.1	-0.5	0.0	+0.3	+0.1	-0.2	+0.1	-0.4
17								Panel destroyed							
18	-1.2	1.0		-0.1	+0.2	-0.3	0.0	+0.3	-0.5	0.1	+0.2	+0.2	-0.2	+0.2	+0.3
19	-1.5	+1.5		-0.1	+0.2	-0.4	0.0	+0.3	-0.2	0.0	+0.5	+0.4	-0.3	+0.5	+0.3
20	-1.8	+2.0		+0.1	+0.1	-0.5	0.0	+0.1	-0.2	+0.2	+0.6	+0.2	-0.2	+0.4	0.0
21	Avg. (12 through 20)			0.0	+0.3	-0.6	+0.1	0.0	-0.2	-0.4	+0.4	+0.3	-0.1	+0.1	+0.4
22				0.10	-0.2	+0.1	-0.2	0.0	+0.1	-0.2	-0.4	+0.1	-0.1	0.0	+0.1
23				0.0	-0.2	+0.2	0.0	0.0	-0.1	+0.1	+0.3	+0.3	+0.1	0.0	0.0
24	-0.6	-0.5	+0.0	Data in process			-0.6	-0.1	+0.3	No additional data available			-0.2	-0.1	-0.6
25	-0.5	-0.7	+0.8				-0.4	-0.1	+0.5				0.0	+0.1	-0.8
26	-0.7	-0.5	+1.1				-0.4	0.0	+0.3				-0.1	+0.1	-1.1
27	-1.0	-0.6	+1.6				-0.2	-0.4	+0.6				0.0	0.0	-0.6
28	-1.4	-0.5	+2.5				-0.5	-0.2	+0.6				0.0	-0.4	-0.2
29	-2.2	-1.0	+2.6				1.5	-0.9	+0.2				-1.0	-0.6	-0.2
30	-2.5	-0.4	+3.0				-0.8	-0.5	+0.5				-0.4	+0.9	-0.2
31	-2.7	-0.6	+3.5				-1.0	+0.4	+0.5				-0.5	+0.7	+0.1
32	-3.2	-1.2	+4.1				-0.9	-0.7	+0.2				-0.2	0.0	-0.1
33	-3.5	-1.0	+5.3				-0.5	-0.3	-0.2				+0.1	+0.3	+0.1
34	-3.0	-1.6	+5.5				-0.4	-0.3	-0.4				+0.3	+0.3	+0.2
35	-3.7	-1.6	+6.7				-0.5	-0.3	-0.1				+0.2	-0.3	+0.1
36	-4.0	-1.7	7.8				-0.2	-0.2	-0.3				+0.6	+0.3	+0.1
37	-5.0	-2.0	+8.5				-0.9	+0.5	-0.1				0.0	+0.9	-0.1
38	-0.5	-2.2	9.0				-0.3	-0.4	+0.2				+0.4	-0.2	-0.2
39	-6.5	-3.2	10.0				-0.5	-0.5	-0.3				0.0	-0.2	-0.4
40	-7.0	-3.3	10.5				-0.5	-0.2	-0.2				-0.4	0.0	-0.2
41				Avg. (1 through 23)			-0.1	-0.1	-0.1				0.0	-0.1	0.0
Avg.	±2.9	±1.3		±0.1	±0.2	±0.3	±0.37	±0.26	±0.34	0.3	0.32	0.25	±0.2	±0.25	±0.24
(b) Wing Points—Vertical Only															
						(0.295)			(0.403)			(0.254)			±(0.34)
69-1	All Kelsh readings + and - through point 61-7					-0.3			-0.3			-0.3			0.0
69-2						0.0			0.0			+0.1			0.0
69-3						+0.1			+0.1			+0.2			+0.1
69-4			0.1			0.0			+0.5			-0.2			-0.2
69-5			0.2			-0.3			+0.5			-0.5			-0.3
69-6			0.1			-0.4			+0.3			+0.8			-0.1
69-7			0.35						+0.7			0.0			-0.6
69-8			0.1			-0.3			+0.8			0.0			-0.5
69-9						+0.2			+0.3			+1.3			-0.3
69-10						0.0			+0.1			+0.2			-0.1
69-11						-0.1			+0.1			+0.2			-0.1
69-12															
67-1															
67-2						+0.2			+0.2			-0.1			-0.3
67-3						+0.3			-0.2			-0.1			0.0
67-4						+0.1			-0.2			+0.6			+0.5
67-5						+0.2			+0.2			+0.4			+0.3
67-6						-0.2			+0.2			+0.1			+0.2
67-7			0.2			-0.3			+0.2			-0.2			-0.1
67-8			0.1			-0.2			+0.3			-0.2			0.0
67-9															
65-1			0.15			-0.2			-0.4			-0.1			+0.5
65-2			0.4			+0.3			-0.4						-0.8
65-3			0.5			+0.3			-0.7			+0.7			+0.5
65-4			0.2			+0.1			-0.6			+0.2			-0.3
65-5			0.35			-0.2			-0.7			-0.1			-1.0
65-6			0.35			+0.5			-0.3			+0.7			-0.2
65-7			0.35			-0.2			+0.1			+0.5			+0.1
65-8			1.0			+0.3			-0.2			+0.7			+0.4
65-9			0.7			+0.4			0.0			+0.1			+0.2
65-10															
63-1			0.1			+0.3			-0.6			0.0			0.0
63-2			0.1			+0.5			-0.5			0.0			+0.4
63-3			0.3			+0.3			-0.5			+0.5			+0.3
63-4			0.5			+0.4			-0.5			+0.3			+0.4
63-5			0.5			-0.1			-0.2			-0.1			-0.2
63-6			0.8			-0.4			+0.2			+0.3			+0.2
63-7			0.4			-0.4			+0.1			+0.4			-0.5
63-8			0.5			-0.2			-0.3			+0.3			-0.4
63-9			0.4			+0.6			-0.2			+0.2			-1.6
61-1			0.6			+0.2			-0.3			-0.2			-0.2
61-2									+0.4			0.0			+0.3
61-3									+0.2			0.0			-0.2
61-4									+0.3			0.0			-0.3
61-5									+0.3			+0.1			-0.5
61-6									+0.7			-0.1			-0.4
61-7			0.4			-0.1			-0.2			+0.2			+0.5
59-1			0.4			-0.6			+0.4	No additional data available					-0.3
59-2															
59-3			1.1			-0.2			+0.8						-0.4
59-4			1.5			-0.1			+5						-0.8
59-5			2.5			-0.3			-1						-0.7
59-6			2.0			+0.3			+1.1						-0.4
59-7			2.1			+0.3			+0.7						-0.6
59-8			1.5			+0.5			+0.5						-0.8
59-9			0.7			-0.1			+0.8						-0.9
57-1			2.5			+0.1			+0.3						-0.4
57-2			3.3			+0.3			+1.1						-1.3
57-3			4.1			-1			+0.7						-0.2
57-4			5.1			-3			-0.5						-0.3
57-5			5.7			-3			-0.5						+0.1
57-6			5.6			-2			+0.5						+0.6
57-7			4.4			0.0			-0.1						+0.2
57-8			3.5			0.0			-0.3						+0.1
57-9			2.5			+0.5			+0.1						+0.4
55-1			6.5			-0.5			+0.2						0.0
55-2			8.4			-1.1			+0.2						0.0
55-3			9.0			-0.8			-0.9						-0.2
55-4			9.4			-0.9			+0.8						+0.1
55-5			10.0			-0.9			-0.2						-0.3
55-6			7.3			-0.4			-0.4						+0.1
53-1			10.4			0.0			-0.3						+0.4
53-2			11.5						+0.4						+0.9
53-3															
53-4			11.4						-0.5						+0.2
53-5			10.8						-0.3						0.0
Avg.	Inconclusive					±0.3			±0.4			±0.25			±0.34

jector Kelsh-type equipment for the initial three to four models. Beyond this distance, the accuracy of the data from the contracted plotters remained fairly constant, whereas the Kelsh accuracies decreased considerably. As indicated in Table 4, there were little significant differences in the X, Y, and Z coordinate results obtained on the two first-order machines and, assuming the same operator techniques and computer programs, very little difference in performance of the equipment.

The acquisition of a Zeiss C-8 Stereoplanigraph by the Texas Highway Department enabled further study of stereotriangulation in areas not explored on the contracted portion of the project. The stereobridges required of the contractors were negotiated and limited in scope. The data and procedures obtained from the contractor's stereobridges were definitely informative and indicated that intermediate control could be obtained for some photogrammetric mapping projects by stereotriangulation. These encouraging preliminary data were a prime factor in determining that first-order plotting equipment would be of more use to the Department than the Kelsh-type stereoplotting equipment then in operation.

The identical test area and skeleton control data were initially utilized on the C-8 Stereoplanigraph to obtain an equipment evaluation and to check out the difficulties indicated by the respective contractors in their synopses. The data obtained on the C-8 Stereoplanigraph are included in Table 4. The Army Map Service Branch Plant in San Antonio allowed the Texas Highway Department's operator to use of one of their first-order machines. During the 3 weeks spent working on the Army Map Service C-5 Stereoplanigraph equipment, the operator stereobridged a portion of the test area. The data obtained were adjusted utilizing the Army Map Service computer program. The program is basically the same as the adjustment program the Texas Highway Department uses; however, the horizontal and vertical input data had to be run through the computer separately. The readout-adjusted X, Y, and Z coordinates were similar to the results obtained by the Zeiss C-8, Wild A-5, and Santoni stereobridges, and are included in Table 4.

At the conclusion of this phase, the test area along I-35 had been stereobridged, using the same control interval, on a two-projector Kelsh plotter, a three-projector Kelsh plotter, a K & E M-2 stereoplotter, a Wild A-5 Cartograph, a Galileo Santoni Model IV Stereocartograph, a Zeiss C-5 Stereoplanigraph, and a Zeiss C-8 Stereoplanigraph. A thorough analysis of the data obtained from these various stereobridges gave a fair indication of the accuracies which could be expected from stereotriangulation utilizing known control in the input data at distance intervals of 1,700, 3,000, and 5,300 ft.

All data thus far evaluated had been obtained from stereobridges developed through one certain area using the same photography and control. In general, the X and Y deviations from the X and Y coordinates established from the ground survey were very small, averaging less than ±0.3 at any one point established by stereotriangulation on first-order equipment. At a horizontal map scale of 1 in. = 40 ft, this ±0.3-ft deviation would amount to slightly less than $^1/_{120}$ in. This fractional difference would be extremely difficult to plot on a map sheet and would have little effect on individual model scaling on a Kelsh-type plotter. Also, this variation of the stereotriangulated points from true coordinate position is plus and minus, and the possibility of accumulative errors is eliminated by the computer program which adjusts the intermediate control points to the coordinate positions of the furnished ground control points throughout the length of the project.

Factors taken into consideration when analyzing and evaluating the horizontal errors of ±0.3 ft incurred from the horizontal stereobridge data obtained on the various types of equipment are as follows:

1. Possible resultant errors in basic control data,
2. Distortion in the aerial photography,
3. Correlation of the bridging equipment lens system and the photographic camera lens,
4. Financial limitations on the photogrammetric contractors for input adjustments, and
5. Control spacing not ideal for first-order bridging.

TABLE 5

DIFFERENTIAL CONTROL INTERVALS STEREOBRIDGED ON C-8

Point	1,200			1,500			2,000			2,500			3,000		
	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
							(a) Centerline Points								
1	+0.1	+0.3	-0.1	+0.2	+0.1	-0.1	0	+0.2	+0.2	0	+0.2	+0.1	+0.1	0	-0.2
2	-0.2	0	-0.2	+0.2	0	-0.2	-0.3	0	+0.2	-0.3	+0.1	-0.2	-0.2	-0.1	-0.2
3	0	+0.1	-0.1	0	-0.1	-0.1	0	0	0	-0.1	0	-0.1	+0.1	-0.2	-0.1
4	-0.2	-0.5	-0.2	-0.2	-0.5	-0.2	-0.1	-0.4	-0.2	-0.2	-0.4	-0.2	-0.1	-0.6	-0.2
5	-0.4	-0.5	0	-0.5	-0.5	0	-0.4	-0.4	-0.1	-0.4	-0.4	-0.2	-0.3	-0.5	0
6	-0.2	-0.3	-0.2	-0.3	-0.3	-0.2	-0.2	-0.2	-0.3	-0.3	-0.2	-0.3	-0.2	-0.3	-0.2
7	0	-0.1	+0.1	-0.1	-0.1	0	0.0	-0.1	0	-0.1	-0.1	0	0	-0.1	+0.1
8	-0.1	-0.4	-0.4	-0.2	-0.4	-0.4	0.0	-0.3	-0.4	-0.1	-0.3	-0.5	-0.1	-0.3	-0.4
9	-0.1	0	+0.2	0	0	+0.2	+0.1	+0.1	+0.1	+0.1	0	+0.1	+0.1	+0.1	+0.2
10	+0.3	-0.5	+0.5	+0.2	-0.5	+0.5	+0.3	-0.4	+0.5	+0.2	-0.5	+0.4	+0.2	-0.4	+0.6
11	+0.3	-0.2	+0.1	+0.2	-0.2	+0.1	+0.4	-0.1	0	+0.3	-0.2	-0.1	+0.3	-0.1	+0.1
12							Panel destroyed								
13	+0.2	0	+0.5	+0.1	-0.1	+0.5	+0.2	0	+0.4	+0.1	-0.1	+0.3	+0.1	0	+0.5
14	+0.3	+0.2	+0.4	+0.2	+0.2	+0.4	+0.3	+0.2	+0.4	+0.3	+0.1	+0.3	+0.3	+0.3	+0.5
15	+0.1	+0.1	0	0	+0.2	0	+0.1	+0.2	-0.1	-0.1	-0.1	-0.1	0	+0.2	+0.1
16	-0.2	-0.2	-0.3	-0.2	-0.1	-0.3	-0.1	-0.1	-0.4	-0.1	-0.2	-0.5	-0.3	-0.1	-0.3
17							Panel destroyed								
18	-0.2	+0.1	+0.1	-0.2	0.0	0.0	-0.1	-0.1	+0.2	-0.1	-0.1	-0.4	-0.2	+0.3	+0.2
19	-0.2	+0.2	+0.3	-0.2	+0.2	+0.3	-0.2	+0.2	+0.3	-0.2	+0.1	+0.1	-0.4	+0.3	+0.4
20	-0.1	+0.1	+0.1	-0.1	+0.1	+0.1	-0.1	+0.1	0	-0.1	0	-0.1	-0.3	+0.2	+0.1
21	0	-0.2	+0.4	0	-0.1	+0.4	0	-0.2	-0.3	0	-0.3	+0.3	-0.2	-0.1	+0.5
22	+0.1	-0.2	+0.2	+0.1	-0.2	+0.2	0	-0.3	+0.1	0	-0.2	0	-0.2	-0.2	+0.2
23	+0.2	-0.3	+0.1	+0.2	-0.3	+0.1	+0.2	-0.3	0	+0.2	-0.4	-0.1	0	-0.2	+0.1
24	-0.1	-0.3	-0.6	-0.1	-0.4	-0.5	-0.1	-0.4	-0.6	-0.1	-0.5	-0.7	-0.3	-0.3	-0.5
25	+0.2	-0.2	-0.8	+0.2	-0.2	-0.7	+0.1	-0.2	-0.8	+0.2	-0.3	-0.9	-0.1	-0.1	-0.7
26	+0.1	-0.1	-1.0	+0.1	-0.2	-1.0	0	-0.2	-1.1	+0.1	-0.3	-1.2	-0.2	-0.1	-1.0
27	+0.2	-0.2	-0.5	+0.2	-0.3	-0.5	+0.1	-0.3	-0.6	+0.2	-0.4	-0.7	-0.1	-0.2	-0.5
28	+0.2	+0.2	-0.1	+0.2	+0.1	-0.1	+0.1	+0.1	-0.2	+0.1	0	-0.2	-0.2	+0.2	-0.1
29	-0.8	-0.8	-0.2	-0.7	-0.9	-0.1	-0.8	-0.9	-0.2	-0.7	-0.9	-0.3	-0.1	-0.7	-0.1
30	-0.2	-0.6	-0.1	-0.2	+0.6	-0.1	-0.3	+0.6	-0.1	-0.2	+0.6	-0.2	-0.5	-0.8	-0.1
31	-0.3	+0.6	+0.2	-0.3	+0.4	+0.3	-0.4	+0.5	+0.2	-0.3	+0.4	+0.1	-0.6	+0.6	+0.2
32	0	-0.2	0	-0.1	-0.4	+0.1	-0.1	-0.3	0	0	-0.4	-0.1	-0.3	-0.2	0
33	+0.3	+0.2	+0.1	+0.3	0	+0.2	+0.2	+0.1	+0.1	-0.4	0	+0.1	0	+0.2	+0.2
34	+0.5	+0.2	+0.3	+0.4	-0.1	+0.4	+0.5	+0.1	+0.2	+0.6	0	+0.1	-0.2	+0.2	+0.3
35	+0.4	+0.2	+0.2	+0.3	-0.1	+0.2	+0.4	0	+0.2	+0.5	0	+0.2	+0.2	+0.2	+0.2
36	+0.7	+0.2	+0.2	+0.6	-0.1	+0.2	-0.3	+0.1	+0.2	+0.9	+0.1	+0.1	+0.5	+0.2	+0.1
37	+0.1	+0.9	0	-0.1	+0.4	+0.1	+0.1	+0.7	+0.1	+0.3	+0.7	0	-0.1	+0.9	0
38	+0.5	-0.1	-0.1	+0.2	-0.4	0	+0.5	0	-0.1	+0.7	0	-0.1	+0.3	+0.1	-0.1
39	+0.1	-0.2	-0.3	-0.2	-0.8	-0.2	+0.1	-0.3	-0.2	+0.3	-0.4	-0.2	0	-0.2	-0.3
40	-0.4	0	-0.1	-0.7	-0.6	0	-0.2	-0.1	-0.1	0	-0.1	0	-0.3	0	-0.2
41	0	-0.1	+0.1	-0.4	-0.8	+0.2	+0.1	-0.2	+0.2	+0.3	-0.2	+0.2	0	0	0
Avg.	+0.2	+0.25	+0.22	0.21	0.25	0.22	0.18	0.27	0.21	0.23	0.22	0.22	0.2	0.23	0.23
							(b) Vertical Wing Points								
69-1			-0.2			-0.1			-0.1			-0.1			-0.1
69-2			0			0			-0.1			-0.1			0
69-3			0			+0.1			+0.1			0			+0.1
69-4			-0.2			-0.3			-0.3			-0.3			-0.3
69-5			-0.3			-0.3			-0.3			-0.4			-0.3
69-6			-0.2			-0.1			-0.1			-0.1			-0.2
69-7			-0.6			-0.6			-0.7			-0.7			-0.4
69-8			-0.5			-0.6			-0.6			-0.6			-0.5
69-9			-0.3			-0.4			-0.4			-0.4			-0.3
69-10			+0.1			-0.2			-0.1			-0.1			-0.1
69-11			-0.1			-0.2			-0.2			-0.2			-0.2
69-12															
67-1							No Panel								
67-2			-0.3			-0.3			-0.2			-0.2			-0.3
67-3			0			0			0			+0.1			0
67-4			+0.5			+0.6			+0.4			+0.4			+0.6
67-5			+0.3			+0.3			+0.2			+0.2			+0.4
67-6			+0.2			+0.2			0			+0.1			+0.2
67-7			-0.1			-0.1			-0.2			-0.2			0
67-8			0			0			-0.1			0			+0.1
67-9							Bad point—no panel								
65-1			+0.5			+0.4			+0.5			+0.4			+0.4
65-2															
65-3			+0.5			+0.4			+0.6			+0.4			+0.4
65-4			+0.4			+0.3			+0.4			+0.2			+0.3
65-5			0			-0.1			+0.1			-0.1			-0.1
65-6			+0.5			+0.6			+0.3			+0.3			+0.7
65-7			+0.1			+0.2			+0.1			-0.1			+0.3
65-8			+0.4			+0.5			+0.2			+0.2			+0.5
65-9			+0.2			+0.3			0			0			+0.3
65-10							Bad point—no panel								
63-1			0			-0.1			+0.1			-0.1			-0.1
63-2			+0.5			+0.4			+0.6			+0.4			+0.4
63-3			+0.4			+0.2			+0.4			+0.2			+0.3
63-4			+0.5			+0.4			+0.6			+0.3			+0.4
63-5			-0.1			-0.1			0			-0.2			-0.2
63-6			+0.2			+0.4			0			0			+0.4
63-7			-0.5			-0.3			-0.7			-0.7			-0.3
63-8			-0.5			-0.4			-0.5			-0.7			-0.4
63-9			+1.4			+1.6			+1.2			+1.2			+1.6
61-1			0			-0.1			+0.1			0			0
61-2			+0.4			+0.3			+0.5			+0.2			+0.3
61-3			-0.1			-0.2			0			-0.2			-0.2
61-4			-0.3			-0.3			-0.2			-0.3			-0.3
61-5			-0.5			-0.4			-0.7			-0.7			-0.3
61-6			-0.4			-0.3			-0.6			-0.6			-0.2
61-7			+0.5			+0.7			+0.3			+0.3			+0.7
59-1			-0.2			-0.3			+0.1			-0.3			-0.3
59-2															
59-3			-0.3			-0.3			-0.2			-0.4			-0.4
59-4			-0.6			-0.7			-0.6			-0.8			-0.8
59-5			-0.6			-0.6			-0.5			-0.7			-0.7
59-6			-0.4			-0.2			-0.4			-0.5			-0.2
59-7			-0.6			-0.4			-0.7			-0.8			-0.4
59-8			-0.8			-0.6			-0.9			-0.9			-0.6
59-9			-0.9			-0.7			-1.0			-1.0			-0.7
57-1			-0.2			-0.3			-0.2			-0.3			-0.3
57-2			-0.1			-0.2			-0.1			-0.2			-0.2
57-3			0			0			0			-0.1			-0.1
57-4			-0.2			-0.1			-0.2			-0.2			-0.3
57-5			+0.3			+0.3			+0.3			+0.2			+0.2
57-6			+0.6			+0.3			+0.6			+0.6			+0.7
57-7			+0.2			+0.3			+0.2			+0.1			+0.3
57-8			+0.1			0.3			+0.1			+0.1			+0.2
57-9			+0.4			+0.6			+0.4			+0.3			+0.6
55-1			+0.1			+0.2			0.1			+0.1			0
55-2			+0.2			+0.3			+0.1			+0.1			+0.1
55-3			-0.1			0			-0.1			-0.1			-0.2
55-4			+0.1			+0.2			+0.2			+0.2			+0.1
55-5			-0.3			-0.1			-0.1			-0.2			-0.2
55-6			+0.1			+0.3			+0.2			+0.2			+0.2
53-1			+0.5			+0.7			+0.5			+0.5			+0.4
53-2															
53-3															
53-4			+0.2			+0.3			+0.5			+0.4			+0.2
53-5			0			+0.1			+0.2			+0.2			0
Avg.			0.27			0.29			0.27			0.28			0.28

The basic control traverses were established by an experienced field party using precision equipment and the possiblity of error was minimized in the actual survey and in the placement of the panels. A panel might have been displaced off the absolute center of the control point since the test area is in a developed section of the highway and, due to the number of panels, it was difficult to maintain surveillance of all points before photography. The consistently high deviations noted on certain points, with the necessity of cross tilting on some model ties, could have been due to minor localized photographic distortion. Distortion would, very definitely, have some effect in an overall stereobridge—especially when dealing with tenths of a foot.

It is very doubtful that more than one of the stereobridges was run on equipment calibrated in exact correlation with the photographic camera lens. The Texas Highway Department used corrective plates for the average of the type of lens, but these were not correlated with the specific lens of the camera. This source of error should have little effect on the horizontal points but should be considered in an overall evaluation.

The final readout data furnished by the contractors might have been improved by removing certain control points from the computer input data. This would have required additional computer time and additional funds, and was not part of the contract.

It was recognized that the control data furnished for the development of the stereobridging were not ideal for first-order equipment. Better results probably could have been obtained if the control had been spaced at different intervals; however, this interval was preferred for a simultaneous evaluation of the Kelsh-type plotters and the first-order equipment.

The machine X, Y, and Z coordinates of all panel points on this test area had been recorded on the initial C-8 stereobridge, and with only minor computer input data revisions, stereobridge data were obtained at varying distance intervals of 1,200, 1,500, 2,000, 2,500, and 3,000 ft. A comparative analysis of the effect of this differential control spacing on the resultant adjusted X, Y, and Z coordinates is given in Table 5.

Elevation deviations from true ground elevations or Z coordinates noted in evaluating the various stereobridges from the test area were somewhat greater than the X and Y coordinate deviations. The average error incurred was less than 0.4 ft. This elevation differential exceeds the vertical control accuracy desired on mapping projects at a scale of 1 in. = 40 ft. The effect of this average vertical error on the intended use of certain highway mapping projects might be negligible.

Again, the factors mentioned previously that possibly affected the horizontal accuracies obtained were considered in the analysis of the vertical errors incurred. In fact, these factors would have more effect on the vertical data than the horizontal data. Distortion in the aerial photography and correlation of the bridging equipment lens system and photographic camera lens system could greatly affect vertical accuracies.

Additional stereotriangulation research was conducted along F. M. Highway 1604 in Bexar County. Map sheets were currently being developed on this project at a scale of 1 in. = 40 ft with a 1-ft contour interval. The basic control for the project had been established by standard field methods and most models had set up relatively well. A 3-mi tangent was selected and stereobridged on a Zeiss C-8 Stereoplanigraph. Machine coordinates were recorded on all vertical wing points and centerline panels. Known ground control data were inserted into the input computer data at different intervals. The results obtained on this stereobridge are given in Table 6. Unfortunately, none of the wing vertical control points were paneled and identification of the exact location of these points was extremely difficult. Mislocation of a vertical point on this project by a very small amount could easily result in input errors in excess of 1.0 ft. Inasmuch as the successive models were tied by pass points in stereotriangulation and the individual models were not leveled (control not furnished), misidentified vertical control points could not be detected during the bridge. This problem of exact control point identification would definitely indicate that all control points, including vertical wing points, to be used as the basic control on any stereobridge should be paneled before photography for easy photo identification.

Research into several areas of stereotriangulation is continuing. The Texas Highway Department recently purchased a Wild RC-8 aerial camera with an aviogon lens and obtained correction plates for the Zeiss C-8 Stereoplanigraph ground especially

TABLE 6

F. M. 1604 STEREOTRIANGULATION RESEARCH AREA[a]

Point	Three Single Control Bands			Three Cluster Control Bands			Four Single Control Bands		
	X	Y	Z	X	Y	Z	X	Y	Z
1205+00.2	0.0	+0.2	-0.1	+0.1	0.0	-0.4	+0.1	0.0	-0.2
1208	0.0	0.0	+0.5	0.0	-0.2	+0.2	0.0	-0.2	+0.5
1211	-0.1	+0.2	+1.0	-0.2	0.0	+0.8	-0.2	0.0	+1.0
1214	+0.2	+0.2	+1.2	+0.1	+0.1	+0.9	0.0	+0.1	+1.2
1217+15.4	0.0	+0.1	+1.1	-0.2	+0.1	+0.8	-0.2	+0.1	+1.0
1220	0.0	+0.2	+1.4	-0.2	+0.1	+1.1	-0.2	+0.1	+1.3
1230	-0.2	+0.2	+1.9	-0.5	+0.1	+1.6	-0.4	+0.1	+1.8
1233	+0.2	+0.4	+1.5	-0.2	+0.3	+1.2	-0.1	+0.4	+1.4
1236	-0.9	+0.3	+0.9	-0.4	+0.2	+0.6	-0.4	+0.4	+0.7
1239	-0.2	+0.1	0.0	-0.6	0.0	-0.1	-0.4	+0.2	+0.1
1240+34.4	+0.1	+0.3	+0.2	-0.5	+0.2	-0.1	-0.3	+0.4	+0.1
1243	-0.2	+0.2	-0.1	-0.6	+0.1	-0.3	-0.4	+0.3	-0.2
1246	-0.1	+0.4	-0.8	-0.4	+0.3	-1.0	-0.2	+0.5	-0.9
1249	0.0	+0.2	-0.4	-0.3	+0.2	-0.7	0.0	+0.3	-0.6
1252	0.0	+0.2	+0.4	-0.3	+0.1	-0.9	+0.1	+0.4	-0.8
1255	-0.2	+0.2	-0.9	-0.4	+0.2	-1.1	0.0	+0.5	-1.1
1258+02.5	-0.1	+0.3	-0.7	-0.3	+0.2	-1.0	+0.1	+0.5	-1.0
1261	-0.1	+0.3	-0.6	-0.2	+0.3	-0.9	+0.3	+0.5	-0.9
1264	0.0	+0.2	-0.6	-0.1	-0.1	+0.8	+0.4	+0.4	-0.8
1267	-0.2	0.0	-0.7	-0.3	-0.1	-1.0	+0.4	-0.2	-1.0
Avg.	(0.140)	(0.210)	(0.750)	(0.295)	(0.145)	(0.775)	(0.210)	(0.280)	(0.830)

[a]Centerline vertical data indicative of vertical data on wing points.

for the lens characteristics of this camera. An area similar to the I-35 Test area will be controlled, paneled, and photographed with the Wild RC-8 in the immediate future, and numerous research tests of stereotriangulation accuracies on the Zeiss C-8 Stereoplanigraph will be conducted on this area. Stereotriangulation tests on a smaller scale map project (1 in. = 200 ft) are also scheduled. Research is continuing on the three-projector Kelsh plotters utilizing the duplication of models (setting the tie-in model twice), in conjunction with a computer adjustment program.

As a result of a thorough evaluation and analysis of the data obtained on stereotriangulation during this research project, the Texas Highway Department plans to obtain and use control from stereotriangulation for photogrammetric mapping projects to be utilized in highway engineering. Minor limitations will be placed on vertical control data at this time.