D. BROWN ASSOCIATES, INC.
PHOTOGRAMMETRIC STRUCTURAL CALIBRATION
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PHOTOGRAMMETRIC CALIBRATION
Of The
300-FOOT NRAO
RADIO TELESCOPE
(Axis at Zenith Distance of 30°)

Prepared for:
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SECTION 1.

Introduction

PHOTOGRAMMETRIC CALIBRATION OF THE 300-FOOT NRAO RADIO TELESCOPE (Axis at Zenith Distance of 30°)

INTRODUCTION

The ensuing report presents the results of a photogrammetric calibration, performed by D. Brown Associates, Inc. on the 300-foot NRAO Radio Telescope located at the National Radio Astronomy Observatory at Green Bank, West Virginia. This report is submitted as fulfillment and completion of the work set forth in Paragraph 1(c), Schedule A, of Subcontract No. RAP-33 between Associated Universities Incorporated and the Instrument Corporation of Florida.

The photogrammetric theory and techniques employed in this calibration are based on recently perfected adaptations and extensions, by Duane C. Brown, of his earlier derivation of the general solution to the problem of multistation analytical stereotriangulation. Inasmuch as the mathematics of the least squares adjustment and error propagation of this solution are rather involved, they will not be reproduced here. Complete detailed treatments are available in references [1], [2] and [3].

The raw data for this calibration consisted of three photographs of the antenna taken with a special 1000mm focal length metric camera, shock-mounted in a Bell J-2 helicopter. These photographs, taken on ultra-flat, one quarter inch thick glass plates coated with a 103-F emulsion, were obtained on 2 January 1963. The antenna, illumined by sunlight, was exposed for 1/400 of a second at f/35 from three aerial stations situated on an arc

approximately 1800 feet from the vertex of the antenna in such a manner as to obtain a 90° angle of intersection between the camera axes at the vertex of the antenna. The helicopter hovered at altitudes of 1900, 1900, and 600 feet respectively at stations 1, 2, and 3. The antenna axis remained in a fixed position between exposures with approximately five minutes elapsing between each exposure. During this time the temperature ranged from 31°F on the ground to 10°F at an altitude of 1900 feet, and wind velocity was 0 to 10 miles per hour from NNE.

Prior to exposure, 305 targets, fabricated from three-ply plastic, were bolted to the dish in a predetermined pattern. These targets consisted of a solid white circle, 1 inch diameter against a 6 inch diameter circular black background. One such target was also affixed to the RF head of the antenna. To permit precise scaling of the calibrated surface and analysis of anomolistic refraction a calibrated black-faced steel tape, with 1 inch diameter white circles accurately spaced every 12 inches along its face, was stretched across the dish under controlled tension.

Figures 1, 2 and 3 are contact prints of the plates, acquired from the aerial stations, used for the calibration. The closeness of the target images on the plates made circling and numbering of the target points impractical. A graphical display of the target point distribution and identification numbers is presented in Figure 4.

The plates were processed under controlled conditions and proved to be of good to excellent quality. The relatively low elevation angle of the sun at Green Bank at this time of the year

caused sections of the antenna to be in shadow, and thus degraded target image quality somewhat in certain areas of the dish. The plates were measured on a Mann 422 C/D optical comparator and the resultant coordinates of the target images, properly corrected for comparator errors and lens distortion, were processed through the rigorous, least squares analytical stereo-triangulation adjustment on an IBM 1620 electronic computer. Ultimately the adjustment converged to a stable solution which yielded a root mean square error of 10.0 microns for plate residual vectors. This is equivalent to an angular closure of 2.00 arc seconds.

The triangulated X, Y, Z coordinates of the target points, and their associated standard deviations, are presented in Table 1. These coordinates have been properly scaled and are referred to a Cartesian system with origin at the computed vertex of the dish and with the Z axis normal to the dish at the vertex (thus the Z axis is coincident with the axis of the best-fitting paraboloid of revolution). The positive quadrant of the XZ plane passes precisely through target No. 7 and the positive quadrant of the YZ plane passes approximately through target No. 13. The root mean square of the standard deviations of the triangulated target points (from three-station triangulations) are:

$$\sigma_x = 0.0142 \text{ feet},$$

$$\sigma_y = 0.0137 \text{ feet},$$

$$\sigma_z = 0.0174 \text{ feet}.$$

Since the diameter of the dish is 300 feet, they are equivalent to proportional accuracies of:

$$\frac{\sigma_x}{300} \cong \frac{1}{21,100} ,$$

$$\frac{\sigma_y}{300} \cong \frac{1}{21,900} ,$$

$$\frac{\sigma_z}{300} \cong \frac{1}{17,200} .$$

Obscuration of certain targets by the feed supporting structure, and the poor quality of the plate images of a few due to sun shadow and other causes, limited triangulation of 14 of the target points to two stations. These points are noted in the data tables.

Next, the plate coordinate residual vectors from each camera for each triangulated point are tabulated in Table 2. These vectors represent the differences between the projection of each triangulated point onto the plate and the measured coordinates of the image of this point on the plate. Analysis of these residual vectors revealed no patterns of systematic errors, thus from a point of internal consistency, the solution is completely satisfactory.

Finally, the X, Y, Z coordinates of each target point, and their associated covariance matrix, were utilized to determine the paraboloid of revolution which, from a statistical sense of minimum variance, best fitted the array of triangulated target points. Table 3. lists DX, DY, DZ the X, Y, Z components of the departures of each triangulated target point from the best

fitting paraboloid. Subtraction of DX, DY, DZ from X, Y, Z respectively would adjust the triangulated point to the surface of the paraboloid. Table 3.also lists the perpendicular distance, D, from each target point to the best fitting paraboloid. The root mean square perpendicular departure was .0308 feet. This is 1.7 times the rms attributable solely to errors in triangulation. The maximum positive departure from the best fitting paraboloid was .0912 feet (target No. 297) and the maximum negative departure was .0638 feet (target No. 103). These perpendicular departure vectors have been plotted in Figure 5. The departures of these vectors from a true paraboloidal surface are sufficiently systematic to define an error surface. A map of this error surface, with isoerror contours inscribed at intervals of 0.02 feet, is presented in Figure 6. Finally, focal length and coordinates of the vertex of the best fitting paraboloid are discussed in Section 9.

SECTION 2.

Contact Prints of Calibration
Photographic Plates

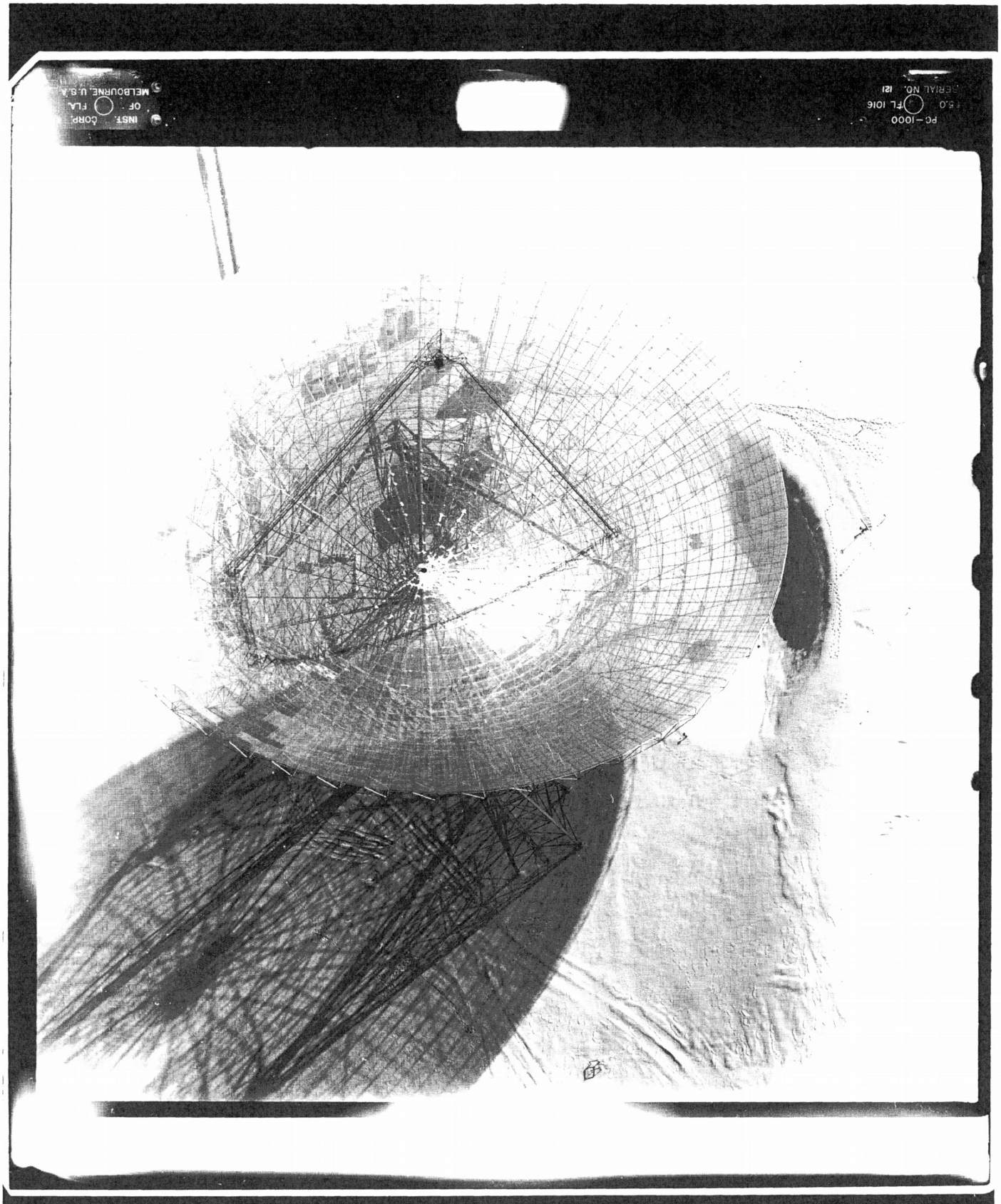

FIGURE 1. Contact print of PC-1000 plate of 300-foot NARO Radio Telescope - Station 1.

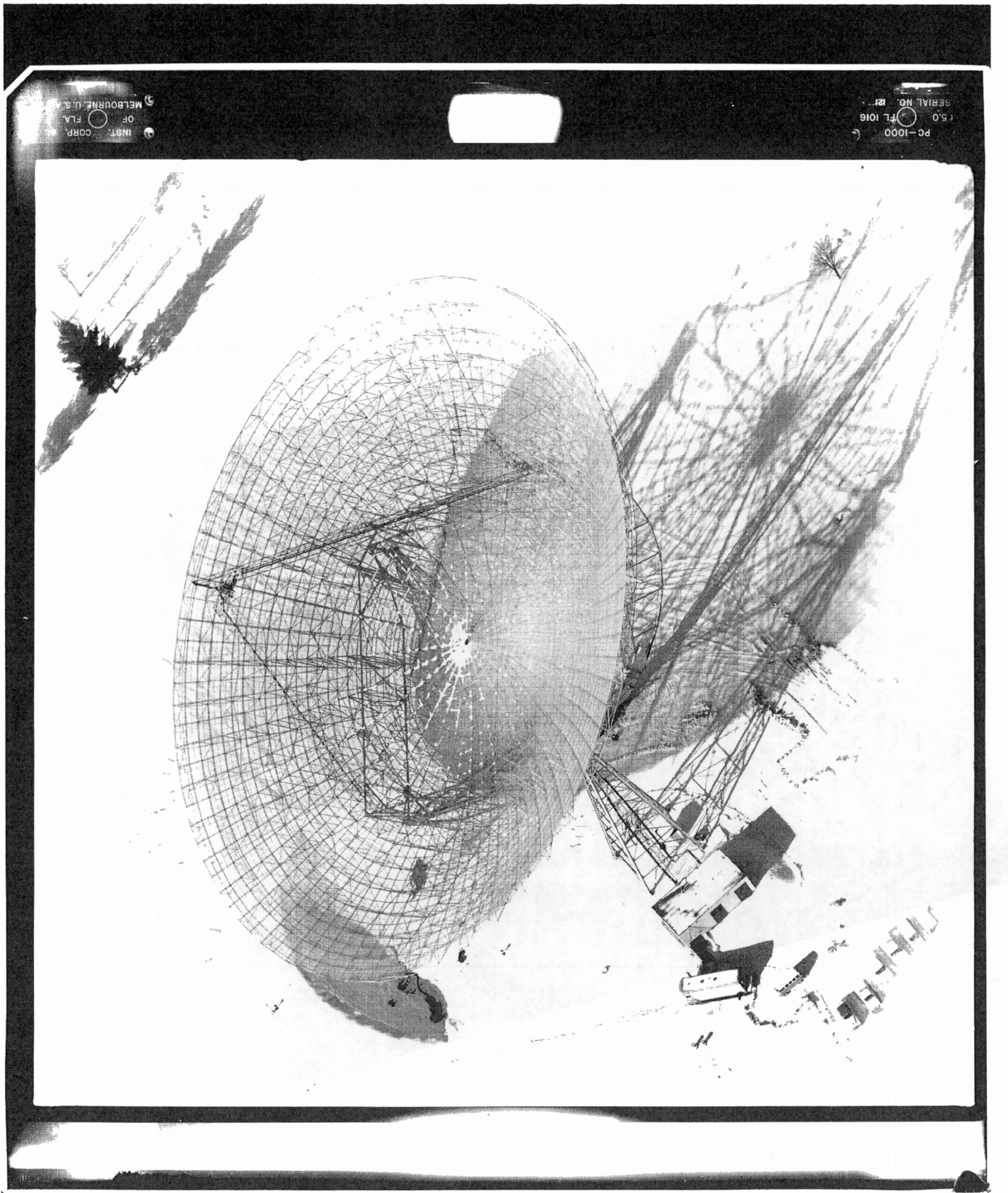

FIGURE 2. Contact print of PC-1000 plate of 300-foot NARO Radio Telescope - Station 2

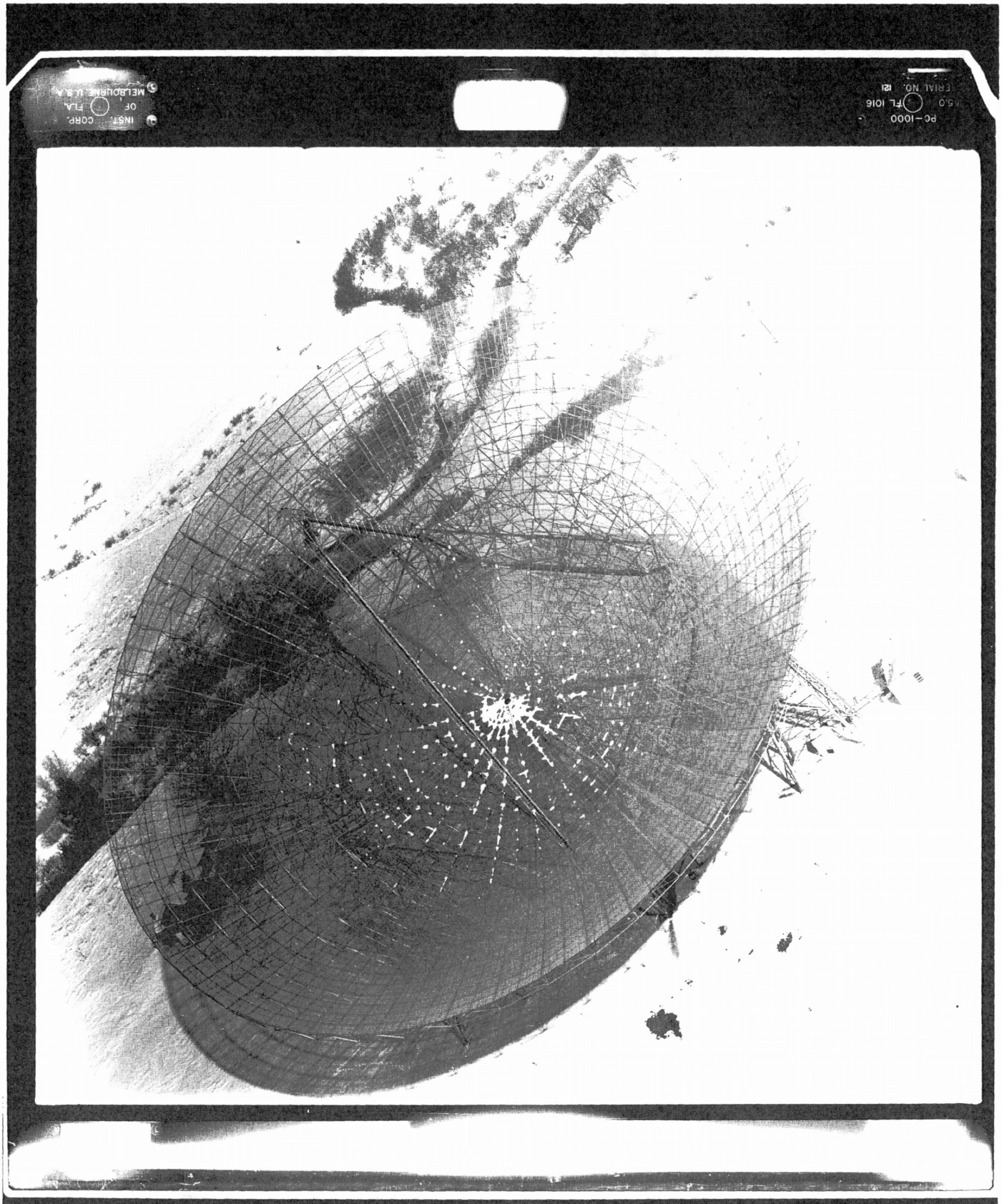

FIGURE 3. Contact print of PC-1000 plate of 300-foot NARO Radio Telescope - Station 3.

SECTION 3.

Diagram of Target Point Distribution
on Dish Surface

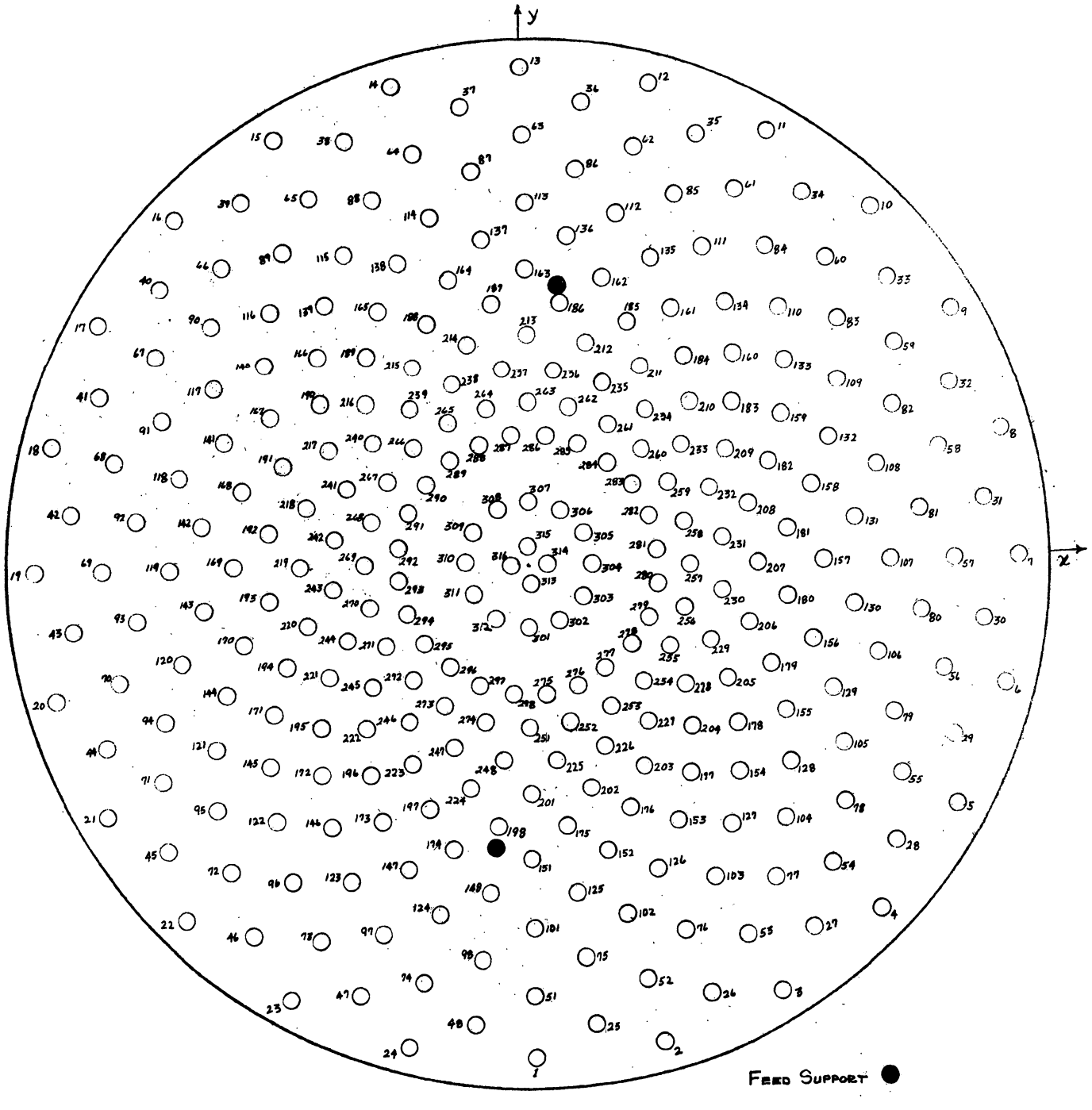

FIGURE 4. POSITION AND IDENTIFICATION OF TARGET POINTS

SECTION 4.

Vector Plot of Perpendicular Departures of Photogrammetrically Triangulated Target Points from Best Fitting Paraboloid of Revolution

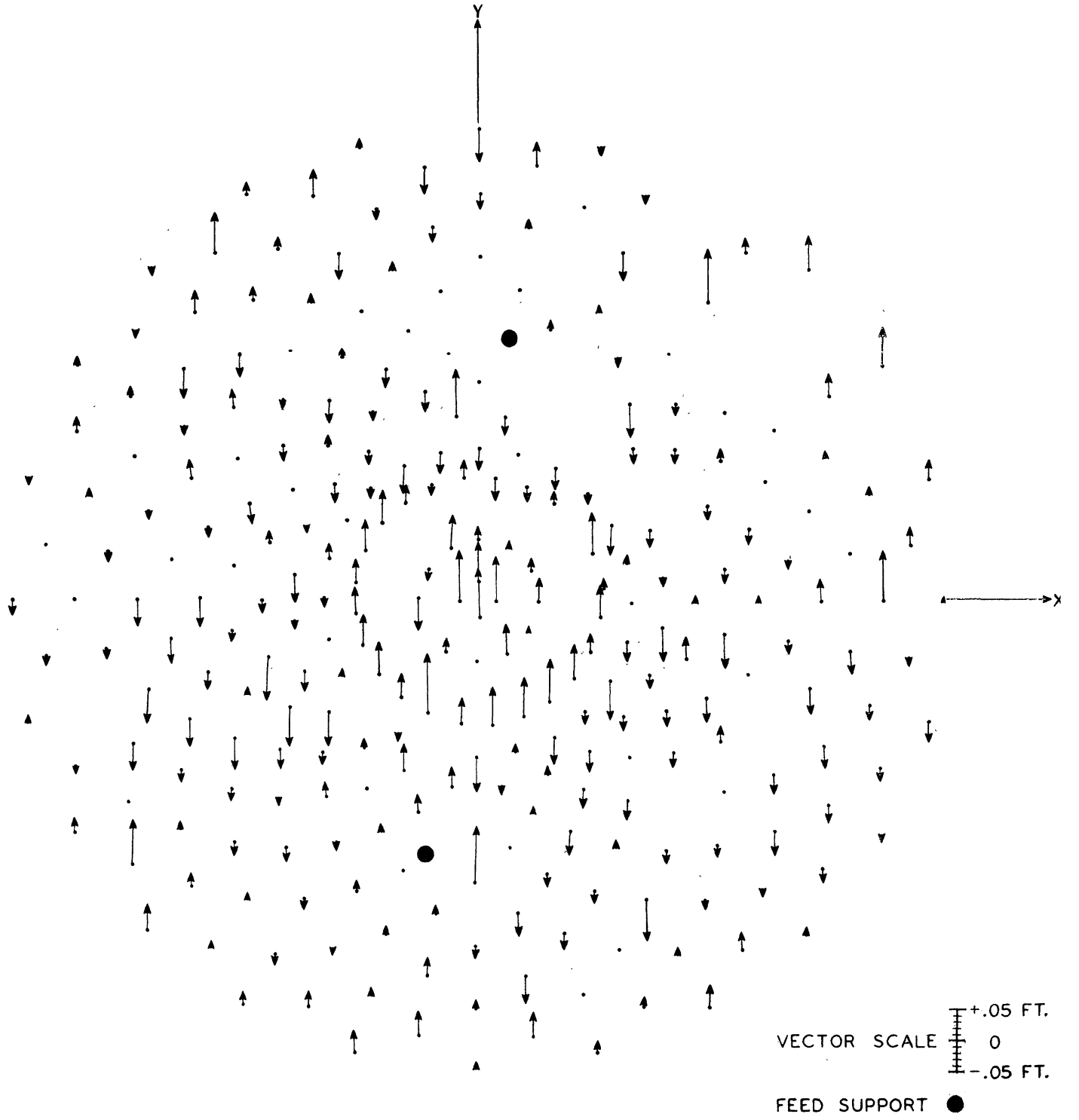

FIGURE 5. Plot of Perpendicular Departures of Photogrammetrically Triangulated Target Points from Best Fitting Paraboloid of Revolution. Positive Departures indicated by Upward Arrows, Negative Departures by Downward Arrows.

SECTION 5.

Contour Map of Error Surface of Dish

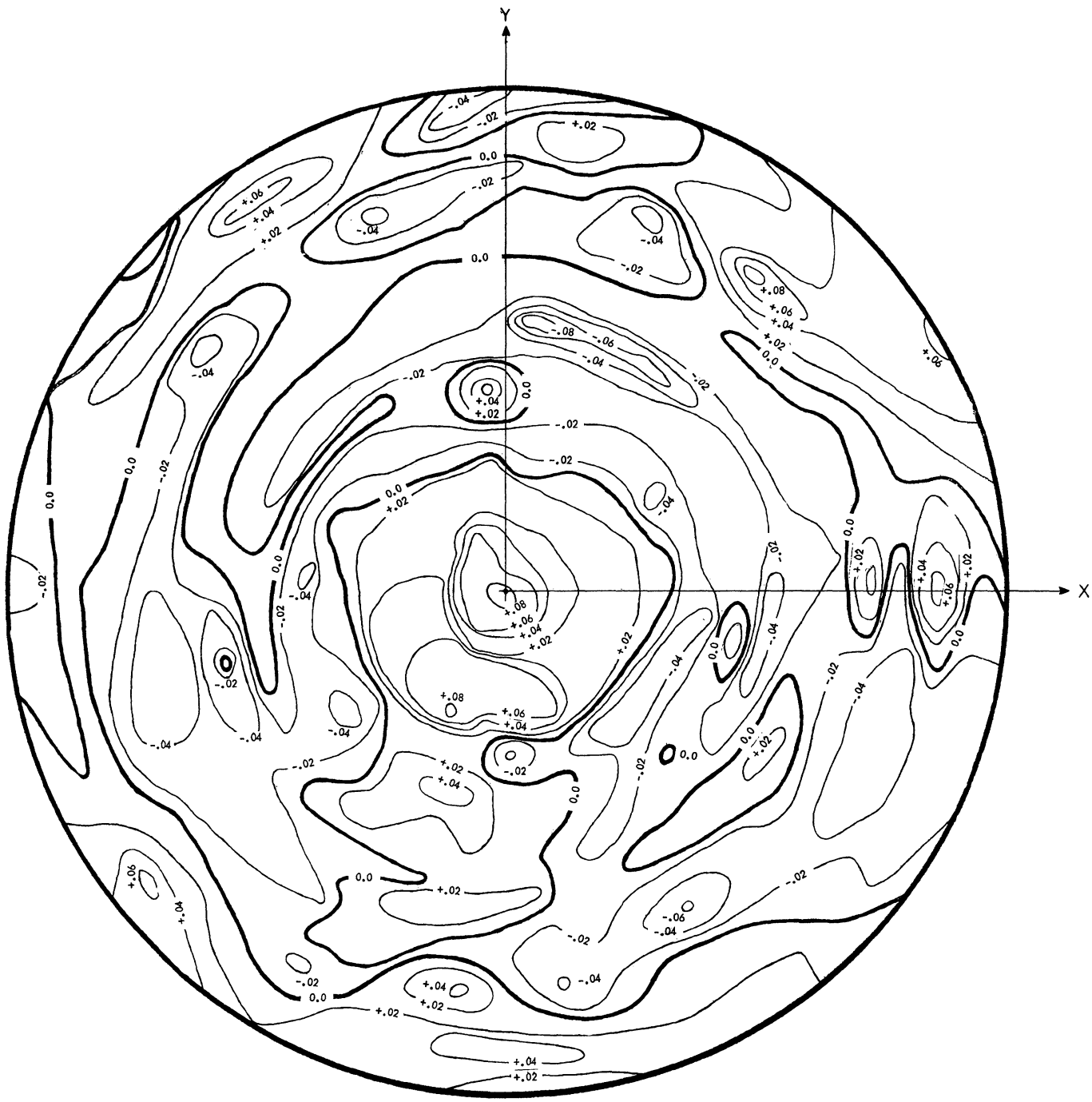

FIGURE 6. Contours of Error Surface of 300-Foot Antenna (0.02 ft. Contour Intervals)

SECTION 6.

XYZ Coordinates (and their associated standard deviations) of Photogrammetrically Triangulated Target Points (in antenna Coordinate System Associated with Best Fitting Paraboloid of Revolution).

TABLE 1. (CONT.)

POINT NO.	X (FEET)	Y (FEET)	Z (FEET)	X SIGMA (FEET)	Y SIGMA (FEET)	Z SIGMA (FEET)
52	33.7131	-124.8041	32.6497	.0138	.0135	.0172
53	64.8107	-111.8735	32.6660	.0138	.0135	.0172
54	91.3732	-91.4115	32.6220	.0138	.0135	.0172
55	111.7568	-64.5665	32.4984	.0139	.0136	.0171
56	124.4704	-33.4152	32.4128	.0139	.0136	.0171
57	128.6111	.0048	32.3897	.0140	.0136	.0171
58	124.2846	33.4565	32.3745	.0141	.0136	.0171
59	111.1723	64.3313	32.2631	.0142	.0137	.0171
62	32.9144	123.9233	32.1156	.0144	.0137	.0172
63	-.3628	128.1525	32.0529	.0145	.0137	.0172
64	-33.7617	123.5713	32.0647	.0145	.0137	.0173
65	-64.5958	110.8809	32.1936	.0145	.0137	.0173
66	-91.0207	90.4847	32.2115	.0144	.0137	.0173
67	-111.5376	63.8323	32.2808	.0144	.0137	.0173
68	-124.4159	32.6140	32.3280	.0143	.0137	.0173
69	-128.7549	-.7840	32.3814	.0142	.0137	.0173
70*	-124.2716	-34.2346	32.4371	.0157	.0174	.0228
71	-111.3106	-65.1952	32.5107	.0141	.0136	.0173
72	-90.8756	-91.8394	32.6295	.0140	.0136	.0173
73	-64.0284	-112.1549	32.5611	.0139	.0135	.0173
74	-32.9343	-124.9999	32.6608	.0139	.0135	.0173
75	15.9218	-118.2942	27.7785	.0138	.0135	.0173
76	45.8076	-110.1635	27.8062	.0138	.0135	.0173
77	72.5691	-94.6217	27.7662	.0138	.0136	.0172
78	94.5107	-72.6642	27.7180	.0139	.0136	.0172
79	109.9723	-45.5647	27.6366	.0139	.0136	.0172
80	117.8638	-15.5355	27.5654	.0140	.0136	.0172
81	117.6577	15.5576	27.5122	.0141	.0136	.0172
82	109.5052	45.5768	27.4890	.0142	.0137	.0172
83*	93.8109	72.3393	27.4603	.0179	.0180	.0227
84	71.9859	93.9529	27.4546	.0143	.0137	.0172
85	45.1700	109.3755	27.3026	.0144	.0137	.0172
86	15.3847	117.2045	27.3065	.0145	.0137	.0173
87	-15.6922	117.2326	27.3046	.0145	.0137	.0173
88	-45.7427	109.1779	27.3228	.0145	.0137	.0173
89	-72.1508	93.6679	27.3307	.0144	.0137	.0174
90	-94.2995	71.7771	27.3880	.0144	.0137	.0174
91	-109.6713	44.8049	27.4189	.0143	.0137	.0174
92	-117.8053	14.8813	27.5310	.0143	.0137	.0174
93	-117.7826	-16.3340	27.6008	.0142	.0137	.0174
94	-109.6618	-46.2113	27.6110	.0141	.0136	.0174
95	-94.0740	-73.1043	27.7435	.0141	.0136	.0174
96	-72.0828	-94.9862	27.7819	.0140	.0136	.0174
97	-45.0335	-110.4285	27.7751	.0139	.0136	.0174
98	-15.1068	-118.3467	27.8472	.0139	.0135	.0173
101	.3135	-109.2997	23.3134	.0139	.0136	.0174
102	28.6207	-105.7045	23.3989	.0139	.0136	.0173

* TWO STATION SOLUTION

TABLE 1. (CONT.)

POINT NO.	X (FEET)	Y (FEET)	Z (FEET)	X SIGMA (FEET)	Y SIGMA (FEET)	Z SIGMA (FEET)
103	54.8046	-94.6887	23.3121	.0139	.0136	.0173
104	77.1725	-77.2533	23.2606	.0139	.0136	.0173
105	94.3817	-54.7764	23.2302	.0139	.0136	.0173
106	105.1297	-28.2973	23.1108	.0140	.0136	.0172
107	108.7011	-.1175	23.1178	.0141	.0136	.0172
108	104.9879	28.2356	23.0913	.0142	.0137	.0172
109	93.9785	54.2586	23.0073	.0142	.0137	.0172
111*	54.1096	93.8098	22.8919	.0183	.0183	.0231
112*	27.9473	104.6368	22.8817	.0186	.0185	.0232
113	-.1766	108.2174	22.8690	.0145	.0138	.0173
114	-28.3418	104.4879	22.9093	.0145	.0138	.0174
115	-54.4447	93.6495	22.9401	.0145	.0138	.0174
116	-76.7913	76.5066	22.9152	.0144	.0137	.0174
117	-94.2481	53.7348	22.9737	.0144	.0137	.0174
118	-105.1760	27.6040	23.0844	.0143	.0137	.0174
119	-108.7028	-.5631	23.0370	.0143	.0137	.0174
120	-105.0688	-29.0104	23.1458	.0142	.0137	.0174
121	-94.1519	-55.1798	23.2389	.0141	.0136	.0174
122	-76.8113	-77.7081	23.2908	.0141	.0136	.0174
123	-54.1656	-94.7938	23.2611	.0140	.0136	.0174
124	-28.0521	-105.6418	23.3488	.0139	.0136	.0174
125	13.1679	-98.5466	19.2705	.0139	.0136	.0174
126	38.1445	-91.8077	19.2811	.0139	.0136	.0174
127	60.4771	-78.7961	19.2452	.0139	.0136	.0174
128	78.6665	-60.5543	19.2498	.0140	.0136	.0173
129*	91.4031	-38.2670	19.1708	.0173	.0178	.0229
130	98.0561	-13.1861	19.0914	.0141	.0137	.0173
131	97.8738	12.5924	19.0055	.0141	.0137	.0173
132	91.1082	37.6513	18.9884	.0142	.0137	.0173
133	78.1539	59.9452	18.9520	.0143	.0137	.0173
134	59.9547	78.0133	18.9168	.0143	.0137	.0173
135	37.5781	90.7687	18.8635	.0144	.0137	.0173
136	12.7857	97.2993	18.8117	.0144	.0138	.0174
137	-13.2231	97.4585	18.8904	.0145	.0138	.0174
138	-38.0526	90.6520	18.8905	.0145	.0138	.0174
139	-60.0616	77.9697	18.9314	.0144	.0138	.0174
140	-78.4146	59.6428	18.9900	.0144	.0137	.0175
141	-91.2229	37.1580	18.9833	.0144	.0137	.0175
142	-98.0720	12.4086	19.0894	.0143	.0137	.0175
143	-97.9465	-13.7840	19.0668	.0142	.0137	.0175
144	-91.2538	-38.6357	19.1379	.0142	.0137	.0175
145	-78.2028	-60.8783	19.1697	.0141	.0137	.0175
146	-59.9134	-79.1046	19.2131	.0141	.0136	.0175
147	-37.5964	-91.9184	19.2834	.0140	.0136	.0174
148	-12.6625	-98.5836	19.3116	.0140	.0136	.0174
151	.0892	-89.3814	15.7002	.0140	.0136	.0175
152	23.1382	-86.3913	15.6071	.0140	.0136	.0174

* TWO STATION SOLUTION

TABLE 1. (CONT.)

POINT NO.	X (FEET)	Y (FEET)	Z (FEET)	X SIGMA (FEET)	Y SIGMA (FEET)	Z SIGMA (FEET)
153	44.5344	-77.4821	15.6070	.0140	.0136	.0174
155	76.8949	-45.0109	15.5267	.0140	.0136	.0174
156	85.7089	-23.4089	15.4186	.0141	.0137	.0173
157	88.7427	-.3855	15.3946	.0141	.0137	.0173
158	85.6876	22.6761	15.3264	.0142	.0137	.0173
159	76.7911	44.0477	15.3216	.0143	.0137	.0173
160	62.6031	62.3713	15.2407	.0143	.0137	.0174
161	44.2007	76.5067	15.2450	.0144	.0138	.0174
162	22.7672	85.3410	15.2438	.0144	.0138	.0174
163*	-.1090	88.2593	15.2122	.0211	.0160	.0222
164	-23.1102	85.1779	15.2152	.0144	.0138	.0174
165	-44.5729	76.2675	15.2567	.0144	.0138	.0175
166	-62.7786	62.2097	15.2441	.0144	.0138	.0175
167	-77.0244	43.7351	15.3271	.0144	.0138	.0175
168	-85.8421	22.4069	15.3578	.0143	.0137	.0175
169	-88.8510	-.6417	15.3765	.0143	.0137	.0175
170	-85.8303	-23.8286	15.4764	.0142	.0137	.0175
171	-76.9081	-45.0462	15.4671	.0142	.0137	.0175
172	-62.7495	-63.3971	15.5345	.0141	.0137	.0175
173	-44.3125	-77.4954	15.5559	.0141	.0136	.0175
174	-22.8398	-86.4446	15.6189	.0140	.0136	.0175
175	10.2949	-78.1159	12.1242	.0140	.0136	.0175
176	30.0328	-72.7760	12.0694	.0140	.0136	.0175
177	47.6520	-62.6568	12.0707	.0140	.0136	.0174
178	62.0450	-48.1579	12.0267	.0140	.0137	.0174
179	72.3546	-30.4520	12.0007	.0141	.0137	.0174
180	77.6098	-10.6879	11.9369	.0141	.0137	.0174
181	77.5236	9.7163	11.9086	.0142	.0137	.0174
182	72.0773	29.4030	11.8214	.0142	.0137	.0174
183	62.0288	47.2026	11.8534	.0143	.0137	.0174
184	47.5249	61.5533	11.7546	.0143	.0138	.0174
186*	10.1528	76.9617	11.6555	.0187	.0185	.0235
187	-10.3217	77.0385	11.7827	.0144	.0138	.0175
188	-30.0850	71.6822	11.7768	.0144	.0138	.0175
189	-47.4697	61.5719	11.7772	.0144	.0138	.0175
190	-62.0847	47.0538	11.8344	.0144	.0138	.0175
191	-72.2226	29.3515	11.8380	.0144	.0138	.0175
192	-77.4848	9.7084	11.9118	.0143	.0137	.0175
193	-77.5311	-10.8508	11.9643	.0143	.0137	.0175
194	-72.1911	-30.6394	12.0189	.0142	.0137	.0175
195	-62.0044	-48.2675	12.0289	.0142	.0137	.0175
196	-47.5822	-62.5812	12.0924	.0141	.0137	.0175
197	-29.8296	-72.8212	12.1043	.0141	.0137	.0175
201*	-.0662	-69.3849	9.4129	.0212	.0167	.0226
202	17.6027	-67.1180	9.4113	.0141	.0137	.0175
203	34.3193	-60.2252	9.3582	.0141	.0137	.0175
204	48.5379	-49.2976	9.3485	.0141	.0137	.0175

* TWO STATION SOLUTION

TABLE 1. (CONT.)

POINT NO.	X (FEET)	Y (FEET)	Z (FEET)	X SIGMA (FEET)	Y SIGMA (FEET)	Z SIGMA (FEET)
205	59.5305	-35.1246	9.3060	.0141	.0137	.0175
206	66.3067	-18.5243	9.2927	.0141	.0137	.0174
207	68.7291	-.7500	9.2365	.0142	.0137	.0174
210	48.6675	47.9536	9.1015	.0143	.0138	.0174
211*	34.4276	58.8648	9.0607	.0184	.0184	.0234
212*	17.8064	65.7888	9.0642	.0185	.0185	.0235
213	.1568	68.2176	9.0822	.0144	.0138	.0175
214	-17.6470	65.8248	9.0426	.0144	.0138	.0175
215	-34.4147	59.0361	9.1144	.0144	.0138	.0175
216	-48.5494	48.1702	9.1541	.0144	.0138	.0175
217	-59.5246	33.9204	9.1668	.0144	.0138	.0176
218	-66.4619	17.3179	9.2241	.0143	.0138	.0176
219	-68.6704	-.3848	9.1972	.0143	.0137	.0176
220	-66.3904	-18.2041	9.2253	.0142	.0137	.0176
221	-59.6403	-34.8624	9.2887	.0142	.0137	.0176
222	-48.7025	-49.1246	9.3266	.0142	.0137	.0176
223	-34.5415	-60.0005	9.3682	.0141	.0137	.0176
224	-17.8501	-67.0025	9.4201	.0141	.0137	.0175
225	7.4171	-58.5762	6.8012	.0141	.0137	.0175
226	22.2091	-54.6033	6.7923	.0141	.0137	.0175
227	35.3967	-47.0199	6.7326	.0141	.0137	.0175
228	46.2527	-36.2777	6.7304	.0141	.0137	.0175
229	53.9293	-22.9868	6.6994	.0141	.0137	.0175
230	58.0853	-8.3481	6.6743	.0142	.0137	.0175
231	57.9572	6.7941	6.6429	.0142	.0137	.0175
232	54.0083	21.6421	6.5954	.0143	.0137	.0175
233*	46.3811	34.8931	6.5430	.0181	.0182	.0234
236	7.9845	57.2158	6.5043	.0144	.0138	.0175
237	-7.3855	57.2813	6.5912	.0144	.0138	.0175
238	-22.2214	53.4349	6.5339	.0144	.0138	.0175
239	-35.4236	45.9314	6.5548	.0144	.0138	.0176
240	-46.2218	35.1525	6.5599	.0144	.0138	.0176
241	-53.8966	21.9798	6.6117	.0143	.0138	.0176
242	-57.9961	7.3207	6.6308	.0143	.0138	.0176
243	-57.9800	-8.0459	6.6811	.0143	.0137	.0176
244	-54.0454	-22.8975	6.7016	.0142	.0137	.0176
245	-46.4699	-36.0312	6.7019	.0142	.0137	.0176
246	-35.6000	-46.8477	6.7715	.0142	.0137	.0176
247	-22.4139	-54.4920	6.8232	.0141	.0137	.0176
248	-7.8128	-58.4313	6.8218	.0141	.0137	.0176
251	-.2717	-49.3804	4.7042	.0141	.0137	.0176
252	12.3315	-47.7998	4.7704	.0141	.0137	.0176
253	24.2842	-42.9809	4.7197	.0141	.0137	.0175
254	34.2505	-35.2557	4.6945	.0141	.0137	.0175
255	42.0292	-25.2455	4.6346	.0142	.0137	.0175
256	47.0399	-13.5223	4.6495	.0142	.0137	.0175

* TWO STATION SOLUTION

TABLE 1. (CONT.)

POINT NO.	X (FEET)	Y (FEET)	Z (FEET)	X SIGMA (FEET)	Y SIGMA (FEET)	Z SIGMA (FEET)
257	48.8444	-.8899	4.6644	.0142	.0137	.0175
258	47.2074	11.6512	4.6247	.0142	.0137	.0175
259	42.3291	23.5986	4.5473	.0143	.0138	.0175
260	34.7281	33.5992	4.5410	.0143	.0138	.0175
261	24.7350	41.5364	4.5445	.0143	.0138	.0175
262	12.8630	46.4698	4.5394	.0144	.0138	.0175
263	.4545	48.1596	4.5023	.0144	.0138	.0175
264	-12.1779	46.6630	4.5198	.0144	.0138	.0176
265	-24.1559	41.8455	4.5177	.0144	.0138	.0176
266	-34.1406	34.2155	4.5470	.0144	.0138	.0176
267	-41.9814	24.2036	4.5835	.0143	.0138	.0176
268	-47.0889	12.4455	4.6484	.0143	.0138	.0176
269	-48.7592	-.0834	4.6386	.0143	.0138	.0176
270	-47.1925	-12.8576	4.6755	.0143	.0137	.0176
271	-42.4856	-24.6159	4.7187	.0142	.0137	.0176
272*	-34.7865	-34.7840	4.7067	.0160	.0179	.0236
273	-24.6624	-42.6972	4.7443	.0142	.0137	.0176
274*	-12.9641	-47.6428	4.7692	.0212	.0167	.0226
275	4.9251	-38.7936	3.0477	.0142	.0137	.0176
276	14.4040	-36.2015	3.0306	.0142	.0137	.0176
277	23.2004	-31.4730	3.0451	.0142	.0137	.0176
278	30.3199	-24.2192	2.9873	.0142	.0137	.0176
279	35.5356	-15.7340	2.9798	.0142	.0137	.0175
280	38.3068	-5.8902	2.9817	.0142	.0137	.0175
281	38.2855	4.0083	2.9041	.0142	.0137	.0175
282	35.7832	13.7864	2.9407	.0143	.0138	.0175
284	23.7433	29.7197	2.8504	.0143	.0138	.0175
285	15.0880	34.9570	2.8158	.0143	.0138	.0176
286	5.3851	37.6867	2.7949	.0144	.0138	.0176
287	-4.5614	37.7426	2.8447	.0144	.0138	.0176
288	-14.3183	35.1552	2.8042	.0144	.0138	.0176
289	-23.1341	30.3422	2.8733	.0144	.0138	.0176
290	-30.3397	23.2329	2.8982	.0143	.0138	.0176
291	-35.5174	14.5894	2.9280	.0143	.0138	.0176
292	-38.2950	4.7691	2.9399	.0143	.0138	.0176
293	-38.3280	-5.2169	2.9619	.0143	.0138	.0176
294	-35.7720	-15.0951	2.9834	.0143	.0137	.0176
295	-30.8655	-23.7330	3.0182	.0142	.0137	.0176
296	-23.6663	-30.9993	3.0151	.0142	.0137	.0176
297	-15.0242	-36.1029	3.0795	.0142	.0137	.0176
298	-5.3648	-38.7240	3.0212	.0142	.0137	.0176
301	-.8448	-19.2376	.7278	.0142	.0137	.0176
302	8.6812	-17.2004	.7754	.0142	.0137	.0176
303	15.9255	-10.6377	.7218	.0142	.0137	.0176
304	18.8678	-1.4018	.7481	.0143	.0138	.0176
305	16.7859	8.0844	.6922	.0143	.0138	.0176
306	10.0874	15.2931	.6445	.0143	.0138	.0176

* TWO STATION SOLUTION

TABLE 1. (CONT.)

POINT NO.	X (FEET)	Y (FEET)	Z (FEET)	X SIGMA (FEET)	Y SIGMA (FEET)	Z SIGMA (FEET)
307	.7795	18.3074	.6406	.0143	.0138	.0176
308	-8.7611	16.0870	.7134	.0143	.0138	.0176
309	-15.9090	9.3756	.6535	.0143	.0138	.0176
310	-18.8170	.0516	.6374	.0143	.0138	.0176
311*	-16.6102	-9.3060	.7224	.0212	.0165	.0226
312	-10.0406	-16.4465	.7429	.0142	.0137	.0176
313	.5407	-4.5124	.1170	.0143	.0138	.0176
314	4.0011	.1121	.1041	.0143	.0138	.0176
315	-.5333	3.4203	.0831	.0143	.0138	.0176
316	-3.9053	-1.2910	.1055	.0143	.0138	.0176
400	-.0990	.0547	149.0550	.0138	.0133	.0159

* TWO STATION SOLUTION

SECTION 7.

Tabulation of Plate Coordinate
Residual Vectors from Each Camera

TABLE 2. PLATE COORDINATE RESIDUALS FROM TRIANGULATED TARGET POINTS

POINT NO.	CAMERA NO. 1		CAMERA NO. 2		CAMERA NO. 3	
	VX	VY	VX	VY	VX	VY
	(MICRONS)		(MICRONS)		(MICRONS)	
1	11.2	-7.7	10.2	-9.4	-2.1	1.3
2	-7.1	-25.6	15.9	-1.8	-11.4	21.2
3	13.7	-6.9	11.2	-8.7	-3.0	-.1
4	8.0	13.3	-.8	5.6	-1.5	-13.4
5	-5.3	-7.8	-3.2	-7.9	6.2	8.7
6	-1.4	1.1	-.0	3.1	-1.6	-.6
7	8.4	-.9	-4.1	-17.0	12.4	-.7
8	14.2	10.3	-2.6	-9.1	7.3	-12.7
9	10.2	13.0	-6.7	-7.0	9.7	-13.5
10	8.5	12.4	5.3	11.1	-9.9	-15.4
11	32.1	11.4	6.8	-16.1	3.3	-20.9
12	8.7	-2.8	1.0	-12.3	5.3	.5
13	12.1	-1.3	7.7	-6.3	-3.1	-3.3
14	3.6	-11.3	2.6	-15.1	4.7	10.6
15	7.3	2.3	-6.2	-13.9	12.0	-2.7
16	-8.1	3.3	-12.7	-1.0	10.3	1.5
17	-.9	4.7	-6.6	-.6	5.6	-3.3
18	-3.7	2.9	-9.3	-2.8	8.2	.0
19	-4.7	10.6	-14.1	3.2	9.2	-6.5
20	7.5	15.4	-13.3	-4.2	12.8	-15.0
21	17.7	9.0	2.5	-5.5	2.5	-14.7
22	17.3	3.3	2.9	-12.5	5.2	-9.1
23	13.3	-8.8	9.7	-15.6	1.1	2.1
24	19.1	-15.0	15.1	-23.2	1.3	4.8
25	13.9	-5.3	19.0	3.5	-14.3	-2.9
26	4.6	-3.0	2.0	-6.5	2.0	.8
27	-3.3	-15.7	6.8	-5.7	-2.6	13.2
28	2.1	-6.2	8.9	2.9	-8.1	3.2
29	-2.9	.8	-3.8	-1.0	3.3	.7
30	3.8	-3.4	-.3	-9.1	5.1	2.0
31	-6.0	15.3	-8.1	13.0	-.2	-10.7
34	15.1	.9	4.5	-10.7	2.0	-5.7
35	10.9	3.7	-.5	-9.4	5.6	-6.3
36	13.7	-5.7	2.5	-20.1	7.9	2.0
37	-2.6	-5.8	-8.5	-14.7	13.9	8.9
38	2.2	-.7	-4.7	-9.8	8.6	1.4
39	-6.9	-1.9	-5.1	-.3	3.8	5.1
40	-14.3	3.0	-16.0	2.0	10.9	4.3
41	-7.6	-3.0	-10.1	-7.2	10.3	7.5
42	-3.0	8.0	-9.3	3.4	5.5	-5.4
43	4.8	3.8	-1.1	-2.0	2.3	-5.0
44	11.4	8.6	-3.1	-5.9	6.2	-11.3
45	22.0	13.4	2.2	-5.0	3.1	-20.0
45	-2.0	7.2	-9.2	.0	6.9	-4.5
46	10.7	-3.0	5.5	-9.9	1.3	-1.5
47	15.3	-3.5	13.6	-4.9	-6.1	-3.9
48	-1.2	-10.8	7.7	-2.3	-4.7	8.5
51	1.6	-6.1	1.1	-8.7	3.2	4.7

TABLE 2. (CONT.)

POINT NO.	CAMERA NO. 1 VX (MICRONS)	CAMERA NO. 1 VY (MICRONS)	CAMERA NO. 2 VX (MICRONS)	CAMERA NO. 2 VY (MICRONS)	CAMERA NO. 3 VX (MICRONS)	CAMERA NO. 3 VY (MICRONS)
52	-3.3	-12.4	5.4	-4.4	-2.3	10.8
53	1.7	-11.3	11.0	-.5	-7.9	7.3
54	2.8	-5.2	3.2	-5.1	.1	3.1
55	3.2	-4.8	4.0	-3.8	-1.0	2.5
56	-4.2	6.2	-13.8	-7.9	14.8	-1.8
57	-5.1	7.6	-9.5	1.1	6.9	-3.7
58	-2.0	5.0	-7.5	-2.4	7.3	-2.6
59	-4.3	5.5	-10.7	-3.6	10.7	-1.8
62	10.8	-2.0	2.8	-11.7	3.7	-1.1
63	2.8	-3.1	1.8	-4.9	.9	2.2
64	6.6	-1.1	.7	-8.5	3.7	-.6
65	-1.4	2.8	-4.0	.1	3.2	-1.6
66	-4.6	1.3	-.2	7.2	-3.3	-.1
67	-3.9	.9	.0	6.3	-3.1	.0
68	2.7	8.4	-7.7	-1.5	7.1	-7.8
69	8.7	11.5	-1.9	2.9	1.2	-13.9
70*	10.4	9.1			1.2	-12.3
71	5.7	4.6	.7	.4	-.0	-6.3
72	15.8	8.3	5.6	-.1	-2.2	-13.8
73	14.1	4.7	-.8	-12.0	7.5	-8.4
74	9.1	-1.9	7.7	-2.8	-3.4	-2.4
75	-2.1	-8.6	2.2	-5.5	.6	7.8
76	.8	-12.4	6.6	-7.5	-1.4	9.3
77	-2.2	-2.5	4.0	5.4	-5.9	2.0
78	-11.5	-5.7	-3.0	2.2	.5	8.8
79	-7.0	-3.6	-4.7	-2.9	4.7	6.0
80	-9.1	2.6	-8.9	.9	6.2	1.8
81	10.0	4.8	-4.3	-12.6	10.4	-6.2
82	6.8	3.9	1.5	-1.4	-.2	-5.7
83*			-8.6	-11.9	13.1	1.7
84	12.9	13.1	3.2	4.2	-4.1	-16.9
85	19.2	5.9	4.2	-10.5	2.4	-11.8
86	7.0	1.1	.2	-6.9	3.5	-2.9
87	-9.8	.9	-9.0	1.3	6.4	3.7
88	-12.9	-2.0	-8.4	2.5	5.1	7.4
89	-10.4	-2.9	-6.5	.8	4.2	7.3
90	-1.9	6.2	-9.9	-1.8	8.8	-3.8
91	-4.2	-1.5	-8.3	-7.3	9.5	4.6
92	-7.2	2.0	-8.9	.2	6.2	1.9
93	-3.4	.1	-5.2	-2.4	4.7	2.0
94	.8	14.8	-10.2	6.3	5.3	-12.8
95	6.5	3.1	.3	-3.2	1.9	-5.0
96	5.5	.0	1.9	-4.0	.9	-2.1
97	5.5	-11.2	9.0	-9.7	-1.8	6.8
98	3.2	-5.8	4.2	-6.0	-.1	3.4
101	-4.3	-11.1	3.6	-4.5	-1.0	10.6

* TWO STATION SOLUTION

TABLE 2. (CONT.)

POINT NO.	CAMERA NO. 1 VX (MICRONS)	CAMERA NO. 1 VY (MICRONS)	CAMERA NO. 2 VX (MICRONS)	CAMERA NO. 2 VY (MICRONS)	CAMERA NO. 3 VX (MICRONS)	CAMERA NO. 3 VY (MICRONS)
102	3.6	-5.5	5.7	-3.4	-2.3	2.8
103	-3.4	-7.8	-.6	-6.8	3.4	7.9
104	.9	-2.8	3.5	.5	-2.9	1.6
105	2.5	-2.2	5.4	2.1	-5.1	.3
106	-2.5	-2.1	2.1	3.5	-3.5	2.2
107	-9.4	12.0	-4.1	19.5	-6.8	-7.5
108	-4.1	14.9	-12.6	4.4	8.0	-10.2
109	1.5	-2.7	-.5	-5.7	3.2	2.2
111*			-1.3	-1.8	2.0	.2
112*			-3.4	-4.6	5.1	.7
113	.5	-2.0	.8	-2.0	.2	1.7
114	-4.7	-1.4	2.0	6.7	-5.2	2.2
115	-2.7	1.4	-4.2	-.3	3.5	.2
116	-3.4	1.9	-2.0	4.3	-.6	-.7
117	-2.3	-.2	-.7	1.6	-.2	1.0
118	.4	3.1	-3.1	-.3	2.7	-2.6
119	-15.4	.9	-11.8	5.2	5.4	5.9
120	8.8	8.0	-.1	.1	1.0	-10.6
121	-6.1	7.9	-14.7	-.8	10.9	-2.9
122	2.1	-3.9	3.8	-3.0	-1.3	2.3
123	2.5	6.0	-1.2	3.5	-.3	-6.2
124	2.8	-5.0	5.6	-2.5	-2.7	2.7
125	-1.1	-4.4	7.5	6.3	-8.7	2.9
126	-10.1	-5.4	-1.6	2.7	-.8	8.1
127	-2.5	3.2	-.2	7.1	-3.4	-2.1
128	-4.7	5.7	-.8	11.7	-5.3	-3.6
129*			3.8	5.5	-5.7	-.6
130	.1	3.8	-.4	3.8	-1.4	-3.4
131	-10.1	1.6	-9.8	.0	7.5	3.0
132	1.7	2.8	2.2	4.4	-4.0	-3.6
133	9.6	6.8	-3.3	-8.1	7.3	-8.4
134	10.9	-1.5	4.3	-8.9	1.2	-2.2
135	23.3	13.0	4.3	-6.7	.9	-19.9
136	4.2	-.9	8.4	4.9	-9.2	-2.0
137	5.5	2.7	1.9	-.8	-.7	-4.6
138	-6.4	-3.5	-3.2	-.8	2.6	6.1
139	-5.5	-2.7	-.9	2.0	-.6	4.6
140	-1.4	-1.9	3.9	4.1	-5.1	1.6
141	-10.1	4.8	-10.3	5.7	4.9	.0
142	-3.6	4.0	-8.5	-1.1	6.9	-1.2
143	-2.7	4.6	-4.3	4.1	1.3	-3.0
144	-5.9	3.1	-5.3	4.8	1.4	-.4
146	-1.3	1.8	3.9	9.7	-7.4	-2.1
147	5.7	-2.0	12.6	7.8	-12.6	-2.2
148	-.4	2.9	-6.6	-4.9	7.3	-1.2
151	-6.7	-2.4	-.9	3.5	-1.6	4.4

* TWO STATION SOLUTION

TABLE 2. (CONT.)

POINT NO.	CAMERA NO. 1 VX (MICRONS)	CAMERA NO. 1 VY (MICRONS)	CAMERA NO. 2 VX (MICRONS)	CAMERA NO. 2 VY (MICRONS)	CAMERA NO. 3 VX (MICRONS)	CAMERA NO. 3 VY (MICRONS)
152	5.4	4.2	5.8	7.2	-7.3	-6.4
153	-14.5	-8.8	4.7	13.0	-11.1	11.2
155	-4.6	6.5	.5	14.6	-7.9	-4.6
156	1.5	10.1	-3.3	5.6	.1	-9.0
157	-9.7	6.9	-4.8	13.0	-2.9	-2.6
158	-5.3	-3.8	-11.7	-14.9	16.8	7.3
159	-18.8	3.5	-11.6	10.5	3.4	3.9
160	-6.9	-.0	-3.2	3.7	.5	2.5
161	.3	3.0	1.0	4.6	-3.0	-3.3
162	-2.9	-8.0	4.0	-.7	-3.2	7.9
163*	8.4	-3.2	4.8	-7.7		
164	7.7	-3.9	3.0	-10.4	2.7	1.3
165	-1.8	1.7	1.3	6.2	-4.0	-1.5
166	.9	2.7	-.1	2.4	-.8	-3.1
167	-5.6	-3.6	1.0	3.5	-2.9	5.1
168	-3.7	-.7	.9	4.6	-3.0	1.6
169	2.1	4.5	1.4	5.2	-3.1	-5.4
170	-3.6	1.9	-4.8	.8	3.0	.1
171	3.5	8.4	-2.1	4.3	.1	-8.8
172	.9	3.7	-.2	3.6	-1.3	-3.8
173	8.8	1.5	6.1	-.2	-3.6	-5.2
174	-1.2	2.5	-3.2	.5	2.1	-1.3
175	-8.1	-8.6	6.1	7.3	-8.9	9.0
176	.1	-2.6	6.2	5.4	-7.4	1.1
177	-9.6	-1.4	7.9	21.4	-17.1	2.6
178	-.1	2.6	-2.0	.4	1.4	-1.9
179	5.3	2.4	3.3	1.4	-3.0	-4.3
180	-1.5	2.5	5.8	13.4	-11.4	-2.9
181	-4.2	5.4	-.8	10.4	-4.6	-3.7
182	6.7	.2	13.8	11.5	-16.6	-4.8
183	-5.6	-2.3	-2.8	.0	2.0	4.3
184	-1.2	4.8	1.3	9.2	-5.6	-4.7
186*			-1.2	-1.6	1.8	.2
187	-8.0	-5.3	-.9	1.8	-.6	7.7
188	-11.1	-5.8	1.5	8.2	-5.8	8.6
189	-7.8	2.5	-7.1	3.5	3.6	1.0
190	-2.0	1.2	1.1	5.7	-3.6	-1.0
191	-8.9	-.0	-3.3	6.6	-1.1	3.2
192	-7.1	4.9	-.5	14.9	-6.8	-2.9
193	-4.9	-1.9	2.2	6.4	-5.1	2.8
194	9.2	-1.3	11.6	2.2	-9.2	-3.6
195	3.8	-2.3	7.8	2.5	-6.8	-.3
196	-4.1	-3.4	11.5	16.2	-16.6	2.1
197	-1.9	-2.7	3.5	3.5	-4.5	2.4
201*	4.6	-2.1	2.9	-4.1		
202	-11.0	-2.5	-2.0	7.1	-2.6	5.9

* TWO STATION SOLUTION

TABLE 2. (CONT.)

POINT NO.	CAMERA NO. 1 VX (MICRONS)	CAMERA NO. 1 VY (MICRONS)	CAMERA NO. 2 VX (MICRONS)	CAMERA NO. 2 VY (MICRONS)	CAMERA NO. 3 VX (MICRONS)	CAMERA NO. 3 VY (MICRONS)
203	-17.3	-11.5	.8	7.4	-5.6	15.2
204	-2.7	7.2	-4.4	6.1	.4	-4.9
205	-9.6	-5.3	-3.3	.1	1.9	8.2
206	1.2	1.2	1.8	2.6	-2.6	-1.8
207	-9.0	2.1	-2.2	10.4	-3.8	.8
210	-3.6	-2.8	-1.7	-1.4	1.8	4.1
211*			4.4	6.0	-6.5	-.9
212*			5.0	6.8	-7.4	-1.0
213	3.8	-.9	7.0	3.6	-7.3	-1.6
214	-12.6	-6.5	7.5	17.1	-15.1	8.3
215	-4.7	.5	-.3	5.9	-2.7	.8
216	-3.0	4.7	.8	10.9	-5.8	-4.1
217	-1.0	-1.3	1.8	1.8	-2.4	1.3
218	1.7	2.2	5.5	8.2	-7.9	-3.9
219	-1.8	.1	.7	3.5	-2.3	.2
220	-4.9	-3.3	-3.8	-3.5	4.0	5.5
221	-15.3	2.6	-10.4	8.4	2.8	3.9
222	-7.4	2.6	2.7	16.5	-10.2	-.9
223	-.6	4.1	-5.3	-1.0	4.5	-2.6
224	-9.7	-9.4	2.2	2.4	-3.8	11.2
225	5.4	.8	2.0	-2.6	.1	-2.7
226	-3.5	2.5	1.2	9.3	-5.6	-1.5
227	-14.7	-7.6	-2.2	4.7	-1.6	11.7
228	-.7	-.8	4.6	6.5	-6.9	.1
229	8.9	-3.6	3.8	-9.7	2.1	.0
230	-5.1	-3.5	-1.4	-.2	.9	5.0
231	-16.3	2.7	-3.5	18.1	-6.9	2.6
232	-15.9	-.8	-7.2	7.9	1.1	6.6
233*			3.4	4.8	-5.1	-.7
234	1.2	9.5	-1.4	8.1	-2.4	-9.2
235	7.8	.8	14.2	11.1	-16.6	-5.9
236	-7.2	-11.5	3.1	-1.3	-2.6	12.8
237	1.9	-2.2	4.9	1.3	-4.6	.7
238	-3.0	8.8	-9.5	2.3	6.6	-6.1
239	3.5	2.4	4.0	3.9	-4.7	-4.2
240	-6.4	-3.9	-2.5	-.6	1.7	6.3
241	-3.5	.3	-.2	4.5	-2.1	.6
242	-2.4	6.2	.5	12.1	-5.9	-5.6
243	-5.7	-5.7	5.7	7.0	-8.2	6.1
244	-3.5	1.8	-2.0	4.0	-.5	-.3
245	-7.9	-.6	-1.8	6.3	-2.2	3.3
246	-2.2	3.8	3.0	12.1	-8.0	-3.6
247	-7.4	-.2	1.2	10.4	-6.4	2.2
248	-.5	3.0	11.6	21.0	-18.7	-4.7
251	-3.7	-6.3	-1.3	-5.7	3.3	7.2
252	-.7	-1.8	-2.8	-5.6	4.8	2.5

* TWO STATION SOLUTION

TABLE 2. (CONT.)

POINT NO.	CAMERA NO. 1 VX (MICRONS)	CAMERA NO. 1 VY (MICRONS)	CAMERA NO. 2 VX (MICRONS)	CAMERA NO. 2 VY (MICRONS)	CAMERA NO. 3 VX (MICRONS)	CAMERA NO. 3 VY (MICRONS)
253	-9.4	-1.7	.4	9.9	-5.8	4.2
254	-6.8	-.9	-1.9	4.3	-1.0	3.1
255	-9.4	-2.3	-.5	7.5	-3.8	4.9
256	-2.7	-5.9	6.0	4.4	-7.2	5.1
257	-7.3	-2.1	-2.8	2.2	.7	4.5
258	-4.2	2.7	2.3	11.8	-7.8	-1.8
259	1.9	-9.3	10.4	.5	-8.7	6.3
260	-5.3	-2.6	2.9	7.2	-6.2	3.4
261	3.3	-6.0	6.2	-3.0	-3.5	3.7
262	-3.8	5.3	3.9	16.8	-11.4	-5.1
263	-6.8	-.0	-4.1	2.6	1.7	2.8
264	-6.6	2.4	-4.3	5.4	.6	.1
265	-7.8	-1.9	-2.1	4.2	-.7	4.5
266	-3.1	-3.3	3.3	4.0	-4.8	3.5
267	.8	-1.1	9.8	10.6	-12.7	-1.1
268	-1.6	.2	1.8	4.9	-3.9	-.1
269	.1	-.8	.4	-.7	-.0	.7
270	-5.1	-1.8	2.8	7.6	-6.1	2.7
271	-6.2	.1	-1.7	5.5	-1.7	1.9
272*	-5.6	-5.1			-.5	6.5
273	-1.8	-4.5	-3.8	-9.0	6.8	5.6
274*	.9	-.4	.5	-.8		
275	-13.0	-6.9	-2.5	3.1	-.5	10.7
276	6.0	5.0	9.9	13.1	-13.5	-8.3
277	-1.4	1.2	3.9	9.1	-7.6	-1.6
278	.3	-4.9	2.2	-3.5	-.2	4.1
279	-5.0	-.9	-2.2	1.7	.6	2.7
280	4.3	-7.6	4.7	-8.1	.3	5.0
281	-3.7	8.2	-6.5	5.6	2.4	-5.4
282	-4.9	6.1	8.3	25.2	-19.1	-6.1
284	-12.6	2.5	2.7	22.1	-13.4	.4
285	-1.3	3.0	.7	6.4	-3.7	-2.7
286	-10.1	-2.8	4.1	14.2	-10.7	4.7
287	-6.7	-3.8	-1.4	1.3	.0	5.9
288	-11.7	-7.8	-4.0	-1.1	2.9	11.8
289	-1.8	-4.4	.9	-2.2	.1	4.7
290	-4.0	-.5	-2.6	.6	1.4	2.1
291	-4.4	-1.5	-.8	2.4	-.8	2.8
292	-5.4	5.1	-.8	12.3	-5.3	-3.4
293	-.6	-4.3	5.4	2.4	-5.6	3.3
294	-5.5	-.4	-.3	5.7	-2.8	2.0
295	-6.1	.0	-2.5	4.2	-.4	2.2
296	-.8	1.8	3.1	7.9	-6.2	-2.1
297	-5.2	-2.9	-1.2	.7	.1	4.6
298	-17.2	-10.2	-5.9	-.8	3.4	15.7
301	-8.1	6.5	-11.6	2.2	7.6	-1.6

* TWO STATION SOLUTION

TABLE 2. (CONT.)

POINT NO.	CAMERA NO. 1 VX (MICRONS)	CAMERA NO. 1 VY (MICRONS)	CAMERA NO. 2 VX (MICRONS)	CAMERA NO. 2 VY (MICRONS)	CAMERA NO. 3 VX (MICRONS)	CAMERA NO. 3 VY (MICRONS)
302	-3.3	-9.9	7.3	1.4	-6.9	9.0
303	2.8	-7.2	13.8	6.5	-13.9	3.4
304	1.7	-.8	1.1	-1.6	-.0	.1
305	-11.4	-.7	1.5	14.9	-9.0	3.6
306	1.8	-2.8	4.0	-.3	-3.0	1.4
307	-1.2	4.0	3.9	12.0	-8.8	-4.3
308	-1.3	4.2	.8	8.5	-4.7	-4.0
309	-.6	.2	3.7	6.1	-5.8	-.7
310	-10.0	-2.7	-.8	7.5	-3.6	5.7
311*	-3.2	1.3	-1.9	2.9		
312	1.0	13.9	-9.2	4.1	5.7	-11.8
313	-2.4	-.6	8.5	13.7	-13.4	-.2
314	7.4	-4.6	16.5	7.7	-16.4	-.9
315	-.5	-2.9	3.6	1.7	-3.8	2.3
316	5.7	5.2	6.5	8.8	-8.8	-8.0
400	-27.0	.1	-22.3	4.1	13.1	12.2

* TWO STATION SOLUTION

SECTION 8.

Tabulation of XYZ Departures and Perpendicular Distances of Target Points from Best Fitting Paraboloid of Revolution

TABLE 3. X,Y,Z, COMPONENT DEPARTURES AND PERPENDICULAR DEPARTURE OF TARGET POINTS FROM BEST-FITTING PARABOLOID OF REVOLUTION.

POINT NO.	DX (FEET)	DY (FEET)	DZ (FEET)	D (FEET)
1	-.0000	.0046	.0080	.0093
2	-.0028	.0103	.0183	.0212
3	-.0084	.0142	.0284	.0329
4	-.0043	.0043	.0105	.0122
5	.0075	-.0042	-.0149	-.0172
6	.0174	-.0045	-.0310	-.0359
7	-.0028	-.0000	.0048	.0056
8	-.0123	-.0034	.0221	.0255
9	-.0286	-.0168	.0573	.0662
10	-.0195	-.0198	.0480	.0555
12	.0016	.0065	-.0116	-.0135
13	-.0002	.0253	-.0437	-.0505
14	.0019	-.0069	.0125	.0144
15	.0068	-.0115	.0231	.0267
16	-.0045	.0044	-.0110	-.0127
17	.0040	-.0022	.0080	.0093
18	-.0090	.0023	-.0161	-.0186
19	-.0135	-.0001	-.0233	-.0270
20	.0057	.0016	.0103	.0119
21	.0091	.0054	.0183	.0212
22	.0172	.0176	.0423	.0490
23	.0058	.0104	.0205	.0238
24	.0043	.0171	.0302	.0350
25	-.0021	.0152	.0282	.0321
26	-.0033	.0077	.0155	.0176
27	-.0070	.0090	.0211	.0241
28	.0092	-.0070	-.0214	-.0244
29	.0092	-.0037	-.0184	-.0209
30	.0089	-.0011	-.0166	-.0189
31	-.0116	-.0016	.0217	.0247
34	-.0068	-.0090	.0209	.0238
35	.0013	.0032	-.0065	-.0074
36	-.0022	-.0183	.0343	.0389
37	-.0033	.0232	-.0435	-.0494
38	.0088	-.0205	.0413	.0470
39	.0180	-.0230	.0541	.0614
40	-.0029	.0021	-.0067	-.0077
41	.0100	-.0039	.0199	.0226
42	.0001	-.0000	.0003	.0003
43	-.0077	-.0011	-.0145	-.0164
44	-.0041	-.0018	-.0083	-.0095
45	.0260	.0205	.0610	.0694
46	.0015	.0020	.0046	.0053
47	.0038	.0096	.0190	.0216
48	.0024	.0206	.0383	.0436
51	-.0000	.0059	.0117	.0131
52	-.0003	.0011	.0022	.0025
53	-.0025	.0042	.0098	.0110

TABLE 3. (CONT.)

POINT NO.	DX (FEET)	DY (FEET)	DZ (FEET)	D (FEET)
54	.0029	-.0028	-.0080	-.0090
55	.0148	-.0084	-.0339	-.0379
56	.0126	-.0032	-.0259	-.0290
57	-.0314	-.0002	.0626	.0701
58	-.0054	-.0015	.0111	.0125
59	-.0123	-.0072	.0286	.0320
62	-.0000	-.0002	.0005	.0005
63	-.0001	.0114	-.0227	-.0254
64	.0010	-.0037	.0076	.0085
65	.0053	-.0090	.0209	.0234
66	.0098	-.0096	.0273	.0306
67	.0068	-.0038	.0156	.0175
68	.0048	-.0012	.0100	.0112
69	-.0013	-.0000	-.0026	-.0029
70*	-.0076	-.0021	-.0157	-.0176
71	.0016	.0010	.0039	.0043
72	.0059	.0061	.0170	.0190
73	-.0036	-.0065	-.0149	-.0167
74	.0019	.0077	.0158	.0177
75	.0028	-.0197	-.0427	-.0471
76	-.0000	.0001	.0004	.0004
77	.0024	-.0031	-.0087	-.0096
78	.0136	-.0103	-.0367	-.0405
79	.0154	-.0062	-.0358	-.0395
80	.0162	-.0020	-.0352	-.0388
81	.0009	.0001	-.0021	-.0023
82	-.0024	-.0010	.0057	.0063
83*	-.0141	-.0110	.0387	.0427
84	-.0203	-.0270	.0731	.0805
85	.0073	.0182	-.0426	-.0470
86	-.0004	-.0038	.0083	.0092
87	-.0012	.0087	-.0191	-.0210
88	-.0073	.0171	-.0403	-.0444
89	.0053	-.0068	.0189	.0208
90	-.0142	.0106	-.0383	-.0422
91	.0007	-.0002	.0016	.0018
92	-.0042	.0005	-.0092	-.0102
93	-.0074	-.0010	-.0161	-.0178
94	-.0181	-.0078	-.0425	-.0469
95	.0049	.0038	.0134	.0148
96	.0017	.0023	.0061	.0068
97	-.0010	-.0026	-.0060	-.0066
98	.0019	.0159	.0343	.0379
101	.0000	-.0083	-.0196	-.0213
102	.0026	-.0096	-.0234	-.0255
103	.0127	-.0216	-.0587	-.0638
104	.0080	-.0079	-.0265	-.0288

* TWO STATION SOLUTION

TABLE 3. (CONT.)

POINT NO.	DX (FEET)	DY (FEET)	DZ (FEET)	D (FEET)
105	.0100	-.0057	-.0270	-.0293
106	.0150	-.0039	-.0365	-.0397
107	-.0130	-.0000	.0306	.0333
108	-.0008	-.0002	.0019	.0021
109	-.0011	-.0006	.0032	.0035
111*	.0031	.0056	-.0152	-.0165
112*	.0028	.0109	-.0268	-.0291
113	-.0000	.0027	-.0064	-.0070
114	.0012	-.0045	.0112	.0122
115	.0032	-.0054	.0150	.0163
116	-.0096	.0094	-.0320	-.0347
117	-.0057	.0032	-.0155	-.0169
118	-.0044	.0011	-.0108	-.0117
119	-.0164	-.0002	-.0387	-.0421
120	-.0218	-.0062	-.0532	-.0578
121	-.0077	-.0046	-.0212	-.0231
122	-.0075	-.0078	-.0255	-.0277
123	-.0041	-.0073	-.0196	-.0213
124	.0009	.0038	.0092	.0100
125	.0018	-.0129	-.0336	-.0361
126	.0034	-.0080	-.0225	-.0242
127	.0057	-.0074	-.0242	-.0260
128	.0004	-.0003	-.0015	-.0016
129*	.0029	-.0012	-.0083	-.0089
130	.0101	-.0012	-.0265	-.0284
131	.0055	.0007	-.0145	-.0156
132	-.0013	-.0005	.0037	.0040
133	-.0002	-.0001	.0008	.0008
134	-.0012	-.0017	.0055	.0059
135	-.0013	-.0033	.0094	.0100
136	.0000	.0003	-.0008	-.0009
137	-.0002	.0016	-.0044	-.0047
138	.0012	-.0028	.0079	.0085
139	.0019	-.0024	.0080	.0086
140	.0080	-.0060	.0260	.0278
141	.0095	-.0037	.0265	.0284
142	.0001	-.0000	.0003	.0003
143	-.0148	-.0022	-.0387	-.0415
144	-.0138	-.0059	-.0388	-.0416
145	-.0043	-.0034	-.0143	-.0153
146	-.0045	-.0061	-.0196	-.0210
147	.0022	.0055	.0154	.0165
148	.0005	.0045	.0118	.0127
151	-.0002	.0293	.0839	.0888
152	.0015	-.0054	-.0161	-.0171
153	-.0008	.0014	.0047	.0050
155	-.0050	.0029	.0167	.0177

* TWO STATION SOLUTION

TABLE 3. (CONT.)

POINT NO.	DX (FEET)	DY (FEET)	DZ (FEET)	D (FEET)
156	.0005	-.0001	-.0015	-.0016
157	-.0032	-.0000	.0093	.0099
158	.0062	.0016	-.0186	-.0197
159	-.0033	-.0019	.0110	.0117
160	.0030	.0031	-.0127	-.0134
161	.0008	.0014	-.0048	-.0050
162	-.0003	-.0012	.0038	.0040
163*	-.0000	.0013	-.0038	-.0040
164	-.0000	.0001	-.0005	-.0006
165	.0020	-.0035	.0118	.0125
166	-.0031	.0031	-.0129	-.0136
167	.0004	-.0002	.0013	.0014
168	-.0052	.0013	-.0155	-.0164
169	-.0141	-.0002	-.0407	-.0431
170	-.0069	-.0019	-.0208	-.0220
171	-.0135	-.0081	-.0454	-.0481
172	-.0018	-.0018	-.0074	-.0078
173	-.0017	-.0030	-.0100	-.0105
174	.0001	.0007	.0022	.0024
175	.0001	-.0008	-.0026	-.0027
176	.0042	-.0100	-.0352	-.0369
177	.0058	-.0075	-.0309	-.0324
178	.0052	-.0040	-.0215	-.0225
179	.0096	-.0039	-.0341	-.0356
180	.0145	-.0018	-.0478	-.0500
181	.0043	.0005	-.0144	-.0150
182	.0040	.0016	-.0144	-.0150
183	.0033	.0025	-.0137	-.0143
184	.0098	.0129	-.0536	-.0560
186*	.0039	.0320	-.1063	-.1111
187	-.0007	.0051	-.0172	-.0180
188	-.0031	.0072	-.0261	-.0273
189	-.0051	.0066	-.0276	-.0288
190	-.0044	.0033	-.0184	-.0192
191	-.0088	.0035	-.0312	-.0326
192	-.0001	.0000	-.0003	-.0004
193	-.0021	-.0003	-.0071	-.0075
194	.0012	.0005	.0042	.0044
195	-.0070	-.0055	-.0293	-.0306
196	.0032	.0043	.0175	.0183
197	.0007	.0018	.0066	.0069
201*	-.0000	.0021	.0080	.0083
202	-.0004	.0014	.0056	.0059
203	.0035	-.0060	-.0259	-.0268
204	.0001	-.0001	-.0009	-.0009
205	.0058	-.0033	-.0249	-.0258
206	-.0082	.0022	.0316	.0327

* TWO STATION SOLUTION

TABLE 3. (CONT.)

POINT NO.	DX (FEET)	DY (FEET)	DZ (FEET)	D (FEET)
207	-.0020	.0000	.0074	.0077
210	.0030	.0030	-.0160	-.0166
211*	.0028	.0050	-.0217	-.0225
212*	.0006	.0023	-.0092	-.0095
213	-.0000	.0020	-.0077	-.0080
214	-.0019	.0071	-.0277	-.0287
215	-.0009	.0015	-.0069	-.0071
216	.0030	-.0029	.0160	.0165
216	.0030	-.0029	.0159	.0165
217	-.0004	.0002	-.0019	-.0020
218	.0023	-.0005	.0090	.0093
219	-.0036	-.0000	-.0137	-.0142
220	-.0077	-.0021	-.0299	-.0310
221	-.0072	-.0043	-.0314	-.0325
222	-.0036	-.0037	-.0194	-.0201
223	.0006	.0011	.0047	.0048
224	.0017	.0068	.0261	.0270
225	.0002	-.0019	-.0084	-.0086
226	-.0003	.0009	.0042	.0044
227	.0044	-.0058	-.0320	-.0329
228	.0033	-.0026	-.0185	-.0190
229	.0028	-.0011	-.0134	-.0138
230	.0113	-.0015	-.0499	-.0512
231	.0019	.0002	-.0084	-.0087
232	.0035	.0014	-.0167	-.0171
233*	.0064	.0049	-.0356	-.0365
236	.0004	.0032	-.0143	-.0147
237	.0021	-.0159	.0715	.0733
238	-.0006	.0016	-.0079	-.0081
239	-.0023	.0029	-.0166	-.0171
240	-.0047	.0035	-.0260	-.0266
241	-.0012	.0005	-.0061	-.0062
242	-.0095	.0011	-.0421	-.0432
243	-.0026	-.0003	-.0115	-.0118
244	-.0056	-.0024	-.0269	-.0276
245	-.0090	-.0070	-.0498	-.0511
246	.0011	.0015	.0081	.0083
247	.0033	.0083	.0392	.0403
248	.0009	.0071	.0314	.0322
251	.0000	-.0110	-.0571	-.0582
252	-.0004	.0017	.0096	.0098
253	.0038	-.0066	-.0395	-.0403
254	.0032	-.0033	-.0242	-.0247
255	.0097	-.0057	-.0589	-.0600
256	.0053	-.0014	-.0291	-.0296
257	-.0004	.0000	.0022	.0022
258	-.0011	-.0002	.0059	.0061

* TWO STATION SOLUTION

TABLE 3. (CONT.)

POINT NO.	DX (FEET)	DY (FEET)	DZ (FEET)	D (FEET)
259	.0064	.0036	-.0392	-.0399
260	.0026	.0025	-.0194	-.0198
261	.0019	.0032	-.0201	-.0205
262	.0001	.0003	-.0020	-.0021
263	.0000	.0052	-.0278	-.0282
264	-.0011	.0041	-.0225	-.0229
265	-.0039	.0066	-.0411	-.0418
266	-.0021	.0021	-.0161	-.0164
267	-.0005	.0003	-.0035	-.0036
268	.0025	-.0006	.0138	.0141
269	-.0010	-.0000	-.0053	-.0054
270	.0003	.0000	.0019	.0019
271	.0014	.0008	.0086	.0088
272*	-.0026	-.0027	-.0198	-.0202
273	-.0004	-.0008	-.0049	-.0050
274*	.0003	.0012	.0067	.0068
275	-.0012	.0089	.0590	.0597
276	-.0036	.0089	.0637	.0644
277	-.0052	.0070	.0572	.0579
278	-.0053	.0041	.0446	.0451
279	-.0040	.0017	.0287	.0291
280	-.0069	.0010	.0463	.0468
281	-.0013	-.0001	.0091	.0092
282	-.0092	-.0036	.0666	.0673
284	-.0021	-.0027	.0232	.0235
285	.0009	.0021	-.0156	-.0158
286	.0007	.0052	-.0354	-.0357
287	.0003	-.0030	.0209	.0211
288	-.0005	.0014	-.0102	-.0103
289	.0026	-.0033	.0287	.0291
290	.0053	-.0040	.0446	.0451
291	.0065	-.0026	.0469	.0474
292	.0045	-.0005	.0300	.0304
293	.0057	.0008	.0382	.0386
294	.0052	.0022	.0377	.0381
295	.0066	.0052	.0556	.0562
296	.0039	.0052	.0428	.0433
297	.0051	.0127	.0902	.0912
298	.0006	.0052	.0348	.0352
301	.0000	.0002	.0034	.0034
302	-.0017	.0033	.0499	.0500
303	-.0003	.0002	.0052	.0052
304	-.0035	.0002	.0485	.0486
305	-.0009	-.0004	.0140	.0140
306	.0004	.0006	-.0111	-.0111
307	.0000	.0010	-.0152	-.0153
308	.0019	-.0036	.0576	.0577

* TWO STATION SOLUTION

TABLE 3. (CONT.)

POINT NO.	DX (FEET)	DY (FEET)	DZ (FEET)	D (FEET)
309	-.0007	.0004	-.0126	-.0126
310	-.0039	-.0000	-.0540	-.0541
311*	.0009	.0005	.0142	.0142
312	.0006	.0011	.0174	.0174
313	-.0001	.0013	.0765	.0765
314	-.0011	-.0000	.0727	.0727
315	.0001	-.0007	.0596	.0596
316	.0011	.0003	.0724	.0724

* TWO STATION SOLUTION

SECTION 9.

Focal Length and Vertex of Best Fitting Paraboloid of Revolution

FOCAL LENGTH AND VERTEX OF BEST FITTING PARABOLOID OF REVOLUTION

The focal length of the paraboloid which best fit the triangulated target points was 127.9800 ft. ± .0110 ft. The coordinates of target No. 400, which was situated near the feed point of the dish, were:

X = -.0990 ft. ± .0138 ft.

Y = .0547 ft. ± .0133 ft.

Z = 149.0550 ft. ± .0159 ft.

Inasmuch as physical characteristics of the dish precluded affixing a target to the center of the dish, the location of the mechanical vertex of the best fitting paraboloid cannot conveniently be described. The tabulated X, Y, Z coordinates of any one of the four targets nearest the center of the dish (targets Nos. 313, 314, 315, 316) with their signs reversed, locate the position of this vertex, with respect to the chosen target, in the previously defined coordinate system.

SECTION 10
References

REFERENCES

1. D. Brown, "Precise Calibration of Surfaces of Large Radio Reflectors by Means of Analytical Photogrammetric Triangulation", Instrument Corporation of Florida, Research & Analysis Technical Report No. 10 (November 1962).

2. D. Brown, "A Solution to the General Problem of Multiple Station Analytical Stereotriangulation", RCA Data Reduction Technical Report No. 43, (February 1958), ASTIA Document No. 134278.

3. D. Brown, "A Treatment of Analytical Photogrammetry with Emphasis on Ballistic Camera Applications", RCA Data Reduction Technical Report No. 33 (November 1956).