Reports of the Department of Geodetic Science

Report No. 199

GLOBAL SATELLITE TRIANGULATION AND TRILATERATION FOR THE NATIONAL GEODETIC SATELLITE PROGRAM (SOLUTIONS WN 12, 14 and 16)

by

Ivan I. Mueller
and
M. Kumar, J. P. Reilly, N. Saxena, T. Soler

Prepared for the

National Aeronautics and Space Administration
Washington, D.C.

Grant No. NGR 36-008-093
OSURF Project No. 2514

The Ohio State University
Research Foundation
Columbus, Ohio 43212

May, 1973

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ACKNOWLEDGEMENT

This report is related to the work performed by the staff of the Department of Geodetic Science, The Ohio State University sponsored by NASA under the National Geodetic Satellite Program. Grateful acknowledgement is given for the generous support given during the past eight years which not only made The Ohio State University's participation in this program possible but also provided a total of thirty-four undergraduate and graduate students with assistantships of various lengths and types during their studies. On NASA's behalf the project was monitored by Jerome D. Rosenberg (currently Deputy Director, Communication Programs, NASA Headquarters) from 1965 to 1972, whose support and encouragement were felt and appreciated throughout. Due to a reorganization within NASA, his work was taken over with enthusiasm by Benjamin Milwitzky, Deputy Director, and James P. Murphy, Special Programs, NASA Headquarters.

Project staff with significant contributions is listed in the table on the next page. The proportion of their individual contributions is reflected in a general way by the length of stay and/or by the issue numbers in the Report Series of the Department of Geodetic Science to which the individual contributed most. In a university environment where there are important interactions between the students themselves and the instructional staff, it is generally difficult to separate out individual contributions from the team work. Thus the Report numbers listed reflect, in most cases, responsibilities in a given area rather than "individual" contributions. Exceptions to this are theoretical studies contained in Reports No. 114, 147, 150, 177, 185, where very little input came from students other than the authors.

	1965		1966		1967		1968		1969		1970		1971		1972		1973		Contribution in the Reports of the Department of Geodetic Science[1]	Degrees Earned		
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	No.	BS	MS	PhD
Administrative Assistants																						
Miller, J. R.		x	x	x	x	x	x	x														
Preston, J. C.		x	x	x	x	x	x	x														
Tesfai, I.						x	x	x	x	x	x											
Rist, E.												x	x	x	x	x	x					
Student Assistants or Associates																						
Preuss, H. D.		x	x																70	x	x	
Krakiwsky, E. J.		x	x	x	x	x	x	x											86, 87, 88, 114	x	x	x
Ferrier, J.			x	x															87, 88			
Pope, A. J.				x															86		x	
Hotter, F. D.*				x	x														82		x	
Blaha, G.					x	x	x	x	x	x	x	x	x						87, 140, 146, 150			x
Reilly, J. P.						x	x	x	x	x	x	x	x	x	x	x	x		88,125,140,187,190,193,199		x	
Schwarz, C. R.						x	x	x	x	x	x	x	x						118, 125, 140, 147, 190		x	x
Hornbarger, D. H.*						x	x												106		x	
Veach, J. P.*						x	x												110		x	
Gross, J.*						x	x												100		x	
Arur, M. G.*										x	x								139		x	
Whiting, M.												x	x	x	x				188, 190, 199	x	x	
Kumar, M.													x	x	x	x	x		184, 193, 195, 196, 199		x	
Soler, T.														x	x	x	x		187, 195, 199			
Tsimis, E.														x	x	x			185, 191		x	
Joshi, C. S.*																x			192		x	
Research Associate																						
Saxena, N. K.										x	x	x	x	x	x	x	x		177, 193, 199			

[1] See Index to Reports in the Bibliography

Those students receiving financial assistance (travel, etc.), other than direct fellowships, have asterisks next to their names. In addition to those listed in the table, fifteen students also carried short-term appointments for various generally nonprofessional responsibilities.

Graduate students on regular fellowships also received full tuition waivers from the University which is acknowledged here. Other University contributions came from the Computer Center, which provided a significant amount of free computer time and from the Department in the form of 4.4% cost sharing of the total research budget.

Last but not least, grateful acknowledgement is given to Defense Mapping Agency (Aerospace and Topographic Centers), NASA (Goddard Space Flight Center and Wallops Island), National Geodetic Survey/NOS/NOAA, Smithsonian Astrophysical Observatory for supplying the observational and survey data, the basic ingredients of the work, and other information, always without reservations and delay. In this connection the Computer Sciences Corporation and the National Space Science Data Center also played important roles.

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1. INTRODUCTION

In 1965 the Department of Geodetic Science at The Ohio State University had been requested to submit a proposal to the National Aeronautics and Space Administration for a multi-year study and analysis of data from satellites launched specifically for geodetic purposes and from other satellites useful in geodetic studies. The program of work included theoretical studies and analysis for the geometric determination of station positions derived from photographic observations of both passive and active satellites and from range observations. This paper examines the current status of data analysis, processing and results. Various theoretical studies have been described in the Report series of the Department of Geodetic Science (Nos. 106, 110, 114, 118, 139, 147, 150, 177, 185, and 191) and are not repeated here.

The ultimate goal of the data analysis was to obtain an improved global net combining all participating tracking stations in a single worldwide coordinate system. In deriving these results OSU representatives were to work with other universities and government agencies to prepare a handbook containing the best goedetic data from satellite observations available at the time. This report condenses the OSU contribution to the above enterprise.

The work performed during the grant period included, but was not limited to, the following:

(1) Deriving the necessary mathematical formulations, programming and testing the same.

(2) Making use of the observational data as they became available to determine the relative positions of the tracking stations in an arbitrary Cartesian coordinate system.

(3) Estimating the position of this coordinate system with respect to an absolute (geocentric) system and also with respect to coordinate systems used by the other agencies.

(4) Participating in working groups and other planning meetings to establish desirable operational procedures, including tracking procedures, data format, analysis procedures, etc.

(5) Providing advice to NASA on various aspects of the National Geodetic Satellite Program.

Thus, the primary objective of the OSU investigation was the geometric analysis of geodetic satellite data. The analysis was to be accomplished in three steps:

(1) The establishment of a primary network where station positions are known to an internal consistency of 10 meters or better to serve the following purposes: (a) to establish the relative relationships between the various geodetic datums in use around the world; (b) connect isolated tracking stations, islands, navigational beacons and other points of interest.
In fulfilling the requirement of (a) a minimum of three tracking stations were to be used on any given datum.

(2) Establishment of a densification network where station positions are known to an internal consistency of three meters or better to serve the following purposes: (a) improve the internal quality of existing geodetic networks (triangulation, etc.) by establishing "super" control

points in sufficient numbers; (b) to provide control for mapping to scales as large as 1:25,000 in areas where no primary geodetic control exists.

(3) Establishment of a set of scientific reference stations where positions are known to an internal consistency of one meter or better for advanced (earth and ocean physics) applications.

This report contains results in connection with (1). The goals of items (2) and (3) still need to be fulfilled when the quality of the observational material and/or the distribution of tracking stations will become better than those made available for this study. Since the National Geodetic Satellite Program is no longer funded, it is only hoped that these goals will be incorporated in the Earth and Ocean Physics Application (EOPAP) or in the GEOS-C Programs.

This report is in six sections. Following the brief section on instrumentation, section 3 contains material on observational and survey data as provided to The Ohio State University by the various data collecting agencies. After describing the theory in section 4, the results of the least squares adjustment are given in section 5. This section also contains the comparison of these results with various dynamic solutions and survey data. In section 6 conclusions are presented with some recommendations for future work. Numbers in brackets after the section captions refer to the appropriate Department of Geodetic Science Report where more detailed information on the content of the section may be found.

2. INSTRUMENTATION

The Ohio State University used data provided by other groups and did not make any observations of its own. It did not develop or use any instruments or equipment which were unique to OSU's work, and the instruments used in getting the data used by OSU are described in [American Geophysical Union, in press].

Table 2-1

Index to Descriptions of Instruments Used in Producing Data for OSU Work

	Responsible Group	Location Chapter[1]
1. Satellite Instrumentation		
ANNA 1B	APL	II
Courier 1B		
Dash 2		
Echo 1	NASA	V
Echo 1 Rocket		
Echo 2	NASA	V
Electron 3		
Explorer 9		
Explorer 19		
GEOS-I	APL	VI
GEOS-II	APL	II
Midas 4		
Midas 7		
PAGEOS	NASA	V
RCS		
Relay 1		
SECOR (EGRS)	DOD/DMA	III
Telstar 1		
2. Ground Instrumentation		
2.1 Cameras		
2.1.1 PC-1000	DOD	III
2.1.2 BC-4	NGS	VII
2.1.3 MOTS	NASA	IV
2.1.4 Baker-Nunn	SAO	IX
2.1.5 Other	Other	
2.2 Radar		
2.2.1 C-Band	NASA	VI
2.2.2 SECOR	DOD	III

[1]in [American Geophysical Union, in press]

3. DATA

Details of the data used by OSU and obtained from various agencies are presented in the tables of section 3.1, 3.21 and 3.3. Before reaching OSU the data was subjected to reductions considered necessary by the respective agencies [Gross, 1968; Hotter, 1967]. Most of the obtained data needed some kind of additional treatment before it could be used for analysis; the more important details of this treatment (preprocessing) are given in section 3.22.

3.1 Satellites and Observation Stations [71]

Data used for OSU investigations was obtained by observing the satellites listed in Table 3.1-1. Orbital and other information on these satellites is tabulated in [Girnius and Joughin, 1968; King-Hele et al., 1970].

Survey information regarding the observation stations is summarized in Tables 3.1-2 to 3.1-4.

Table 3.1-1

Summary of Observed Satellites

Name	Designation	Name	Designation
ANNA 1B	62 60 1	GEOS-I	65 89 1
Courier 1B	60 13 1	GEOS-II	68 02 1
Dash 2	63 30 4	Midas 4	61 28 1
Echo 1		Midas 7	63 30 1
Echo 1 Rocket	60 09 2	PAGEOS	66 56 1
Echo 2		RCS	65 34 3
Elektron 3	64 38 1	Relay 1	62 68 1
Explorer 9	61 04 1	SECOR (EGRS)	1967 65A
Explorer 19	63 53 1	Telstar 1	62 20 1

Table 3.1-2

Survey Information of Observation Stations

STATION NO	STATION NAME	DATUM CODE[1]	SURVEY COORDINATES[2] LATITUDE	SURVEY COORDINATES[2] LONGITUDE	SURVEY COORDINATES[2] ELL. H(M)	MSL[3] (M)	INSTR. HEIGHT[4] (M)	INSTR. TYPE	SOURCE CODE[5]
1021	BLOSSOM POINT	29	38° 25' 49".628	282° 54' 48".225	7.0	5.76	1.23	MOTS 40	1
1022	FORT MYERS	29	26 32 51.091	278 8 3.926	21.0	4.81	1.23	MOTS 40	1
1030	GOLDSTONE	29	35 19 48.088	243 6 2.730	907.0	929.10	1.71	MOTS 40	1
1032	ST. JOHN'S	29	47 44 29.739	307 16 43.369	106.0	69.00	1.95	MOTS 40	1
1033	FAIRBANKS	29	64 52 19.721	212 9 47.168	165.0	162.70	2.18	MOTS 40	2
1034	E. GRAND FORKS	29	48 1 21.403	262 59 21.561	256.0	252.58	1.71	MOTS 40	1
1042	ROSMAN	29	35 12 6.926	277 7 41.008	916.0	909.40	1.69	MOTS 40	1
3106	ANTIGUA	29	17 8 52.685	298 12 37.552	8.0	1.90	*	PC-1000	1
3334	STONEVILLE	29	33 25 31.950	269 5 11.350	44.0	39.00	*	PC-1000	1
3400	COLORADO SPRINGS	29	39 0 22.440	255 7 1.010	2191.0	2184.10	*	PC-1000	1
3401	BEDFORD	29	42 27 17.530	288 43 35.033	89.0	83.00	1.32	PC-1000	1
3402	SEMMES	29	30 46 49.350	271 44 52.370	80.0	73.00	*	PC-1000	1
3404	SWAN ISLAND	*	17 24 16.570	276 3 29.870	*	40.40	*	PC-1000	1
3405	GRAND TURK	29	21 25 46.796	288 51 13.786	8.0	2.20	*	PC-1000	1
3406	CURACAO	41	12 5 26.843	291 9 45.803	-4.0	6.83	1.25	PC-1000	1
3407	TRINIDAD	41	10 44 35.844	298 23 25.652	237.0	254.80	1.25	PC-1000	1
3413	NATAL	41	- 5 54 56.253	324 49 57.605	63.0	36.90	*	PC-1000	1
3414	BRASILIA	41	-15 51 35.540	312 6 2.679	1059.0	1058.25	1.14	PC-1000	2
3431	ASUNCION	41	-25 18 56.192	302 25 15.376	162.0	149.74	1.65	PC-1000	2
3476	PARAMARIBO	41	5 26 54.645	304 47 44.226	8.6	18.27	1.25	PC-1000	1
3477	BOGOTA	41	4 49 2.379	285 55 35.482	2586.0	2557.90	1.25	PC-1000	2
3478	MANAUS	*	- 3 8 44.820	300 0 59.620	*	83.60	*	PC-1000	3
3499	QUITO	41	- 0 5 50.468	281 34 49.212	2706.4	2681.80	*	PC-1000	1
3648	HUNTER AFB	29	32 0 5.868	278 50 46.359	17.0	12.00	1.32	PC-1000	1
3657	ABERDEEN	29	39 28 18.971	283 55 44.780	6.0	5.50	1.32	PC-1000	1
3861	HOMESTEAD	29	25 30 24.690	279 36 42.690	16.0	0.20	*	PC-1000	1
3902	CHEYENNE	29	41 7 59.200	255 8 2.650	1890.0	1882.20	*	PC-1000	
3903	HERNDON	29	38 59 32.360	282 40 21.200	169.0	168.00	*	PC-1000	1
4050	PRETORIA	3	-25 56 35.340	28 21 29.950	1592.0	1584.00	*	MPS-25	2
4061	ANTIGUA	29	17 8 34.780	298 12 24.470	48.0	42.30	*	FPC-6	2
4081	GRAND TURK	29	21 27 43.490	288 52 3.050	42.0	36.00	*	TPQ-18	2
4062	MERRITT ISLAND	29	28 25 27.930	279 20 7.380	21.0	11.25	*	TPQ-18	2
4280	VANDENBERG AFB	29	34 39 57.130	239 25 10.430	89.0	123.00	*	TPQ-18	2
4740	BERMUDA	29	32 20 52.300	295 20 44.300	11.0	19.86	*	FPS-16	2
4742	KAUAI	33	22 7 35.830	200 19 53.960	1151.0	1155.00	*	FPS-16	2
5001	HERNDON	29	38 59 37.697	282 40 16.705	129.0	127.80	9.39	SECOR	1
5201	MOSES LAKE	29	47 11 5.916	240 39 50.463	358.0	368.92	2.00	SECOR	1
5410	SAND ISLAND	27	28 12 32.061	182 37 49.531	6.0	6.10	4.13	SECOR	2
5648	FORT STEWART	29	31 55 18.405	278 26 0.260	34.0	27.80	3.90	SECOR	1
5712	PARAMARIBO	41	5 26 59.817	304 47 44.990	12.0	21.90	4.93	SECOR	1
5713	TERCEIRA	17	38 45 36.725	332 54 21.064	56.0	56.00	4.25	SECOR	1
5715	DAKAR	50	14 44 41.008	342 30 52.935	27.0	27.30	4.42	SECOR	1
5717	FORT LAMY	1	12 7 49.300	15 2 6.148	320.0	298.50	4.83	SECOR	1
5720	ADDIS ABABA	1	8 46 9.479	38 59 49.196	1881.0	1889.40	4.29	SECOR	1
5721	MASHHAD	16	36 14 30.404	59 37 40.105	962.0	994.40	4.35	SECOR	1
5722	DIEGO GARCIA	*	- 7 20 57.440	72 28 31.570	*	6.10	4.60	SECOR	2
5723	CHIANG MAI	*	18 47	99 00	*	310.80		SECOR	1
5726	ZAMBOANGA	26	6 55 26.213	122 4 3.558	14.0	13.30	4.83	SECOR	2
5730	WAKE ISLAND	49	19 17 24.100	166 36 41.206	8.0	8.10	4.29	SECOR	1

Table 3.1-2 (cont'd)

STATION NO	STATION NAME	DATUM CODE[1]	SURVEY COORDINATES[2] LATITUDE	LONGITUDE	ELL. H (M)	MSL[3] (M)	INSTR. HEIGHT[4] (M)	INSTR. TYPE	SOURCE CODE[5]
5732	PAGO PAGO	*	*	*	*	*	*	SECOR	
5733	CHRISTMAS ISLAND	12	2 0 35.622	202 35 21.962	4.0	3.50	2.29	SECOR	1
5734	SHEMYA	29	52 42 54.894	174 7 37.870	-7.0	39.30	1.50	SECOR	1
5735	NATAL	41	- 5 54 56.253	324 49 57.605	66.0	39.40	*	SECOR	1
5736	ASCENSION ISLAND	5	- 7 58 15.220	345 35 32.385	74.0	74.00	4.32	SECOR	1
5739	TERCEIRA	17	38 45 36.311	332 54 19.686	56.0	56.10	4.25	SECOR	1
5744	CATANIA	16	37 26 40.831	15 2 44.955	-4.0	11.80	4.17	SECOR	1
5907	WORTHINGTON	*	*	*	*	*	*	SECOR	
5911	BERMUDA	*	*	*	*	*	*	SECOR	
5912	PANAMA	*	*	*	*	*	*	SECOR	
5914	PUERTO RICO	*	*	*	*	*	*	SECOR	
5915	AUSTIN	*	*	*	*	*	*	SECOR	
5923	CYPRUS	*	*	*	*	*	*	SECOR	
5924	ROTA	*	*	*	*	*	*	SECOR	
5925	ROBERTS FIELD	*	*	*	*	*	*	SECOR	
5930	SINGAPORE	*	*	*	*	*	*	SECOR	
5931	HONG KONG	*	*	*	*	*	*	SECOR	
5933	DARWIN	*	*	*	*	*	*	SECOR	
5934	MANUS	*	*	*	*	*	*	SECOR	
5935	GUAM	*	*	*	*	*	*	SECOR	
5937	PALAU	*	*	*	*	*	*	SECOR	
5938	GUADALCANAL	*	*	*	*	*	*	SECOR	
5941	MAUI	*	*	*	*	*	*	SECOR	
6001	THULE	29	76 30 3.411	291 27 51.887	238.0	206.00	1.50	BC-4	2
6002	BELTSVILLE	29	39 1 39.003	283 10 26.942	45.0	44.30	1.50	BC-4	1
6003	MOSES LAKE	29	47 11 7.132	240 39 48.118	358.0	368.74	1.50	BC-4A	1
6004	SHEMYA	29	52 42 54.890	174 7 37.870	-9.0	36.80	1.50	BC-4	1
6006	TROMSO	16	69 39 44.270	18 56 31.908	119.0	106.00	1.50	BC-4	2
6007	TERCEIRA	17	38 45 36.725	332 54 21.064	53.0	53.30	1.49	BC-4	1
6008	PARAMARIBO	41	5 26 55.325	304 47 42.832	8.7	18.38	1.49	BC-4	1
6009	QUITO	41	- 0 5 50.468	281 34 49.212	2706.7	2682.10	1.50	BC-4	1
6011	MAUI	33	20 42 38.561	203 44 28.529	3041.3	3049.27	1.50	BC-4	4
6012	WAKE ISLAND I	49	19 17 23.227	166 36 39.780	4.0	3.50	1.50	BC-4	1
6013	KANOYA	46	31 23 30.140	130 52 24.860	47.0	65.90	1.50	BC-4	1
6015	MASHHAD	16	36 14 29.527	59 37 42.729	959.0	991.00	1.50	BC-4	1
6016	CATANIA	16	37 26 42.628	15 2 47.308	-7.0	9.24	1.50	BC-4A	1
6019	VILLA DOLORES	41	-31 56 33.954	294 53 41.342	621.0	608.18	1.50	BC-4	2
6020	EASTER ISLAND	15	-27 10 39.213	250 34 17.495	231.0	230.80	1.50	BC-4	1
6022	TUTUILA	2	-14 20 12.216	189 17 13.242	5.0	5.34	1.50	BC-4A	1
6023	THURSDAY ISLAND	6	-10 35 8.037	142 12 35.495	62.0	60.50	1.50	BC-4	2
6031	INVERCARGILL	28	-46 25 3.491	168 19 31.155	1.0	0.90	1.49	BC-4	1
6032	CAVERSHAM	6	-31 50 28.992	115 58 26.618	33.0	26.30	*	BC-4	2
6038	SOCORRO ISLAND	23	18 43 44.930	249 2 39.280	23.0	23.20	1.50	BC-4	1
6039	PITCAIRN ISLAND	36	-25 4 7.146	229 53 11.882	339.0	339.40	1.50	BC-4	1
6040	COCOS ISLAND	*	-12 11 57.910	96 49 47.080	*	4.40	*	BC-4	2
6042	ADDIS ABABA	1	8 46 8.501	38 59 49.164	1878.0	1886.46	1.52	BC-4	1
6043	CERRO SOMBRERO	39	-52 46 52.468	290 46 29.573	81.0	80.70	1.48	BC-4A	1
6044	HEARD ISLAND	20	-53 1 12.030	73 23 27.420	4.0	3.80	1.50	BC-4	1
6045	MAURITIUS	*	-20 13 50	57 25 15	*	149.40	*	BC-4	1

Table 3.1-2 (cont'd)

STATION NO	STATION NAME	DATUM CODE[1]	SURVEY COORDINATES[2] LATITUDE	LONGITUDE	ELL. H(M)	MSL[3] (M)	INSTR. HEIGHT[4] (M)	INSTR. TYPE	SOURCE CODE[5]
6047	ZAMBOANGA	26	6 55 26.132	122 4 4.838	9.0	9.39	1.50	BC-4	2
6050	PALMER STATION	51	-64 46 33.980	295 56 37.040	16.0	16.44	1.58	BC-4	2
6051	MAWSON STATION	*	-67 36 3.080	62 52 24.410	*	11.30	*	BC-4	2
6052	WILKES STATION	*	-66 16 45.120	110 32 4.610	*	*	1.50	BC-4	2
6053	MCMURDO STATION	10	-77 50 46.249	166 38 7.584	19.0	19.00	1.50	BC-4	1
6055	ASCENSION ISLAND	5	- 7 58 16.634	345 35 32.764	71.0	70.94	1.50	BC-4	1
6059	CHRISTMAS ISLAND	12	2 0 35.622	202 35 21.962	3.0	2.75	1.50	BC-4A	1
6060	CULGOORA	6	-30 18 39.418	149 33 36.892	212.0	211.08	*	BC-4	2
6061	SOUTH GEORGIA IS.	43	-54 16 39.515	323 30 42.531	4.0	4.20	1.49	BC-4A	1
6063	DAKAR	50	14 44 44.228	342 30 55.394	26.0	26.30	1.50	BC-4A	1
6064	FORT LAMY	1	12 7 51.750	15 2 6.151	316.0	295.40	1.50	BC-4A	1
6065	HOHENPEISSENBERG	16	47 48 7.011	11 1 29.378	943.0	943.20	*	BC-4A	1
6066	WAKE ISLAND II	49	19 17 24.100	166 36 41.206	5.0	5.30	1.51	BC-4	1
6067	NATAL	41	- 5 55 37.414	324 50 6.200	66.7	40.63	*	BC-4A	1
6068	JOHANNESBURG	3	-25 52 56.980	27 42 25.170	1531.8	1523.80	*	BC-4	4
6069	TRISTAN DA CUNHA	47	-37 3 26.257	347 40 53.555	25.0	24.80	*	BC-4	1
6072	CHIANG MAI	*	18 46 10	98 58 15	*	319.20	*	BC-4	1
6073	DIEGO GARCIA	*	- 7 20 58.527	72 28 32.156	*	3.90	1.50	BC-4	2
6075	MAHE	42	- 4 40 7.230	55 28 50.360	589.0	588.98	1.55	BC-4A	1
6078	PORT VILA	52	-17 41 46.956	168 17 57.921	15.0	15.20	1.50	BC-4	2
6111	WRIGHTWOOD I	29	34 22 54.537	242 19 9.484	2259.0	2284.30	1.50	BC-4	2
6123	POINT BARROW	29	71 18 49.882	203 21 20.720	-6.0	8.30	*	BC-4	2
6134	WRIGHTWOOD II	29	34 22 44.444	242 19 9.259	2173.0	2198.40	1.50	BC-4	2
7036	EDINBURG	29	26 22 45.443	261 40 9.033	66.0	59.59	1.11	MOTS 40	1
7037	COLUMBIA	29	38 53 36.068	267 47 42.120	273.0	272.68	1.11	MOTS 40	1
7039	BERMUDA	29	32 21 48.790	295 20 32.460	23.0	31.18	1.13	MOTS 40	1
7040	SAN JUAN	29	18 15 26.216	294 0 22.174	59.0	49.70	1.07	MOTS 40	1
7043	GREENBELT	29	39 1 15.014	283 10 19.934	55.0	53.46	0.64	PTH-100	1
7045	DENVER	29	39 38 48.026	255 23 41.194	1796.0	1789.63	1.11	MOTS 40	1
7072	JUPITER	29	27 1 13.168	279 53 12.485	26.0	14.19	1.10	MOTS 40	1
7075	SUDBURY	29	46 27 20.988	279 3 10.354	281.0	281.90	1.17	MOTS 40	1
7076	KINGSTON	29	18 4 31.980	283 11 26.528	486.0	445.90	1.07	MOTS 40	1
8009	WIPPOLDER	16	52 0 9.240	4 22 21.230	21.0	24.70	*	BOUWERS	2
8010	ZIMMERWALD	16	46 52 40.300	7 27 58.070	900.0	903.44	*	SCHM H	1
8011	MALVERN	16	52 8 39.130	358 1 59.470	109.0	113.20	*	SCHM A	1
8015	HAUTE PROVENCE	16	43 56 1.140	5 42 49.280	651.0	659.00	*	SCHM D	2
8019	NICE	16	43 43 36.496	7 18 3.309	369.0	377.42	*	ANTARES	1
8030	MEUDON	16	48 48 25.354	2 13 [illegible]1.339	155.0	165.46	*	REFR A	1
9001	ORGAN PASS	29	32 25 24.560	253 26 51.[illegible]70	1650.0	1651.33	*	B-N	1
9002	OLIFANTSFONTEIN	3	-25 57 33.850	28 14 53.910	1552.1	1544.10	*	B-N	4
9004	SAN FERNANDO	16	36 27 51.370	353 47 42.090	-9.0	25.90	*	B-N	1
9005	TOKYO	46	35 40 11.078	139 32 28.222	60.0	59.77	*	B-N	1
9006	NAINI TAL	16	29 21 38.970	79 27 25.510	1827.0	1927.00	*	B-N	1
9007	AREQUIPA	41	-16 27 55.085	288 30 26.814	2486.0	2451.86	*	B-N	1
9008	SHIRAZ	16	29 38 18.112	52 31 11.445	1553.0	1597.40	*	B-N	2
9009	CURACAO	41	12 5 25.912	291 9 46.078	-2.0	8.70	*	B-N	1
9010	JUPITER	29	27 1 12.882	279 53 13.008	27.0	15.13	*	B-N	1
9011	VILLA DOLORES	41	-31 56 33.228	294 53 38.949	621.0	608.00	*	B-N	4
9012	MAUI	33	20 42 37.500	203 44 24.080	3026.1	3034.14	*	B-N	4

Table 3.1-2 (cont'd)

STATION NO	STATION NAME	DATUM CODE[1]	SURVEY COORDINATES[2] LATITUDE	LONGITUDE	ELL. H(M)	MSL[3] (M)	INSTR. HEIGHT[4] (M)	INSTR. TYPE	SOURCE CODE[5]
9021	MOUNT HOPKINS	29	31 41 2.670	249 7 21.350	2371.0	2382.00	*	B-N	1
9028	ADDIS ABABA	1	8 44 47.230	38 57 30.480	1895.0	1925.20	*	B-N	2
9029	NATAL	41	- 5 55 38.616	324 50 8.660	71.4	45.34	*	B-N	4
9031	COMODORO RIVADAVIA	41	-45 53 11.028	292 23 12.215	173.0	186.54	*	B-N	1
9051	ATHENS	16	37 59 40.310	23 46 42.890	180.0	187.90	*	GEO 36	1
9091	DIONYSOS	16	38 4 48.240	23 56 1.610	459.0	467.00	*	B-N	1
9424	COLD LAKE	29	54 44 33.858	249 57 26.389	702.0	704.60	*	B-N	1
9425	EDWARDS AFB	29	34 57 50.742	242 5 11.584	760.0	764.23	*	B-N	1
9426	HARESTUA	16	60 12 40.380	10 45 8.740	582.0	575.92	*	B-N	1
9427	JOHNSTON ISLAND	24	16 44 45.390	190 29 5.590	5.0	5.00	*	B-N	1
9431	RIGA	16	56 56 54.980	24 3 37.810	2.0	8.00	*	AFU 75	1
9432	UZHGOROD	*	48 38 4.560	22 17 57.880	*	189.00	*	AFU 75	1
DSN1	GOLDSTONE	29	35 23 22.346	243 9 [illegible].262	1014.3	1036.30	11.80	85' H-D	4
DSN2	GOLDSTONE	29	35 17 59.854	243 11 43.414	966.9	988.90	11.70	85' H-D	4
DSN4	GOLDSTONE	29	35 25 33.340	243 6 40.850	1009.8	1031.80	15.50	210'A-E	4
DSN6	TIDBINBILLA	6	-35 24 8.038	148 58 48.206	664.5	656.08	15.08	85' H-D	4
DSN7	JOHANNESBURG	3	-25 53 21.150	27 41 8.530	1399.0	1391.00	13.00	85' H-D	4

* INSUFFICIENT DATA

[1] REFER TO TABLE 3.1-3

[2] GEODETIC COORDINATES OF THE INSTRUMENTAL REFERENCE POINT (OPTICAL/ELECTRONIC CENTER,ETC.) ON THE LOCAL GEODETIC DATUM

[3] MEAN SEA LEVEL HEIGHT OF THE INSTRUMENTAL REFERENCE POINT

[4] HEIGHT OF INSTRUMENTAL REFERENCE POINT ABOVE SURVEY MONUMENT

[5] REFER TO TABLE 3.1-4

NOTE : ZERO IN THE LAST DIGIT MAY INDICATE THAT THE DIGIT IS UNKNOWN.

Table 3.1-3

Geodetic Datums

Code	Datum	Ellipsoid	Origin	Latitude	Longitude
1	Adindan (Ethiopia)	Clarke 1880	STATION Z5 ADINDAN	22°10'07".110	31°29'21".608
2	American Samoa 1962	Clarke 1866	BETTY 13 ECC	-14 20 08.341	189 17 07.750
3	Arc-Cape (South Africa)	Clarke 1880	Buffelsfontein	-33 59 32.000	25 30 44.622
4	Argentine	International	Campo Inchauspe	-35 58 17	297 49 48
5	Ascension Island 1958	International	Mean of three stations	-07 57	345 37
6	Australian Geodetic	Australian National	Johnston Memorial Cairn	-25 56 54.55	133 12 30.08
7	Bermuda 1957	Clarke 1866	FT. GEORGE B 1937	32 22 44.360	295 19 01.890
8	Berne 1898	Bessel	Berne Observatory	46 57 08.660	07 26 22.335
9	Betio Island, 1966	International	1966 SECOR ASTRO	01 21 42.03	172 55 47.90
10	Camp Area Astro 1961-62 USGS	International	CAMP AREA ASTRO	-77 50 52.521	166 40 13.753
11	Canton Astro 1966	International	1966 CANTON SECOR ASTRO	-02 46 28.99	188 16 43.47
12	Christmas Island Astro 1967	International	SAT.TRI.STA. 059 RM3	02 00 35.91	202 35 21.82
13	Chua Astro (Brazil-Geodetic)	International	CHUA	-19 45 41.16	311 53 52.44
14	Corrego Alegre (Brazil-Mapping)	International	CORREGO ALEGRE	-19 50 15.140	311 02 17.250
15	Easter Island 1967 Astro	International	SATRIG RM No. 1	-27 10 39.95	250 34 16.81
16	European	International	Helmert Tower	52 22 51.45	13 03 58.74
17	Graciosa Island (Azores)	International	SW BASE	39 03 54.934	331 57 36.118
18	Gizo, Provisional DOS	International	GUX 1	-09 27 05.272	159 58 31.752
19	Guam	Clarke 1866	TOGCHA LEE NO. 7	13 22 38.49	144 45 51.56
20	Heard Astro 1969	International	INTSATRIG 0044 ASTRO	-53 01 11.68	73 23 22.64
21	Iben Astro, Navy 1947 (Truk)	Clarke 1866	IBEN ASTRO	07 29 13.05	151 49 44.42
22	Indian	Everest	Kalianpur	24 07 11.26	77 39 17.57
23	Isla Socorro Astro	Clarke 1866	Station 038	18 43 44.93	249 02 39.28
24	Johnston Island 1961	International	JOHNSTON ISLAND 1961	16 44 49.729	190 29 04.781
25	Kusaie, Astro 1962, 1965	International	ALLEN SODANO LIGHT	05 21 48.80	162 58 03.28
26	Luzon 1911 (Philippines)	Clarke 1866	BALANCAN	13 33 41.000	121 52 03.000
27	Midway Astro 1961	International	MIDWAY ASTRO 1961	28 11 34.50	182 36 24.28
28	New Zealand 1949	International	PAPATAHI	-41 19 08.900	175 02 51 .00
29	North American 1927	Clarke 1866	MEADES RANCH	39 13 26.686	261 27 29.494
30	*NAD 1927 (Cape Canaveral)	Clarke 1866	CENTRAL	28 29 32.364	279 25 21.230
31	*NAD 1927 (White Sands)	Clarke 1866	KENT 1909	32 30 27.079	253 31 01.306
32	Old Bavarian	Bessel	Munich	48 08 20.000	11 34 26.483
33	Old Hawaiian	Clarke 1866	OAHU WEST BASE	21 18 13.89	202 09 04.20
34	Ordnance Survey G.B. 1936	Airy	Herstmonceux	50 51 55.271	00 20 45.882
35	Pico de las Nieves (Canaries)	International	PICO DE LAS NIEVES	27 57 41.273	344 25 49.476
36	Pitcairn Island Astro	International	PITCAIRN ASTRO 1967	-25 04 06.97	229 53 12.17
37	Potsdam	Bessel	Helmert Tower	52 22 53.954	13 04 01 153
38	Provisional S.American 1956	International	LA CANOA	08 34 17.17	296 08 25.12
39	Provisional S. Chile 1963	International	HITO XVIII	-53 57 07.76	291 23 28.76
40	Pulkovo 1942	Krassovski	Pulkovo Observatory	59 46 18.55	30 19 42.09
41	South American 1969	South American 1969	CHUA	-19 45 41.653	311 53 55.936
42	Southeast Island (Mah	Clarke 1880		-04 40 39.460	55 32 00.166
43	South Georgia Astro	International	ISTS 061 ASTRO POINT 1968	-54 16 38.93	323 30 43.97
44	Swallow Islands (Solomons)	International	1966 SECOR ASTRO	-10 18 21.42	166 17 56.79
45	Tananarive	International	Tananarive Observatory	-18 55 02.10	47 33 06.75
46	Tokyo	Bessel	Tokyo Observatory (old)	35 39 17.51	139 44 40.50
47	Tristan Astro 1968	International	INTSATRIG 069 RM No. 2	-37 03 26.79	347 40 53.21
48	Viti Levu 1916 (Fiji)	Clarke 1880	MONAVATU (latitude only)	-17 53 28.285	
			SUVA (longitude only)		178 25 35.835
49	Wake Island, Astronomic 1952	International	ASTRO 1952	19 17 19.991	166 38 46.294
50	Yof Astro 1967 (Dakar)	Clarke 1880	YOF ASTRO 1967	14 44 41.62	342 30 52.98
51	Palmer Astro 1969	International	ISTS 050	-64 46 35.71	295 56 39.53
52	Efate	International	Belle Vue IGN	-17 44 17.400	168 20 33.250

*Local datums of special purpose, based on NAD 1927 values for the origin stations.

Table 3.1-4

Summary of Source Information

Code	Source
1	[CSC, 1971]
2	[CSC, 1972/73]
3	[Huber, 1971]
4	[Gaposchkin et al., 1973]

3.2 Satellite Observational Data and Its Handling

3.21 Satellite Observational Data [187, 188, 193, 195, 196]

Data used in the four OSU partial solutions (networks) reported earlier, namely, MPS, BC, SECOR, and SA, and in the current combined solutions designated WN, is summarized in Table 3.2-1. These networks are shown in Figs. 3.2-1 through 3.2-7. Various statistical information on the solutions are provided in Tables 3.2-2 and 3.2-3.

Table 3.2-1

Basic Information on the OSU Solutions (Networks)

OSU Solution (Network)	No. of Stations	No. of Observations	No. of Constraints Used						[6]σ_0	[7]Reference	Fig.
			Origin	Relative Position	Scale (Length)	Station Position	Height	Directional			
[1]MPS	66	28774	inner	9	7	--	63	--	1.07	188	3.2-1,2,3
[2]BC	49	30302	inner	2	7	--	48	--	2.80	193	3.2-4
[3]SECOR	50	28844	inner	14	--	--	37	9	1.37	195	3.2-5
[4]SA	14	2524	inner	3	1	--	14	--	2.50	196	3.2-6
[5]WN	159	90444	inner	43	11	--	158	--	1.02	199	3.2-7

[1] MPS includes 14 PC-1000 stations, 15 MOTS-40 stations, 1 PTH-100 station, 7 C-Band stations, 6 European stations (8000 series), and 23 SAO stations (9000 series).

[2] BC includes all 49 stations of BC-4 Worldwide Geometric Satellite Network.

[3] SECOR includes 37 SECOR stations of the Equatorial Network and 13 collocated BC-4 camera stations.

[4] SA includes 9 PC-1000 stations of South American Densification Net and 5 BC-4 stations.

[5] WN includes all the above-mentioned four networks, namely, MPS (less one C-Band station: 4742), BC, SECOR, and SA.

[6] A posteriori standard deviation of unit weight.

[7] OSU Department of Geodetic Science Report No.

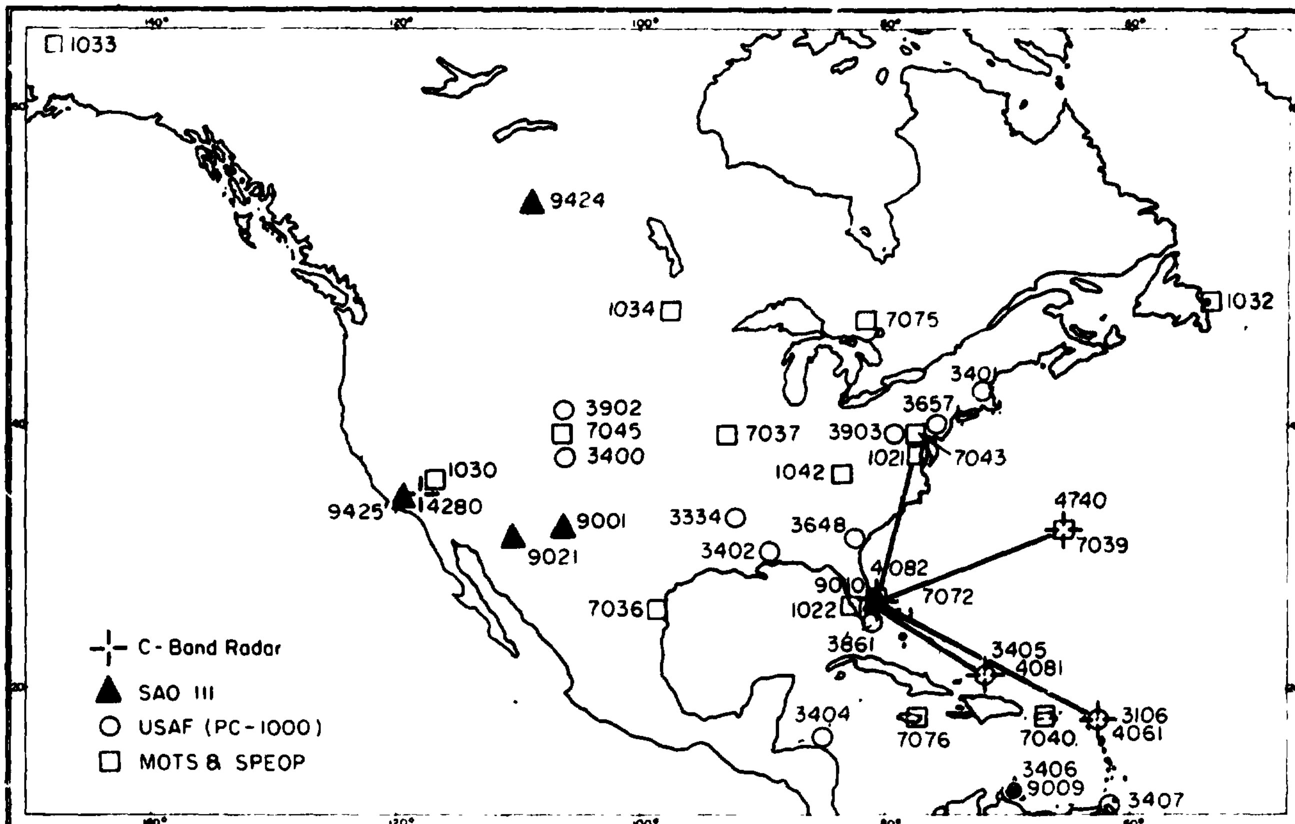


Fig. 3.2-1 MPS stations in North America.

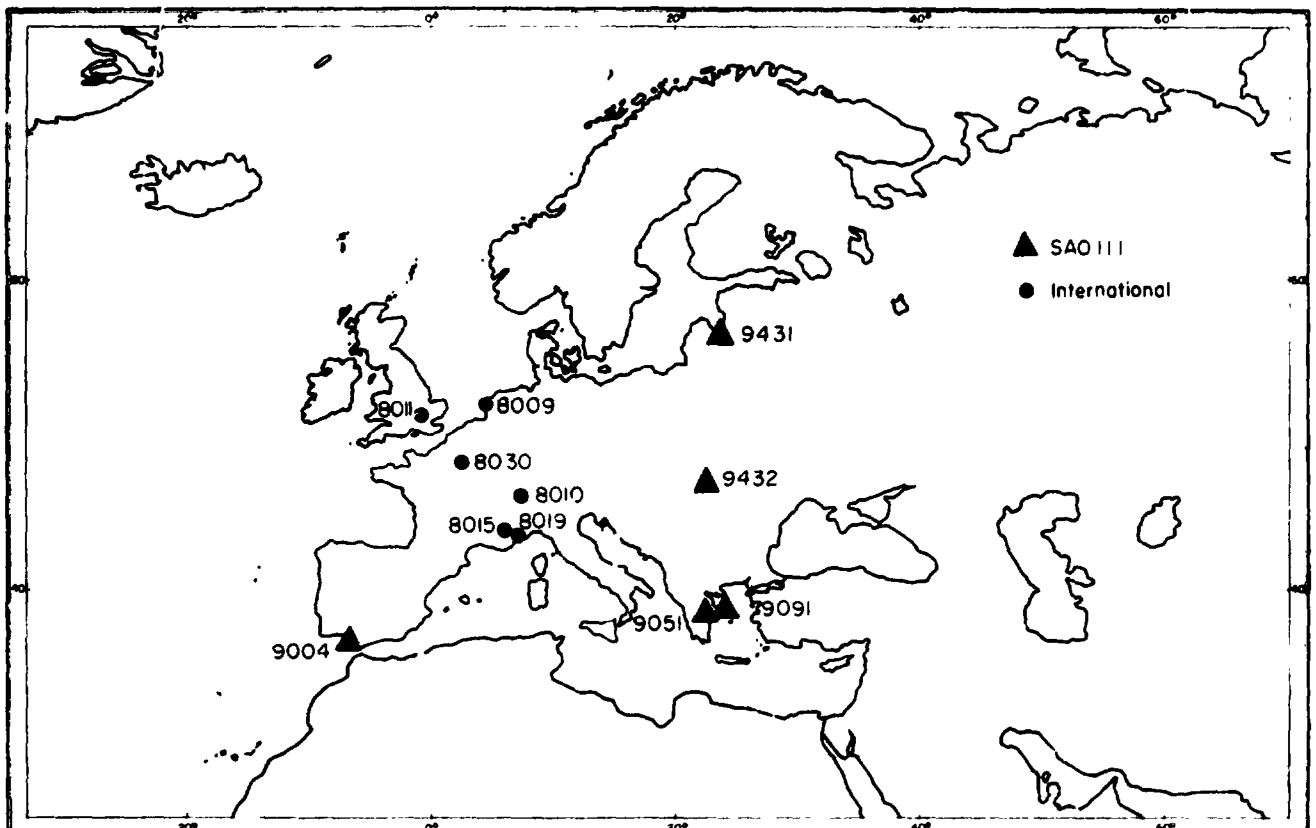


Fig. 3.2-2 MPS stations in Europe.

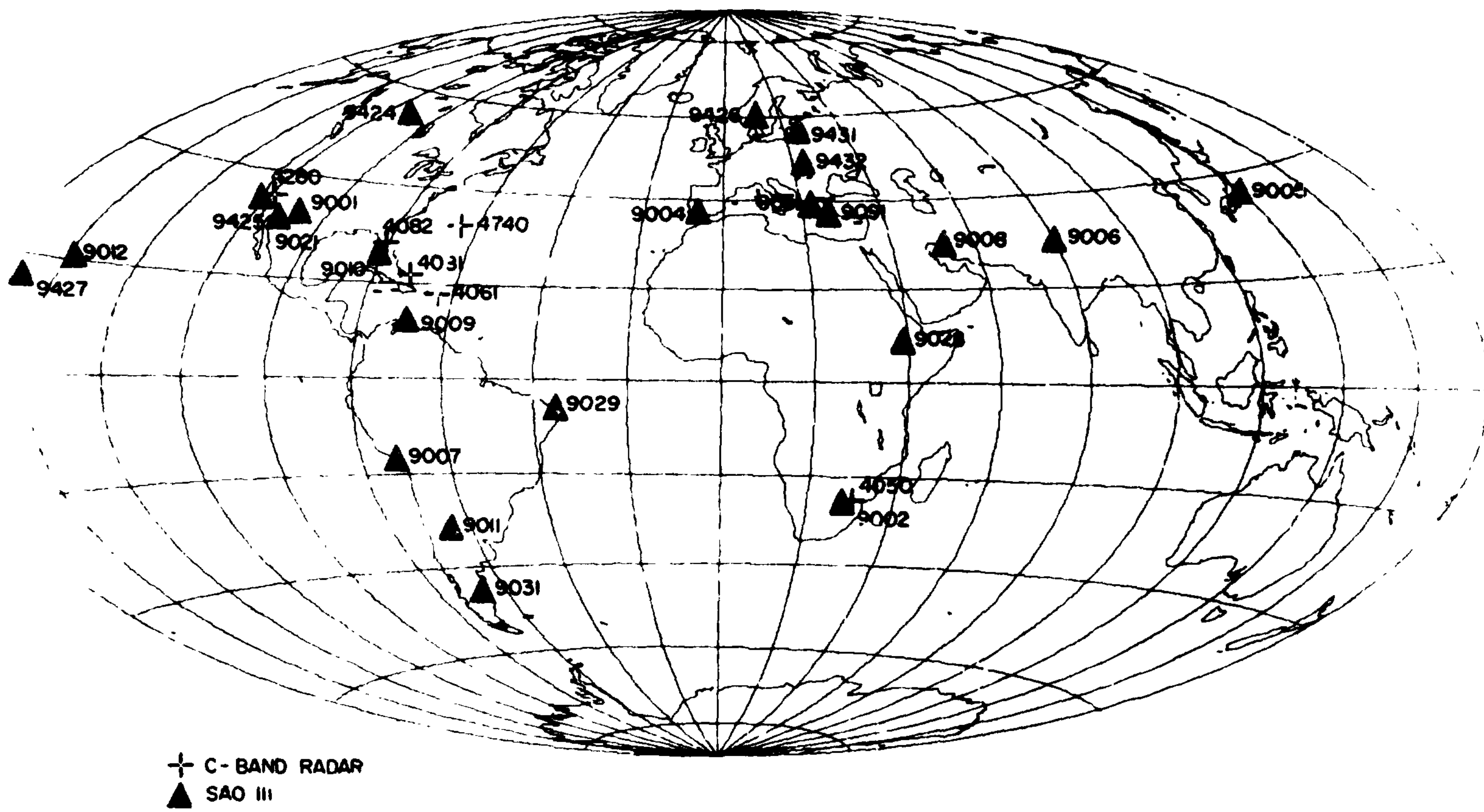


Fig. 3.2-3 SAO and C-Band stations in the MPS net.

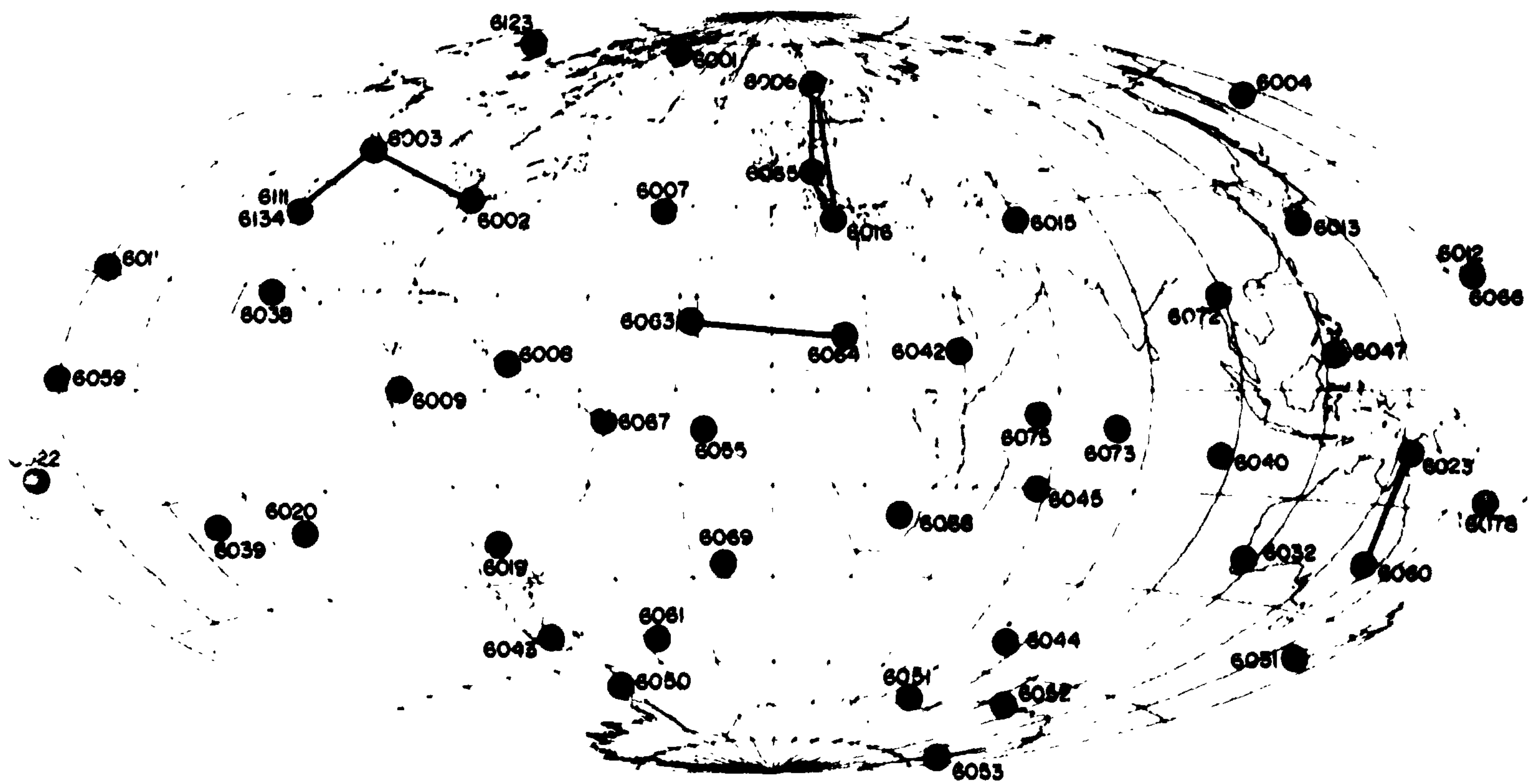


Fig. 3.2-4 BC-4 Worldwide Geometric Satellite Network.

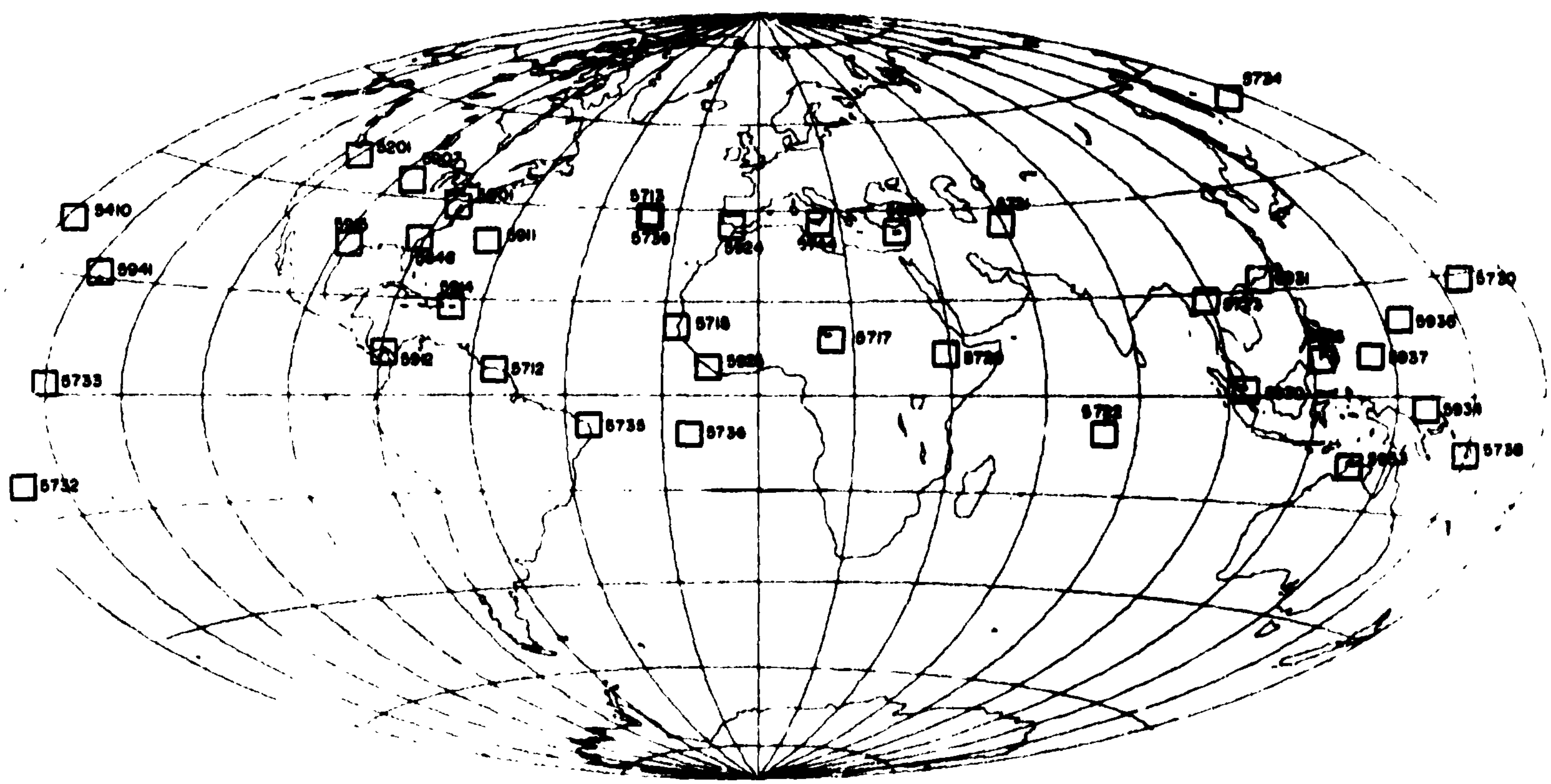


Fig. 3.2-5 SECOR Equatorial Network.

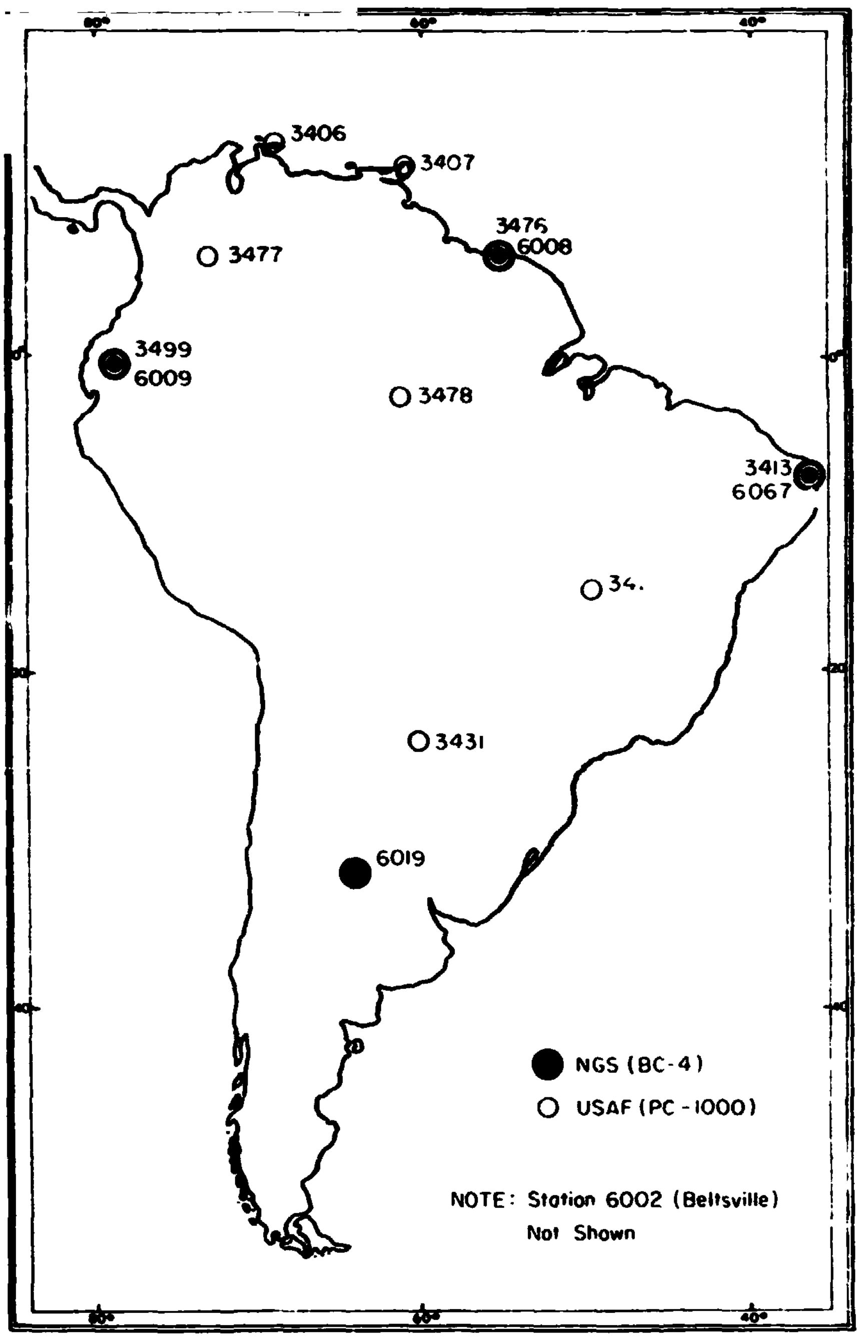


Fig. 3.2-6 South American densification net.

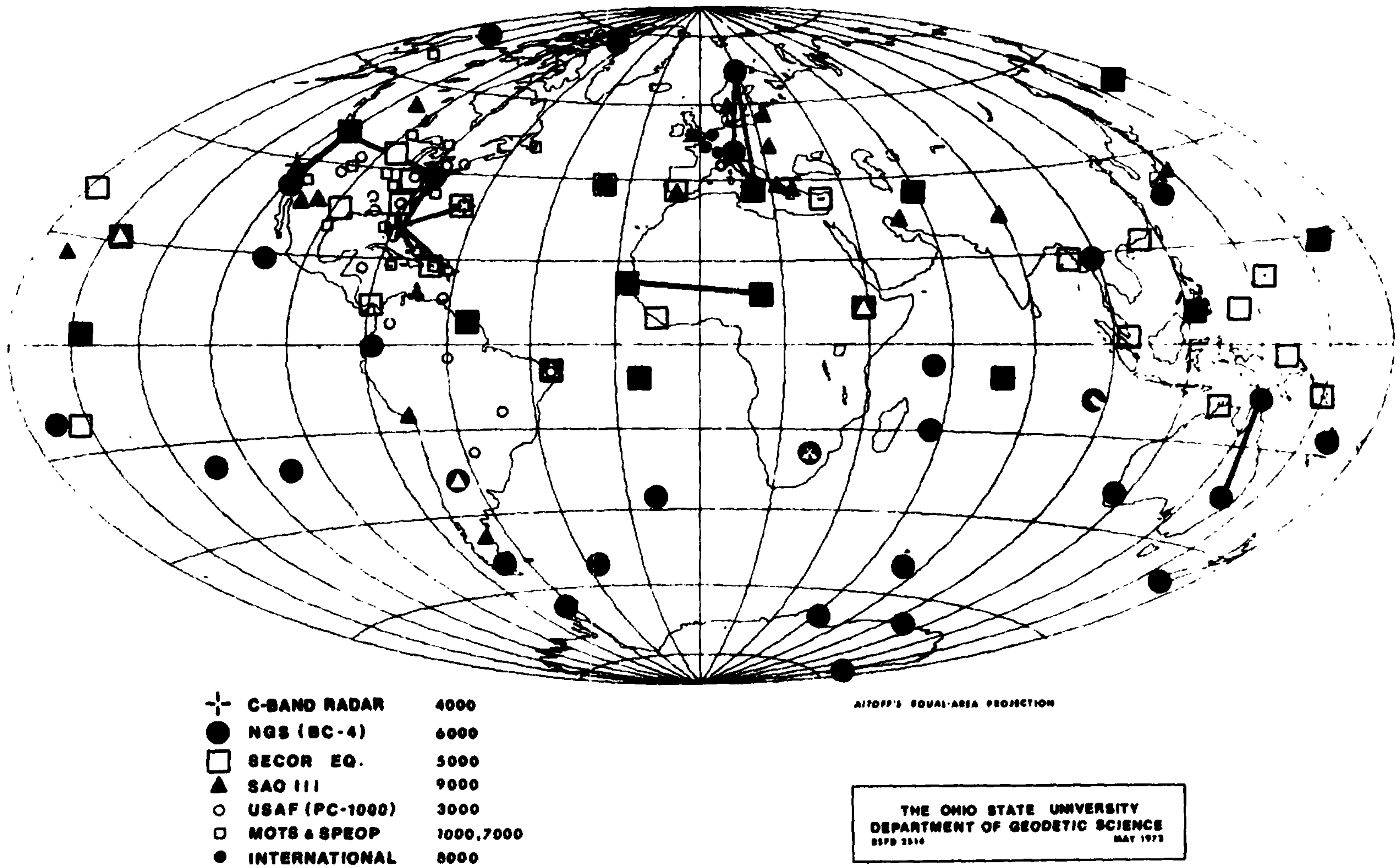


Fig. 3.2-7 OSU Geometric Satellite Network (WN)

Table 3.2-2

Summary of Observation Types

Instrument	NASA Series No.	Satellite Observed	OSU Network Where Used	Data Source*
MOTS	1000	GEOS-I	MPS	NSSDC
PC-1000	3000	GEOS-I	MPS	NSSDC
PC-1000 So. America	3000	Echo I,II PAGEOS GEOS-II	SA	DMA/Aerospace Center
C-Band Radar	4000	GEOS-II	MPS	NASA/Wallops Isl.
SECOR	5000	SECOR (EGRS)	SECOR	DMA/Topographic Center
BC-4	6000	PAGEOS	BC, SA	NGS, NSSDC
Special Optical	7000	GEOS I	MPS	NSSDC
International Optical	8000	GEOS, PAGEOS Echo I, II	MPS	SAO
Smithsonian Optical	9000	ANNA 1B Courier 1B Dash 2 Echo 1 Rocket Elektron 3 Explorer 9,19 Midas 4, 7 RCS, Relay 1 Telstar 1	MPS	SAO

*DMA Defense Mapping Agency
NGS National Geodetic Survey
NSSDC National Space Science Data Center
SAO Smithsonian Astrophysical Observatory

Table 3.2-3a

Summary of Simultaneous Observations by Line (MPS Network)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
1021-1022	47	1022-7037	91
1021-1030	11	1022-7039	52
1021-1032	4	1022-7040	90
1021-1034	35	1022-7043	88
1021-1042	39	1022-7045	43
1021-3106	6	1022-7072	221
1021-3401	25	1022-7075	31
1021-3402	17	1022-7076	44
1021-3405	22	1030-1033	10
1021-3406	13	1030-1034	97
1021-3407	6	1030-1042	34
1021-3648	5	1030-3401	4
1021-3657	36	1030-3402	22
1021-3861	13	1030-3404	4
1021-7036	24	1030-3657	6
1021-7037	41	1030-3861	12
1021-7039	6	1030-3903	6
1021-7040	29	1030-7036	94
1021-7043	59	1030-7037	75
1021-7045	11	1030-7043	20
1021-7072	10	1030-7045	98
1021-7075	31	1030-7072	10
1021-9001	14	1030-7075	35
1021-9010	24	1032-1042	3
1022-1030	60	1032-3401	[illegible]
1022-1034	78	1032-7043	6
1022-1042	127	1032-7072	1
1022-3106	31	1033-1034	13
1022-3400	5	1033-7045	9
1022-3401	81	1033-9425	10
1022-3402	62	1034-1042	117
1022-3404	53	1034-3334	4
1022-3405	24	1034-3400	6
1022-3406	54	1034-3401	33
1022-3407	4	1034-3402	2[illegible]
1022-3648	28	1034-3404	
1022-3657	30	1034-3648	5
1022-3861	114	1034-3657	15
1022-3903	6	1034-3861	27
1022-7036	109	1034-3902	5

Table 3.2-3a (cont'd)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
1034-3903	6	3106-3405	7
1034-7036	51	3106-3406	41
1034-7037	163	3106-3407	23
1034-7039	12	3106-3648	18
1034-7040	4	3106-3657	4
1034-7043	24	3106-3861	10
1034-7045	84	3106-7039	16
1034-7072	14	3106-7040	64
1034-7075	36	3106-7043	10
1034-7076	6	3106-7072	20
1034-9001	51	3106-7076	5
1034-9010	49	3334-3400	4
1034-9424	20	3334-3402	7
1034-9425	63	3334-3402	4
1042-3106	12	3334-7036	12
1042-3400	8	3334-7037	2
1042-3401	26	3334-7045	4
1042-3402	46	3400-3902	6
1042-3404	16	3400-7036	13
1042-3406	15	3400-7037	3
1042-3648	5	3400-7045	13
1042-3657	7	3401-3402	17
1042-3861	15	3401-3406	9
1042-3903	6	3401-3407	7
1042-7036	19	3401-3648	9
1042-7037	86	3401-3657	25
1042-7040	22	3401-3861	37
1042-7043	51	3401-3903	4
1042-7045	35	3401-7036	10
1042-7072	34	3401-7037	12
1042-7075	53	3401-7039	11
1042-7076	5	3401-7040	16
1042-9001	13	3401-7043	39
1042-9009	7	3401-7072	39
1042-9010	20	3401-7076	22
1042-9424	7	3402-3405	6
1042-9425	19	3402-3406	6
3106-3401	14	3402-3648	6
3106-3402	10	3402-3657	23
3106-3404	13	3402-3861	42

Table 3.2-3a (cont'd)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
3402-3902	4	3406-7072	25
3402-7036	23	3406-7076	19
3402-7037	22	3407-3657	6
3402-7039	10	3407-3861	14
3402-7040	6	3407-7039	4
3402-7043	20	3407-7040	31
3402-7072	13	3407-7043	7
3402-7076	8	3648-3657	10
3404-3401	14	3648-3861	28
3404-3402	17	3648-7036	6
3404-3405	4	3648-7037	20
3404-3406	7	3648-7039	6
3404-3407	5	3648-7040	7
3404-3648	12	3648-7072	16
3404-3657	7	3657-3861	24
3404-3861	29	3657-7036	19
3404-7037	9	3657-7037	15
3404-7039	6	3657-7039	4
3404-7040	28	3657-7040	6
3404-7043	7	3657-7043	31
3404-7072	3	3657-7045	6
3404-7076	4	3657-7072	28
3405-3406	7	3861-7036	33
3405-3407	12	3861-7037	34
3405-3657	12	3861-7039	5
3405-3861	6	3861-7040	8
3405-7036	9	3861-7043	8
3405-7037	6	3861-7072	73
3405-7039	5	3861-7076	13
3405-7040	19	3902-7036	12
3405-7043	13	3902-7037	12
3405-7072	6	3902-7045	6
3406-3407	19	3903-7037	6
3406-3861	23	3903-7043	6
3406-3903	5	3903-7045	6
3406-7036	11	7036-7037	124
3406-7037	5	7036-7039	14
3406-7039	21	7036-7043	6
3406-7040	31	7036-7045	56
3406-7043	3	7036-7072	44

Table 3.2-3a (cont'd)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
7036-7075	31	7075-9010	22
7036-7076	43	7076-9010	21
7036-9001	66	8009-8010	4
7036-9009	6	8009-8011	10
7036-9010	49	8009-8015	10
7036-9425	17	8009-8019	11
7037-7039	27	8009-9431	8
7037-7040	5	8009-9432	4
7037-7043	33	8010-8015	58
7037-7045	63	8010-8019	48
7037-7072	24	8010-9004	74
7037-7075	48	8010-9051	6
7037-7076	29	8010-9431	27
7037-9001	27	8010-9432	11
7037-9009	6	8011-8030	7
7037-9010	57	8011-9004	4
7037-9425	38	8011-9008	5
7039-7040	10	8011-9426	1
7039-7072	5	8011-9431	7
7039-7075	21	8015-8019	112
7039-7076	17	8015-9004	68
7039-9010	18	8015-9051	39
7040-7043	18	8015-9091	16
7040-7072	9	8015-9431	16
7040-7075	7	8015-9432	48
7040-7076	10	8019-8030	7
7040-9009	7	8019-9004	349
7040-9010	22	8019-9091	83
7043-7045	33	8019-9431	44
7043-7072	24	8019-9432	13
7043-7076	6	8030-9004	7
7045-7072	9	9001-9007	35
7045-7075	11	9001-9009	189
7045-7076	4	9001-9010	288
7045-9001	6	9001-9012	205
7045-9010	11	9001-9424	74
7045-9024	11	9001-9427	17
7045-9025	54	9002-9008	7
7072-7076	29	9002-9028	30
7075-7076	7	9004-9006	14

Table 3.2-3a (cont'd)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
9004-9008	146	9424-9425	56
9004-9009	44	9424-9426	5
9004-9010	43	9424-9427	2
9004-9028	44	9425-9427	15
9004-9029	48	9431-9432	21
9004-9051	40		
9004-9091	381		
9004-9424	1		
9004-9426	89		
9004-9431	74		
9005-9006	63		
9005-9008	3		
9005-9012	3		
9005-9427	3		
9006-9008	181		
9006-9028	30		
9006-9426	19		
9007-9009	276		
9007-9010	92		
9007-9011	467		
9007-9029	5		
9007-9031	36		
9008-9028	11		
9008-9051	16		
9008-9426	45		
9009-9010	117		
9009-9011	76		
9009-9424	7		
9010-9012	3		
9010-9424	12		
9011-9029	4		
9011-9031	9		
9012-9021	32		
9012-9424	26		
9012-9427	247		
9021-9425	61		
9028-9091	49		
9029-9031	32		
9091-9431	17		
9091-9432	23		

Table 3.2-3b

Summary of Simultaneous Observations by Line (BC Network)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
6001-6002	105	6007-6067	28
6001-6003	121	6008-6009	53
6001-6004	37	6008-6019	87
6001-6006	103	6008-6061	4
6001-6007	33	6008-6063	4
6001-6011	7	6008-6067	29
6001-6015	7	6009-6019	69
6001-6016	18	6009-6020	22
6001-6038	7	6009-6038	67
6001-6065	60	6009-6043	25
6001-6123	43	6011-6012	71
6002-6003	156	6011-6022	12
6002-6006	7	6011-6038	67
6002-6007	57	6011-6059	114
6002-6008	93	6011-6111	32
6002-6009	39	6011-6134	64
6002-6038	71	6012-6013	60
6002-6111	79	6012-6022	41
6002-6134	21	6012-6023	57
6003-6004	52	6012-6059	57
6003-6011	84	6012-6060	7
6003-6012	11	6013-6015	14
6003-6038	96	6013-6040	8
6003-6111	89	6013-6047	87
6003-6123	24	6013-6072	57
6003-6134	32	6013-6078	4
6004-6006	4	6015-6016	170
6004-6011	7	6015-6040	41
6004-6012	53	6015-6042	99
6004-6013	60	6015-6045	58
6004-6123	24	6015-6064	65
6006-6007	30	6015-6065	80
6006-6015	87	6015-6072	75
6006-6016	94	6015-6073	77
6006-6065	76	6015-6075	44
6007-6016	125	6016-6042	23
6007-6055	14	6016-6063	61
6007-6063	111	6016-6064	113
6007-6064	25	6016-6065	108
6007-6065	40	6019-6020	35

Table 3.2-3b (cont'd)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
6019-6043	132	6038-6134	71
6019-6061	77	6039-6059	49
6019-6067	70	6040-6044	4
6019-6069	8	6040-6045	96
6020-6038	60	6040-6047	36
6020-6039	18	6040-6060	19
6020-6043	52	6040-6072	16
6022-6023	15	6040-6073	52
6022-6031	44	6040-6075	53
6022-6039	14	6042-6045	93
6022-6059	103	6042-6064	96
6022-6060	33	6042-6068	93
6022-6078	21	6042-6073	22
6023-6031	51	6042-6075	75
6023-6032	116	6043-6050	74
6023-6040	14	6043-6061	88
6023-6047	50	6044-6045	11
6023-6060	224	6044-6051	33
6023-6066	29	6044-6052	7
6023-6072	28	6044-6068	4
6023-6078	28	6045-6051	42
6031-6032	102	6045-6068	112
6031-6039	15	6045-6073	99
6031-6051	7	6045-6075	90
6031-6052	57	6047-6060	8
6031-6053	101	6047-6072	88
6031-6059	4	6047-6078	4
6031-6060	305	6050-6051	7
6031-6078	28	6050-6052	14
6032-6040	72	6050-6053	25
6032-6044	36	6050-6061	63
6032-6045	18	6051-6052	100
6032-6047	54	6051-6053	103
6032-6051	12	6051-6061	35
6032-6052	34	6051-6068	106
6032-6053	8	6052-6053	98
6032-6060	174	6052-6060	47
6032-6072	7	6053-6060	35
6038-6039	55	6053-6061	7
6038-6059	35	6055-6061	14

Table 3.2-3b (cont'd)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
6055-6063	101		
6055-6064	99		
6055-6067	86		
6055-6068	11		
6055-6069	47		
6061-6067	18		
6061-6068	18		
6061-6069	29		
6063-6064	84		
6063-6065	7		
6063-6067	62		
6063-6069	14		
6064-6068	106		
6067-6069	4		
6068-6069	21		
6068-6075	14		
6072-6073	15		
6072-6075	14		
6073-6075	80		

Table 3.2-3c

Summary of Simultaneous Observations by Line (SA Network)

Line Station-Station	No. of Pairs	Line Station-Station	No. of Pairs
6002-6008	23	3406-3478	14
6002-3406	14	3406-3499	4
6002-3407	11	3407-3431	16
6002-3476	7	3407-3476	19
6002-3477	7	3407-3477	23
6008-6009	10	3407-3478	9
6008-6019	36	3413-3414	29
6008-6067	14	3413-3431	2
6008-3406	25	3414-3431	22
6008-3477	3	3476-3477	15
6008-3478	6	3477-3478	2
6009-6019	7	3477-3499	5
6009-3406	14		
6009-3407	6		
6009-3476	6		
6009-3477	5		
6009-3499	9		
6019-6067	35		
6019-3406	19		
6019-3407	38		
6019-3431	4		
6019-3476	19		
6019-3477	6		
6067-3407	3		
3406-3407	9		
3406-3413	25		
3406-3414	41		
3406-3431	53		
3406-3476	20		
3406-3477	13		

Table 3.2-3d

Summary of SECOR Observations by Quadrangle

Quad Stations Involved	No. of Observations	Quad Stations Involved	No. of Observations
5001-5907-5648-5911	432	5726-5930-5933-5934	644
5911-5001-5648-5914	168	5726-5933-5934-5935	808
5911-5907-5915-5912	1008	5931-5726-5934-5935	1144
5911-5915-5912-5712	92	5935-5726-5934-5730	2048
5911-5907-5912-5712	260	5935-5726-5934-5937	1264
5911-5915-5912-5712	228	5730-5935-5934-5938	2216
5911-5912-5712-5713	684	5730-5935-5938-5732	1380
5713-5911-5712-5715	1220	5730-5938-5732-5733	756
5715-5713 5712-5735	548	5730-5732-5733-5411	752
5715-5739-5712-5735	288	5730-5733-5411-5410	648
5715-5712-5735-5736	660	5730-5733-5411-5734	508
5715-5735-5736-5717	640	5734-5410-5411-5201	312
5715-5736-5717-5744	28	5734-5730-5411-5201	264
5739-5715-5717-5744	384		
5715-5736-5717-5744	464		
5744-5715-5717-5923	868		
5744-5715-5717-5924	804		
5744-5715-5717-5925	512		
5923-5744-5717-5720	1236		
5923-5717-5720-5721	772		
5744-5717-5720-5721	20		
5721-5923-5720-5722	752		
5721-5720-5722-5723	296		
5923-5721-5722-5723	36		
5723-5721-5722-5930	460		
5723-5722-5930-5931	588		
5722-5723-5930-5726	68		
5931-5723-5930-5726	768		
5931-5930-5726-5933	1064		
5723-5930-5726-5933	652		

3.22 Data Handling

3.221 Preprocessing. [70, 82, 93, 100, 106, 110, 195]

The term preprocessing covers any treatment (reductions, corrections, etc.) necessary to be applied to the observed data prior to its analysis for the purpose of removing systematic errors burdening the observations. From the point of view of the investigator who has not participated in the actual observations preprocessing can be considered as consisting of two parts, namely,

(1) Reductions and corrections of observed data by the respective agencies responsible for the observations prior to sending the data either to the National Space Science Data Center or to the individual investigator. This part of the preprocessing is dealt with by Hotter [1967] and by Gross [1968].

(2) Additional corrections to the reduced data, or homogenization of the data obtained from various agencies, screening of data for blunders and ambiguities are the parts of the preprocessing procedure to be done by the investigator.

Fig. 3.2-8 is a self-explanatory summary of both types of preprocessing for optical observations as handled in practice. The shaded blocks represent the portion of the work performed at OSU. For more details see [Hotter, 1967].

Fig. 3.2-9 is a summary of preprocessing applied to the SECOR data. For more details see [Gross, 1968].

No preprocessing was applied to the C-Band radar data [Mueller and Whiting, 1972].

CAMERA	NAME	DMA			NGS			NASA/GSFC			SAO		
		PC-1000			BC-4 (ASTRO) BC-4 (COSMO)			MOTS 24 MOTS 40 PTH 100			BAKER-NUNN K-50		
CATALOGUE		SAO			SAO			SAO			SAO		
CALIBRATION	TYPE	PHOTO			PHOTO			PHOTO			ASTRO		
	NO. OF STARS	25-30			120			40-50			8-10		
	NO. OF SAT. IMAGES (PASSIVE)	-			600			-			1		
	NO. OF PARAMETERS	18 (EXT. INT.: 6, REFRACT.: 2)			14-20 (EXT INT: 6, DIST.: 6, NON ⊥: 1, DIFF. SC.: 1, AVAIL.: 6)			8 (EXT. INT.: 6, REFRACT.: 2)			6		
	LENS DIST. PREDETERMINED	YES			NO			YES			-		
TIME SYNCHRONIZATION		PORTABLE CLOCK & VLF			PORTABLE CLOCK & VLF			ACTIVE SAT ONLY			PORTABLE CLOCK & VLF		
		STAR	SATELLITE	TIME	STAR	SATELLITE	TIME	STAR	SATELLITE	TIME	STAR	SATELLITE	TIME
STAR UPDATING AND SATELLITE IMAGE CORRECTIONS	PROPER MOTION	C			M			C			C		
	PRECESSION	C			M,C			M				▨	
	NUTATION	C			C			C				▨	
	ANNUAL ABERRATION	C			C			C				▨ C	
	DIURNAL ABERRATION	C			C			C				▨	
M MATRIX CORRECTION	ASTRO REFRACTION (GARFINKEL)	CP	- CP WITH ADJ. COEF.		CP	- CP		CP	- CP WITH ADJ. COEF.		IMPLICIT IN PLATE REDUCTION		
C CONVENTIONAL CORR.	PARALL. REFRACTION								C			▨	
CP: CONVENTIONAL DURING PLATE PROCESSING	SAT. ABERRATION (LIGHT TIME)						C (P.S.O.)					▨	C TO STA (A.S.O.)
PSO: PASSIVE SAT ONLY	UTC → UT1			▨			C			▨			
A.S.O.: ACTIVE SAT ONLY	UTC → A.S.												C
	A.S. → UT1												▨
	PHASE (PASSIVE ONLY)					C						▨	

▨ : PREPROCESSING CORRECTION NEEDED

Fig. 3.2-8 Optical data preprocessing procedure summary for major U.S. agencies.

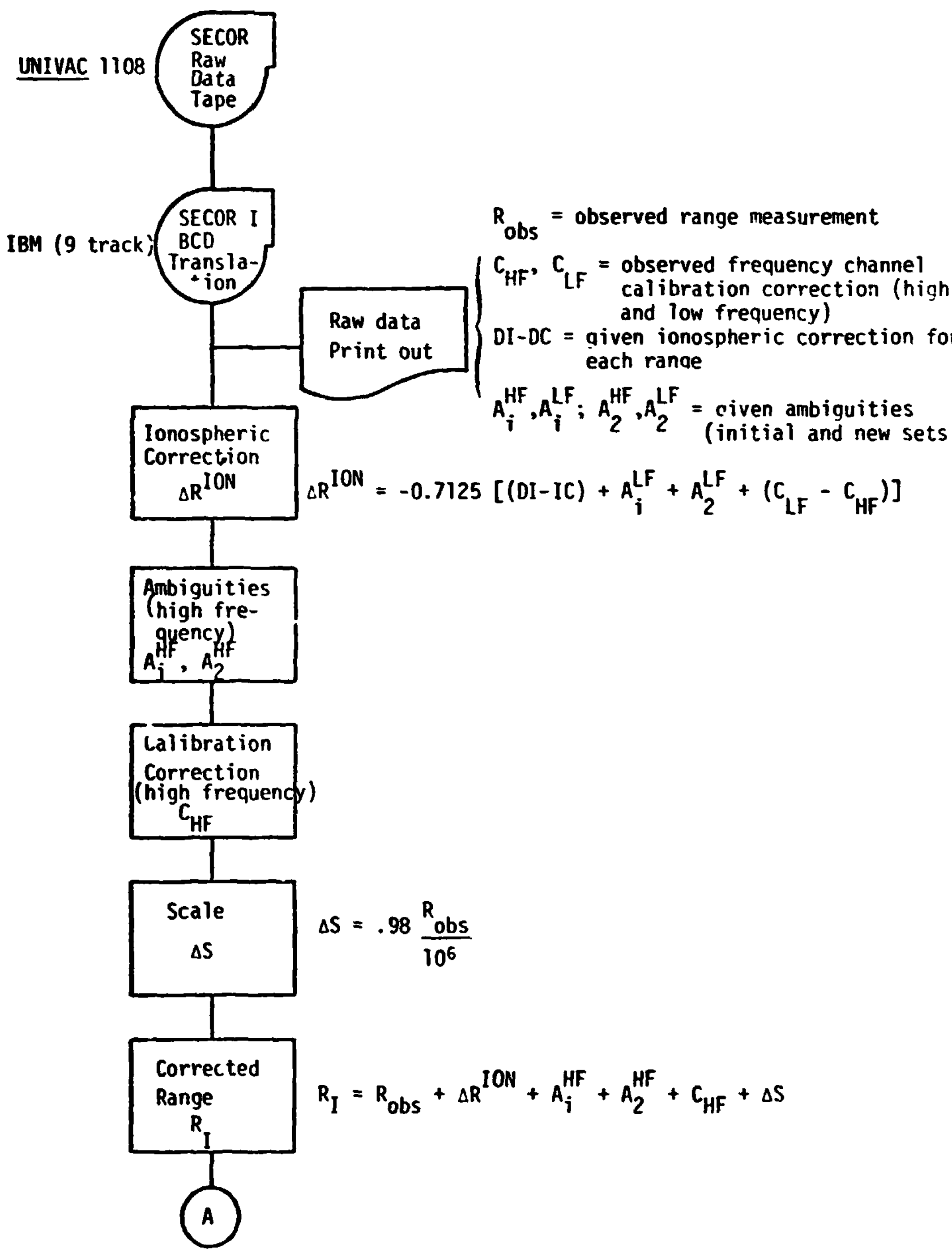


Fig. 3.2-9 Scheme of SECOR preprocessing procedure at OSU.

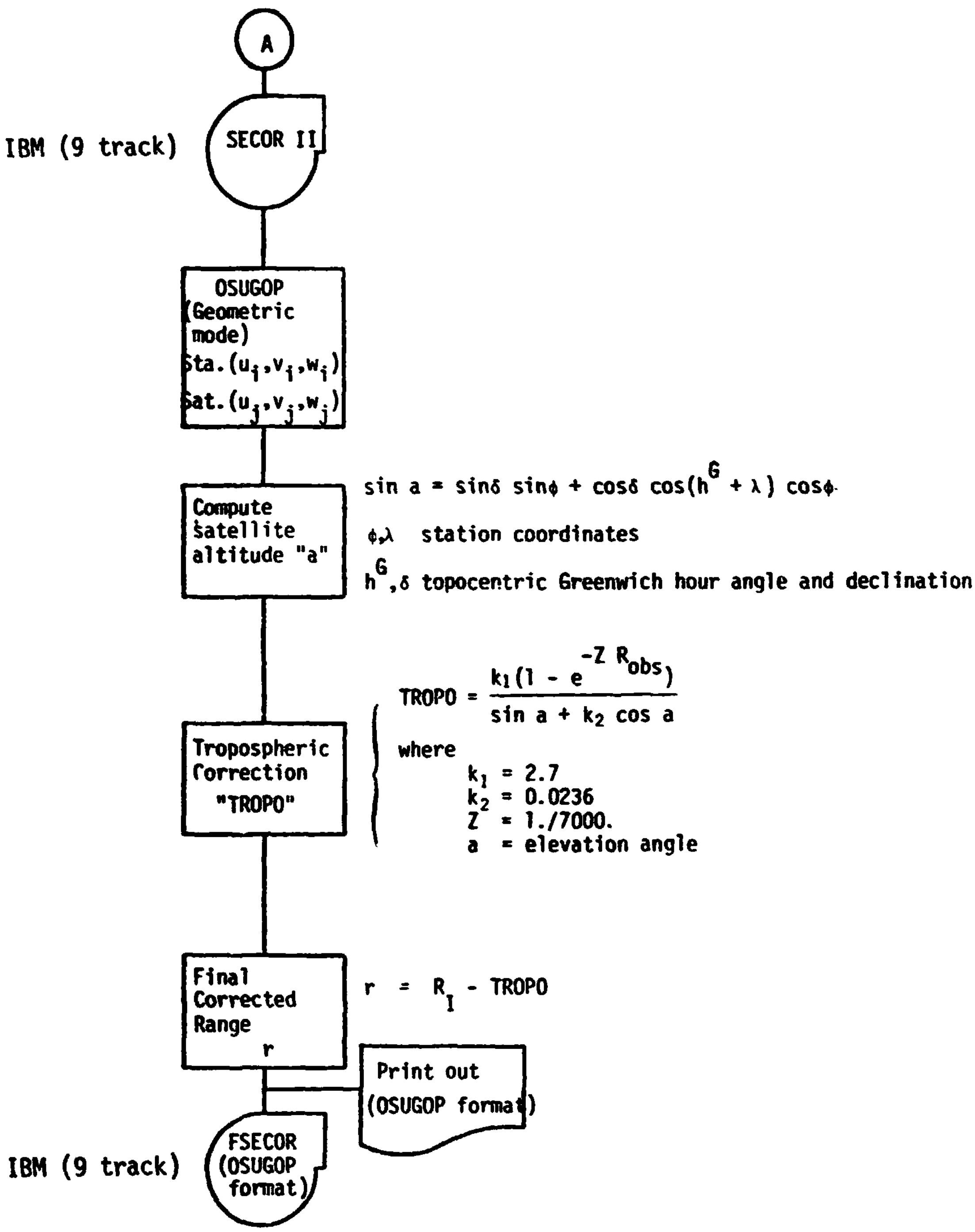


Fig. 3.2-9 Cont'd

3.222 Detection of Blunders and Rejection.* [86]

A. Optical Data. Blunders in the observed declinations and right ascensions and/or observing ground station coordinates are detected during the formation of the normal equations. The procedure used is to test the variance of unit weight that would result from a preliminary least squares adjustment of each simultaneous event. In this adjustment the ground stations are held fixed. The residuals on the ijth observed α, δ pair from such a preliminary adjustment are the first two elements of the 3 x 1 vector

$$V_{ij} = B_{ij}^{-1} (\vec{X}_i - \vec{X}_j^o) \quad \vec{X}_j^o = \{\sum_i M_{ij}^{-1}\}^{-1} \{\sum_i M_{ij}^{-1} \vec{X}_i\}$$

(The third element is the range to the preliminary adjusted satellite position.) And, therefore,

$$\sum_i V_{ij}' P_{ij} V_{ij} = \sum_i (\vec{X}_i - \vec{X}_j^o)' M_{ij}^{-1} (\vec{X}_i - \vec{X}_j^o)$$

since the third element is dispensed within the product

$$P_{ij} B_{ij}^{-1} (\vec{X}_i - \vec{X}_j^o)$$

(see equation 4.2-16). Therefore, the variance of unit weight is computed from

$$\sigma_o^2 = \frac{\sum_{event} (\vec{X}_i^o - \vec{X}_j^o)' M_{ij}^{-1} (\vec{X}_i^o - \vec{X}_j^o)}{2n - 3} \qquad 3.2 - 1$$

where the numerator can be shown to be the sum square of the weighted residuals (arc seconds squared) of all the observed declinations and right ascensions in the event; n is the number of ground stations in the event.

If a number of rejected simultaneous events repeatedly contain a particular ground station, it is probably due to a blunder in the coordinates

*To appreciate this section the reader is advised to study section 4 first.

of the particular ground station rather than in the observed quantities. In this case, the preliminary coordinates of that ground station should be verified.

B. Range Data. Blunders in the observed topocentric ranges and/or ground station coordinates are detected during the formation of the normal equations. The procedure used is to test the variance of unit weight (equation 3.2-10) arising from a preliminary least squares adjustment of each simultaneous event.

The preliminary adjustment is basically an iterative adjustment for the u_j, v_j, w_j rectangular coordinates of the satellite position by fixing the ground stations and applying the residuals of the adjustment to the observed ranges. The approximation to the parameters u_j, v_j, w_j is obtained bv converting the so-called approximate geodetic coordinates of the satellite into rectangular coordinates by use of equation 4.2- 18. The approximate geodetic coordinates of the satellite are obtained by averaging the latitudes and longitudes of the ground stations involved in the simultaneous event and estimating the ellipsoidal height of the satellite. The idea that the above is crude is immediately rejected upon the knowledge that at most four iterations (to a tolerance of 1 cm in u_j, v_j, w_j) are required and that the electronic computers perform these iterations more quickly than the time necessary to solve the corresponding simultaneous, exact, second-order equations.

The equation giving the mathematical structure of this preliminary adjustment is identical to equation 4.3-1, the mathematical structure for the main range adjustment. Since only three parameters are involved, the linearized form of the mathematical structure for n ground stations in one simultaneous event becomes

$$AX - \bar{V} + W = 0 \qquad 3.2 - 2$$

where the coefficient matrix

$$A = \begin{bmatrix} \frac{u_j^o - u_1^o}{r_{1j}^o} & \frac{v_j^o - v_1^o}{r_{1j}^o} & \frac{w_j^o - w_1^o}{r_{1j}^o} \\ \frac{u_j^o - u_2^o}{r_{2j}^o} & \frac{v_j^o - v_2^o}{r_{2j}^o} & \frac{w_j^o - w_2^o}{r_{2j}^o} \\ \vdots & \vdots & \vdots \\ \frac{u_j^o - u_k^o}{r_{kj}^o} & \frac{v_j^o - v_k^o}{r_{kj}^o} & \frac{w_j^o - w_k^o}{r_{kj}^o} \\ \vdots & \vdots & \vdots \\ \frac{u_j^o - u_m^o}{r_{mj}^o} & \frac{v_j^o - v_m^o}{r_{mj}^o} & \frac{w_j^o - w_m^o}{r_{mj}^o} \end{bmatrix} \qquad 3.2 - 3$$

the correction vector for the satellite coordinates

$$X = \begin{bmatrix} du_j \\ dv_j \\ dw_j \end{bmatrix} \qquad 3.2 - 4$$

the residual vector for the ranges

$$\bar{V} = \begin{bmatrix} \bar{v}_{1j} \\ \bar{v}_{2j} \\ \vdots \\ \bar{v}_{kj} \\ \vdots \\ \bar{v}_{mj} \end{bmatrix} \qquad 3.2 - 5$$

and the constant vector

$$W = \begin{bmatrix} r^o_{1j} - r^b_{1j} \\ r^o_{2j} - r^b_{2j} \\ \vdots \\ r^o_{mj} - r^b_{mj} \end{bmatrix} \qquad 3.2 - 6$$

where r^o_{1j} and r^b_{1j} are preliminary and observed ranges respectively.

The normal equations

$$NX + U = 0 \qquad 3.2 - 7$$

where

$$N = A'PA \qquad 3.2 - 8$$

and

$$U = A'PL \qquad 3.2 - 9$$

are solved for X by iteration until the elements of the vector X are less than 1 cm. At this point, X is entered into equations 3.2 - 2 and the vector of residuals $\overline{V}$ is determined; the variance of unit weight is then computed according to

$$\sigma^2_o = \frac{\overline{V}'P\overline{V}}{n - 3} \qquad 3.2 - 10$$

The complete set of data for the simultaneous event is printed out for evaluation in the case that the particular σ^2_0 is greater than a chosen input value. At the same time, no contribution is made to the normal equations by the rejected event.

3.3 Constraints

For the explanation of the type of constraints used in the solution, see section 4.5. Only the data used in applying the various constraints is summarized here in Tables 3.3-1 to 3.3-4.

Table 3.3-1

Summary of Constraint-Types with the Source Information

Code	Constraint Type	Source (Agency)*
	Relative Position	
1	BC-4 - Baker-Nunn	SAO, NGS
2	BC-4 - SECOR	DMA/TC
3	BC-4 - BC-4	NGS
4	Others	OSU
	Height	
5	MSL (mean sea level heights)	CSC, NGS, NWL
6	Geoidal undulations	OSU [Rapp, 1973]
	Length (Chord)	
7	North America	NGS
8	Europe	NGS, DGFI
9	Africa	NGS
10	Australia	NGS, DNP
11	C-Band	NASA/Wallops Isl.

*CSC Computer Sciences Corporation
DGFI Deutsche Geodätisches Forschungsinstitut
DMA/TC Defense Mapping Agency Topographic Center
DNP Division of National Mapping, Dept. of National Development, Australia
NGS National Geodetic Survey
NWL Naval Weapons Laboratory
SAO Smithsonian Astrophysical Observatory

Table 3.3-2

Relative Position Constraints

STATIONS	RELATIVE COORDINATES (METERS) Δu	Δv	Δw	WEIGHTS[1] ($1/\sigma^2$)	SOURCE CODE[2]
1033-6123	-417481.74	-623256.41	-267774.54	0.01	4
3106-4061	245.98	359.44	514.15	0.75	4
3405-4081	-928.41	-1670.35	-3352.87	0.75	4
3406-9009	-10.62	4.41	27.55	3.00	4
3413-6067	-48.64	-289.13	1258.05	3.00	4
3476-6008	36.31	22.94	-20.80	3.00	4
3499-6009	0.0	0.0	0.0	100.00	4
3648-5648	37875.28	10510.31	7502.84	3.00	4
4050-9002	-4500.31	10094.67	1601.88	0.75	4
4082-9010	-65710.25	62288.48	137731.57	0.28	4
4280-9425	-221861.49	103220.84	-27546.08	0.12	4
4740-7039	674.06	-699.92	-1476.31	0.75	4
4712-9012	-77910.13	349731.80	145328.72	0.05	4
5201-6003	29.55	-48.21	-25.52	1.00	2
5712-6008	48.95	45.97	137.68	1.00	2
5713-5739	8.05	33.26	9.95	20.00	2
5713-6007	2.08	-1.06	1.88	1.00	2
5715-6063	1.05	-83.72	-95.45	1.00	2
5720-6042	-1.87	-0.26	30.16	1.00	2
5720-9028	-2977.60	3046.18	2495.80	1.00	4
5721-6015	49.67	-44.84	23.59	1.00	2
5726-6047	30.82	24.81	3.07	1.00	2
5730-6012	-4.69	-41.68	26.66	1.00	2
5733-6059	-0.92	-0.38	0.04	1.00	2
5734-6004	-1.20	0.12	1.59	1.00	2
5735-6067	-46.20	-290.84	1257.74	1.00	2
5736-6055	5.82	-13.48	42.60	1.00	2
5744-6016	49.84	-46.49	-42.16	1.00	2
6002-7043	56.22	499.51	568.41	3.00	4
6011-9012	49.30	-118.74	35.91	3.00	4
6012-6066	1.93	42.34	-25.67	100.00	3
6013-9005	380844.93	754432.31	-395410.11	0.01	4
6019-9011	52.02	37.19	-18.98	3.00	1
6042-9028	-2975.73	3046.44	2465.64	3.00	1
6067-9029	-44.28	-61.36	37.21	3.00	1
6068-9002	28721.97	-46167.30	7673.52	2.50	1
6111-6134	53.73	90.04	305.32	100.00	3
6111-9425	1157.34	-43554.26	-52281.82	1.62	4
6134-9021	-512117.65	409642.99	250524.73	0.02	4
7072-9010	-15.04	2.34	7.39	3.00	4
8015-8019	-1141.50	-128638.06	15776.51	0.45	4
8015-8030	372698.34	294250.47	-373345.41	0.02	4
9051-9091	11702.66	-9725.37	-9108.39	3.00	4

[1] APPLIED EQUALLY TO ALL THREE RELATIVE COORDINATES IN M^{-2} UNIT

[2] REFER TO TABLE 3.3-1

Table 3.3-3

Geoidal Undulations and Heights Used in the Constraints

STATION NO	STATION NAME	NREF[1] (M)	HCONSTR[2] (M)	$\sigma_{HCONSTR}$[3] (M)
1021	BLOSSOM POINT	-37.32	-45.65	2.5
1022	FORT MYERS	-31.58	-39.92	4.0
1030	GOLDSTONE	-30.00	896.45	4.0
1032	ST. JOHN'S	11.57	61.03	4.0
1033	FAIRBANKS	9.11	168.16	6.0
1034	E. GRAND FORKS	-25.47	218.56	2.5
1042	ROSMAN	-34.38	862.55	4.0
3106	ANTIGUA	-49.83	-68.70	8.0
3334	STONEVILLE	-31.54	-2.54	4.0
3400	COLORADO SPRINGS	-18.42	2159.63	2.5
3401	BEDFORD	-30.59	36.93	2.5
3402	SEMMES	-29.04	33.07	4.0
3404	SWAN ISLAND	-6.69	20.89	6.0
3405	GRAND TURK	-49.77	-64.73	6.0
3406	CURACAO	-29.19	-41.02	4.0
3407	TRINIDAD	-38.57	194.83	4.0
3413	NATAL	-12.03	-5.87	6.0
3414	BRASILIA	- 9.88	1021.23	6.0
3431	ASUNCION	11.98	137.72	6.0
3476	PARAMARIBO	-28.31	-34.02	6.0
3477	BOGOTA	10.71	2551.44	6.0
3478	MANAUS	- 7.17	53.63	6.0
3499	QUITO	16.73	2682.74	6.0
3648	HUNTER AFB	-35.70	-36.84	2.5
3657	ABERDEEN	-36.55	-45.38	2.5
3861	HOMESTEAD	-33.70	-47.20	4.0
3902	CHEYENNE	-16.53	1859.48	2.5
3903	HERNDON	-36.87	117.14	6.0
4050	PRETORIA	24.12	1573.21	6.0
4061	ANTIGUA	-49.83	-28.30	8.0
4081	GRAND TURK	-49.84	-31.01	6.0
4082	MERRITT ISLAND	-35.74	-37.91	4.0
4280	VANDERBERG AFB	-36.78	84.53	4.0
4740	BERMUDA	-43.45	-41.92	4.0
4742	KAUAI	5.61	1166.61	8.0
5001	HERNDON	-36.87	76.95	6.0

Table 3.3-3 (cont'd)

STATION NO	STATION NAME	NREF[1] (M)	HCONSTR[2] (M)	$\sigma_{HCONSTR}$[3] (M)
5201	MOSES LAKE	-17.65	347.84	4.0
5410	MIDWAY ISLANDS	- 4.13	7.51	8.0
5648	FORT STEWART	-35.07	-20.18	2.5
5712	PARAMARIBO	-28.31	-30.79	4.0
5713	TERCEIRA	54.00	83.29	4.0
5715	DAKAR	27.20	21.50	4.0
5717	FORT LAMY	10.35	273.29	6.0
5720	ADDIS ABABA	- 5.78	1850.34	6.0
5721	MASHHAD	-20.67	949.29	4.0
5722	DIEGO GARCIA	-73.64	-92.76	8.0
5723	CHIANG MAI	-40.39	256.21	8.0
5726	ZAMBOANGA	62.16	69.14	8.0
5730	WAKE ISLAND	13.75	26.83	8.0
5732	PAGO PAGO	27.35	40.70	6.0
5733	CHRISTMAS ISLAND	16.07	25.90	8.0
5734	SHEMYA	6.22	45.72	8.0
5735	NATAL	-12.03	-3.37	6.0
5736	ASCENSION ISLAND	16.26	55.09	8.0
5739	TERCEIRA	54.00	83.39	4.0
5744	CATANIA	37.43	18.89	4.0
5907	WORTHINGTON	-28.11	445.03	2.5
5911	BERMUDA	-43.44	-39.80	8.0
5912	PANAMA	6.16	0.39	6.0
5914	PUERTO RICO	-50.08	-5.07	6.0
5915	AUSTIN	-26.32	172.03	2.5
5923	CYPRUS	24.64	158.72	8.0
5924	ROTA	54.48	36.90	6.0
5925	ROBERTS FIELD	33.75	10.31	6.0
5930	SINGAPORE	8.28	1.16	6.0
5931	HONG KONG	2.32	155.02	6.0
5933	DARWIN	50.66	61.75	8.0
5934	MANUS	74.75	81.69	8.0
5935	GUAM	48.15	86.00	8.0
5937	PALAU	69.93	137.52	8.0
5938	GUADALCANAL	59.97	74.99	8.0
5941	MAUI	2.05	40.25	8.0

Table 3.3-3 (cont'd)

STATION NO	STATION NAME	NREF[1] (M)	HCONSTR[2] (M)	$\sigma_{HCONSTR}$[3] (M)
6001	THULE	11.66	204.62	8.0
6002	BELTSVILLE	-36.90	-6.73	2.5
6003	MOSES LAKE	-17.65	347.66	4.0
6004	SHEMYA	6.22	43.22	8.0
6006	TROMSO	27.06	113.19	4.0
6007	TERCEIRA	54.00	80.59	4.0
6008	PARAMARIBO	-28.31	-33.91	4.0
6009	QUITO	16.73	2683.04	6.0
6011	MAUI	1.75	3056.88	8.0
6012	WAKE ISLAND I	13.75	22.23	8.0
6013	KANOYA	34.27	96.47	6.0
6015	MASHHAD	-20.67	945.89	4.0
6016	CATANIA	37.43	16.33	4.0
6019	VILLA DOLORES	22.80	609.43	6.0
6020	EASTER ISLAND	- 4.75	219.02	8.0
6022	TUTUILA	27.35	38.04	8.0
6023	THURSDAY ISLAND	67.94	127.40	4.0
6031	INVERCARGILL	8.68	6.35	8.0
6032	CAVERSHAM	-30.51	-15.59	6.0
6038	SOCORRO ISLAND	-35.47	-15.81	6.0
6039	PITCAIRN ISLAND	-16.68	32..45	8.0
6040	COCOS ISLAND	-38.11	-50.26	8.0
6042	ADDIS ABABA	- 5.78	1847.40	6.0
6043	CERRO SOMBRERO	15.60	76.25	8.0
6044	HEARD ISLAND	36.61	17.16	8.0
6045	MAURITIUS	- 6.07	113.55	8.0
6047	ZAMBOANGA	62.17	65.24	8.0
6050	PALMER STATION	15.70	11.71	6.0
6051	MAWSON STATION	29.20	17.68	6.0
6053	MCMURDO STATION	-56.10	-50.90	6.0
6055	ASCENSION ISLAND	16.26	52.04	8.0
6059	CHRISTMAS ISLAND	16.07	25.15	8.0
6060	CULGOORA	27.33	236.27	6.0
6061	SOUTH GEORGIA	11.28	-10.88	8.0
6063	DAKAR	27.20	20.50	4 [illegible]
6064	FORT LAMY	10.35	270.19	6.0

Table 3.3-3 (cont'd)

STATION NO	STATION NAME	NPEF [1] (M)	HCONSTR [2] (M)	$\sigma_{HCONSTR}$ [3] (M)
6065	HOHENPEISSENBERG	44.23	960.09	2.5
6066	WAKE ISLAND II	13.74	24.02	8.0
6067	NATAL	-12.03	-2.14	6.0
6068	JOHANNESBURG	24.65	1513.46	6.0
6069	TRISTAN DA CUNHA	25.52	17.30	8.0
6072	CHIANG MAI	-40.39	264.61	8.0
6073	DIEGO GARCIA	-73.64	-94.96	8.0
6075	MAHE	-44.40	514.23	8.0
6078	PORT VILA	63.10	81.72	8.0
6111	WRIGHTWOOD I	-33.18	2248.74	4.0
6123	POINT BARROW	- 1.40	1.62	6.0
6134	WRIGHTWOOD II	-33.19	2167.83	4.0
7036	EDINBURG	-19.78	32.17	4.0
7037	COLUMBIA	-33.87	229.20	2.5
7039	BERMUDA	-43.43	-30.60	4.0
7040	SAN JUAN	-50.55	-20.06	6.0
7043	GREENBELT	-36.91	2.46	2.5
7045	DENVER	-18.10	1765.36	2.5
7072	JUPITER	-36.04	-35.56	4.0
7075	SUDBURY	-39.20	230.07	2.5
7076	KINGSTON	-26.62	403.91	8.0
8009	WIPPOLDER	42.33	41.11	4.0
8010	ZIMMERWALD	44.77	920.58	2.5
8011	MALVERN	47.43	134.97	4.0
8015	HAUTE PROVENCE	46.38	676.87	4.0
8019	NICE	45.91	394.73	4.0
8030	MEUDON	44.64	183.23	2.5
9001	ORGAN PASS	-27.93	1623.14	4.0
9002	OLIFANTSFONTEIN	24.27	1533.45	6.0
9004	SAN FERNANDO	54.57	50.44	6.0
9005	TOKYO	30.20	88.17	6.0
9006	NAINI TAL	-48.12	1858.89	6.0
9007	AREQUIPA	31.82	2464.57	6.0
9008	SHIRAZ	-10.91	1559.17	6.0
9009	CURACAO	-29.19	-39.15	4.0
9010	JUPITER	-36.04	-34.63	4.0

Table 3.3-3 (cont'd)

STATION NO	STATION NAME	NREF [1] (M)	HCONSTR [2] (M)	$\sigma_{HCONSTR}$ [3] (M)
9011	VILLA DOLORES	22.80	609.25	6.0
9012	MAUI	1.76	3041.76	8.0
9021	MOUNT HOPKINS	-27.00	2351.01	4.0
9028	ADDIS ABABA	- 5.78	1886.15	6.0
9029	NATAL	-12.03	2.57	6.0
9031	COMODORO RIVADAVIA	13.43	179.36	8.0
9051	ATHENS	32.81	190.96	8.0
9091	DIONYSOS	32.84	470.13	8.0
9424	COLD LAKE	-26.21	672.13	2.5
9425	EDWARDS AFB	-32.39	749.47	4.0
9426	HARESTUA	36.39	589.17	2.5
9427	JOHNSTON ISLAND	8.83	20.59	8.0
9431	RIGA	25.67	9.76	2.5
9432	UZHGOROD	39.71	201.99	2.5

[1] FROM [RAPP,1973]

[2] HCONSTR = MSL - NREF + ΔN (SEE SECTION 5.1)

[3] USED IN COMPUTING THE WEIGHTS OF THE HEIGHT CONSTRAINTS

Table 3.3-4

Chord Constraints

Station-Station	Chord Distance (meters)	$\sigma \times 10^6$ [1]	Source Code[2]
6002-6003	3 485 363.232	1.00	7
6003-6111	1 425 876.452	1.11	7
6006-6065	2 457 765.810	1.43	8
6016-6065	1 194 793.601	1.18	8
6063-6064	3 485 550.755	1.18	9
6023-6060	2 300 209.803	2.00	10
6032-6060	3 163 623.866	Rejected	10
6006-6016	3 54[illegible] 871.454	1.00	8
3861-7043	1 531 562.9	1.33	7
4082-4050	10 909 592	Rejected	11
4082-4742	7 362 142	Rejected	11
4082-4740	1 593 106	2.00	11
4082-4081	1 230 691	2.00	11
4082-4061	2 288 026	2.00	11
4742-4280	3 977 684	Rejected	11

[1] Used in computing the weights.

[2] Refer to Table 3.3-1.

4. THEORY AND MATHEMATICAL MODELS [86, 150, 185, 191]

This section presents almost the complete theory used in transforming the observational data (section 3) into geodetic results. Left out of this section and given in section 3 instead is that part of the theory which concerns the preprocessing procedure of the observed data where systematic errors in the observed data are removed, detected, and eliminated, or where generally the necessary corrections to the observed data are made before inserting them into the method of least squares adjustment.

4.1 Definitions and Coordinate Systems [86]

4.11 Basic Concepts and Statement of the Problem

A theory proceeds from a set of known facts or assumptions called the data, and by manipulating these according to accepted rules called theory, produces certain conclusions called results. This process is started in response to the posing of a problem. The problem in this case can be stated as follows:

Given are the approximate coordinates of a number of points (stations) on the surface of the earth, which are assumed to be in error by unknown amounts. Also given are measured distances and/or directions from these points to other points on and also above the surface of the earth (artificial satellites); the observations occur in sets with all observations within a given set being made at the same time. The problem is then to find the most probable values for the unknown errors in the coordinates of points (stations) on the earth's surface.

Thus in this "space triangulation (trilateration)" method satellites are observed simultaneously from groups of known and unknown ground stations, permitting a purely geometric solution. The main characteristic of this method is that orbital elements are not required. If the satellite positions are needed they can be computed from the preliminary coordinates of the ground stations and the observations themselves.

The method used to get a solution is therefore (1) to set up the equations giving the observations (angle or distance) in terms of observer and satellites coordinates; (2) linearize these equations to give observation residuals in terms of observer and satellites coordinate errors; (3) select from the data available those which can be put into simultaneity sets; (4) using known and assumed statistical properties of the observations, solve the equations of (2) using the data of (4).

Since the method is geometric and involves coordinates of earth surface points and of points in "inertial" space, transformation between coordinate systems occurs frequently. The systems used and their interrelation are described in 4.12 and 4.13 respectively.

4.12 Coordinate Systems

The optical observations after preprocessing (section 3.22) are assumed to be in the true topocentric celestial system, while the preprocessed topocentric ranging data is independent of the coordinate system used.

Two distinct types of coordinate systems have been used here:

(a) the terrestrial (average and instantaneous) system,

(b) the celestial (true) system.

The following summary of these systems assumes right-handed rectangular coordinates with axes numbered according to Fig. 4.1-1. Generally the origin of the coordinate system coincides with or is near to the center of gravity of the earth.

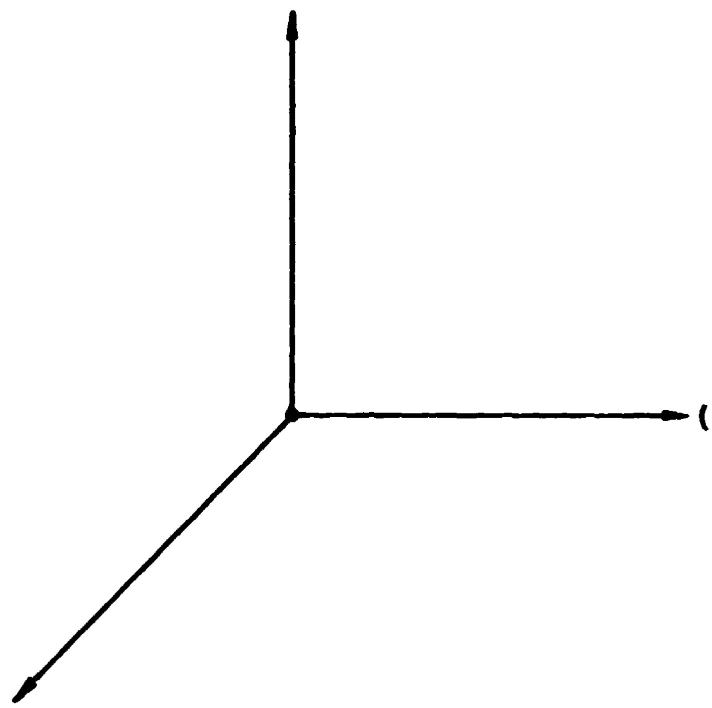


Fig. 4.1-1 Numbering of coordinate axes.

Average Terrestrial (X)

(·) 3-axis directed toward the average north terrestrial pole as defined by the International Polar Motion Service (IPMS), commonly known as the Conventional International Origin (CIO) [Mue''er, 1969, p. 351].

(b) 1-3 plane parallel to the mean Greenwich astronomic meridian as defined by the Bureau International de l'Heure (BIH) [Mueller, 1969, p. 343].

This system is the geodetic (terrestrial) coordinate system later also referred to as the u,v,w system.

Instantaneous Terrestrial (Y)

(a) 3-axis directed toward the instantaneous rotation axis of the earth (true celestial pole), the coordinates of which are given by the IPMS or by the BIH with respect to the CIO.

(b) 1-3 plane contains the point where the mean Greenwich astronomic meridian intersects the true equator of date.

This coordinate system is used as the intermediate connection between the terrestrial and celestial coordinate systems.

True Celestial (Z)

(a) 3-axis equivalent to 3-axis of instantaneous terrestrial system (true celestial pole).

(b) 1-axis directed toward the true vernal equinox of date.

These and still other coordinate systems are discussed in detail in [Veis, 1963; Mueller, 1969].

4.13 Transformations of Coordinate Systems

Transformation between terrestrial and celestial coordinate systems becomes necessary in the case that topocentric directions to satellites are obtained by photographing the satellite against a background of stars. After corrections for the physical effects such as differential refraction and aberration, shimmer, etc. [Mueller, 1964, pp. 309-317; Hotter, 1967] have been applied, the resulting topocentric right ascension and declination form the purely geometric ground-to-satellite direction. In terms of the corresponding direction cosines, $\vec{Z}$ can be expressed by the column vector

$$\vec{Z} = \begin{bmatrix} \cos\delta & \cos\alpha \\ \cos\delta & \sin\alpha \\ \sin\delta & \end{bmatrix} = \begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \end{bmatrix} \qquad 4.1 - 1$$

In order to transform $\vec{Z}$ from the celestial to the average terrestrial system (in which the mathematical model for the adjustment is expressed), rotations about the coordinate axes are required.

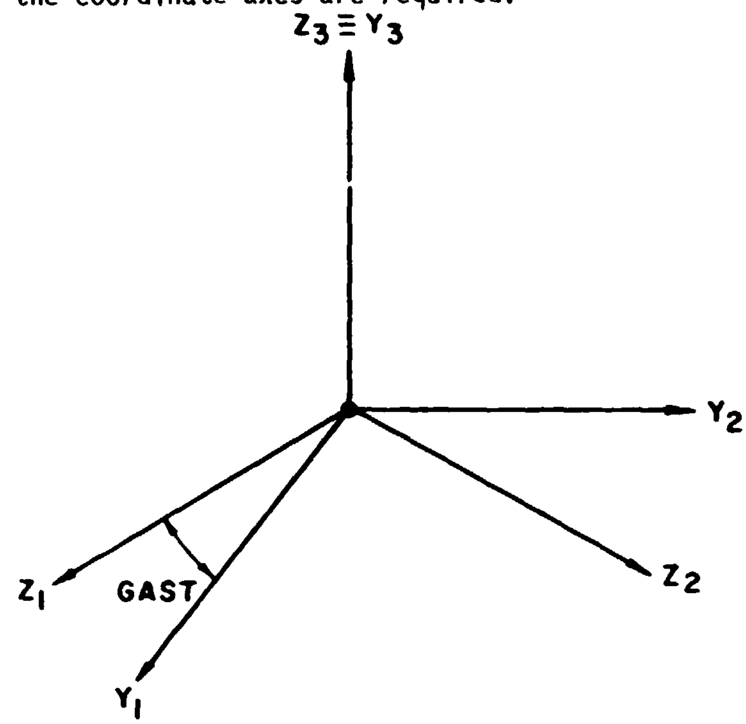


Fig. 4.1-2 True celestial and instantaneous terrestrial coordinate systems.

Transformation is first made into the instantaneous terrestrial system (see Fig. 4.1-2). This transformation is a function of a single finite rotation through the Greenwich apparent sidereal time (GAST). A vector $\vec{Z}$ in the true celestial system is transformed into the instantaneous terrestrial system by the following equation:

$$\vec{Y} = R_3 \text{ (GAST) } \vec{Z} \qquad 4.1 - 2$$

where $\vec{Y}$ is the resulting vector in the instantaneous terrestrial system and R_3 (GAST) is a 3 x 3 matrix that expresses a counterclockwise rotation, as viewed from the positive end of the 3 axis, by the amount GAST, namely:

$$R_3\ (GAST) = \begin{bmatrix} \cos(GAST) & \sin(GAST) & 0 \\ -\sin(GAST) & \cos(GAST) & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad 4.1 - 3$$

Next the vector $\vec{Y}$ in the instantaneous terrestrial system (Y) is transformed to the average terrestrial (X) system (see Fig. 4.1-3). This transformation is a function of two rotations through the x and y coordinates of the instantaneous terrestrial pole.

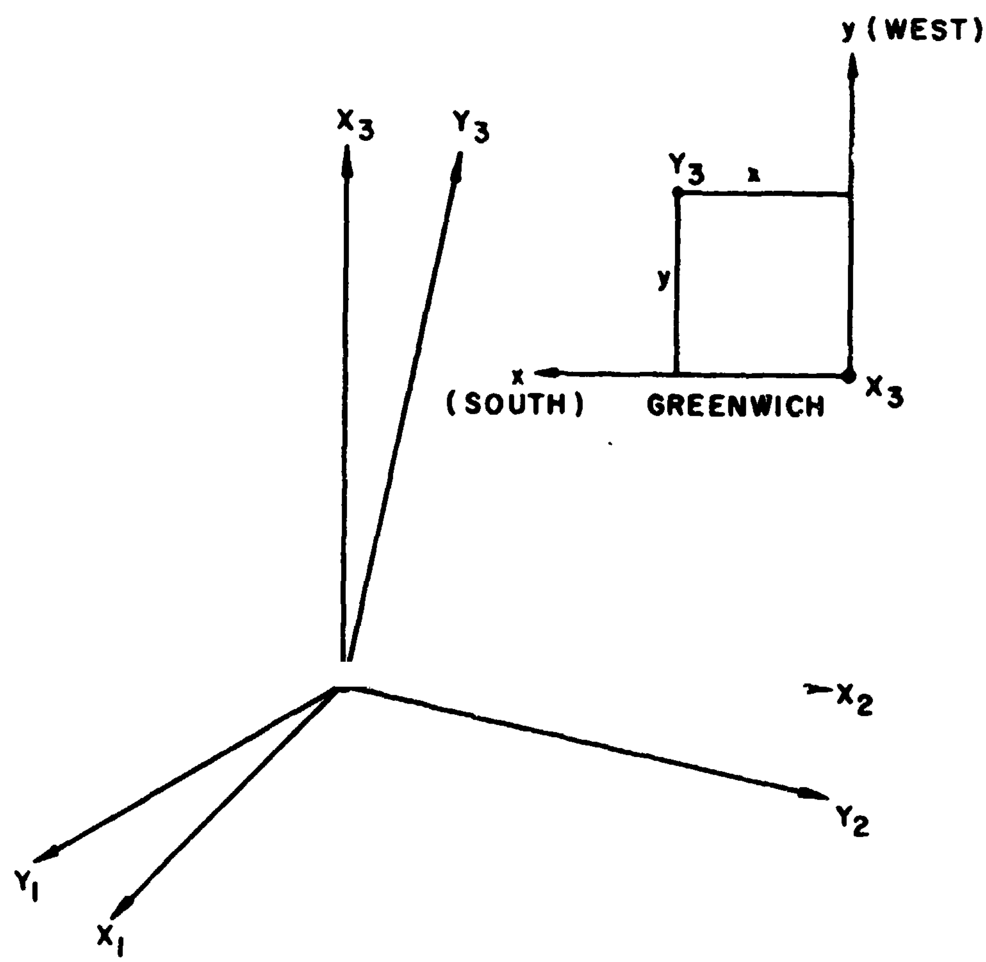


Fig. 4.1-3 Instantaneous and average terrestrial coordinate systems.

$$\vec{X} = R_2(-x)\, R_1(-y)\, \vec{Y} \qquad 4.1 - 4$$

where $\vec{X}$ is the resulting vector in the average terrestrial coordinate system; $R_1(-y)$ and $R_2(-x)$ are 1-axis and 2-axis rotations through -y and -x. Since the x and y values are differentially small, the finite rotations may be replaced by differential rotations and equation 4.1 - 4 is reduced to

$$\vec{X} = \begin{bmatrix} 1 & 0 & x \\ 0 & 1 & -y \\ -x & y & 1 \end{bmatrix} \vec{Y} \qquad 4.1 - 5$$

by omitting the products of x and y. Thus the transformation from the true celestial to the average terrestrial coordinate system is achieved by combining the rotations expressed in equations 4.1 - 2 and 4.1 - 4, namely:

$$\vec{X} = R_2(-x)\, R_1(-y)\, R_3(\mathrm{GAST})\, \vec{Z} \qquad 4.1 - 6$$

and after considering equation 4.1 - 5, the matrix form is

$$\vec{X} = S\, \vec{Z} \qquad 4.1 - 7$$

where

$$S = \begin{bmatrix} \cos(\mathrm{GAST}) & \sin(\mathrm{GAST}) & x \\ -\sin(\mathrm{GAST}) & \cos(\mathrm{GAST}) & -y \\ -x\cos(\mathrm{GAST})-y\sin(\mathrm{GAST}) & -x\sin(\mathrm{GAST})+y\cos(\mathrm{GAST}) & 1 \end{bmatrix} \qquad 4.1 - 8$$

The quantities x, y and GAST in the above equation are obtained as described in [Mueller, 1969, pp. 80, 153, 337].

4.2 The Direction Adjustment

4.21 Uncorrelated Events [86]

4.211 The Mathematical Model.

The adjustment method is by least squares, where the parameters are the three-dimensional rectangular coordinates of the ground stations and satellite positions,* while the observables are the topocentric range,* and topocentric declination and right ascension of the satellite.

The mathematical structure relating the parameters and the observables is a function of three vectors. The three vectors as depicted in Fig. 4.2-1 are (the arrow over the symbol will be reserved for those vectors which have a finite magnitude as opposed to, say, vectors containing differential corrections):

(1) $\vec{X}_i$, the coordinate-system-origin to ground station vector,

(2) $\vec{X}_j$, the coordinate-system-origin to satellite position vector,

(3) $\vec{X}_{ij}$, the ground station i to satellite position j vector.

Thus

$$\vec{X}_j - \vec{X}_i = \vec{X}_{ij} \qquad 4.2 - 1$$

or

$$F_{ij} = \vec{X}_j - \vec{X}_i - \vec{X}_{ij} = 0 \qquad 4.2 - 2$$

where

$$\vec{X}_j = \begin{bmatrix} u_j \\ v_j \\ w_j \end{bmatrix} \qquad 4.2 - 3$$

---

*Needed in the algebraic derivation but, in fact, in the numerical computation, they are either not needed, or obtained to a sufficient accuracy from the observed quantities.

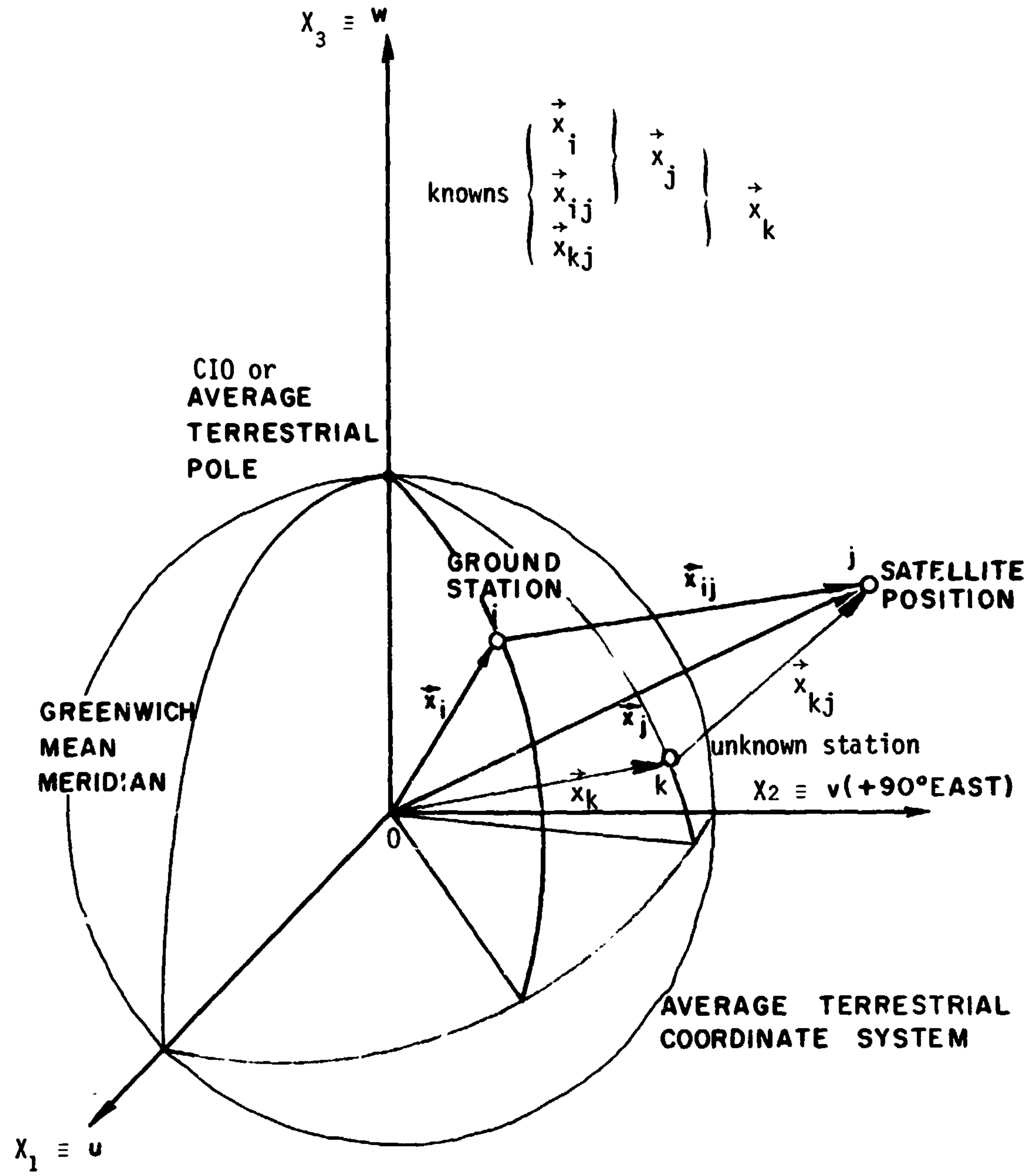


Fig. 4.2-1 The adjustment coordinate system.

is a vector composed of the rectangular coordinates of an arbitrary satellite position;

$$\vec{X}_i = \begin{bmatrix} u_i \\ v_i \\ w_i \end{bmatrix} \qquad 4.2 - 3(a)$$

is a vector composed of the rectangular coordinates of an arbitrary ground station;

$$\vec{X}_{ij} = S \begin{bmatrix} r_{ij} \cos\delta_{ij} \cos\alpha_{ij} \\ r_{ij} \cos\delta_{ij} \sin\alpha_{ij} \\ r_{ij} \sin\delta_{ij} \end{bmatrix} \qquad 4.2 - 4$$

r_{ij}, δ_{ij}, α_{ij} being the topocentric range, true declination and right ascension from i to j, respectively, while S is the matrix which transforms the vector from the true celestial to the average terrestrial coordinate system (section 4.13).

The point-by-point build-up of the network can be visualized in the following way. Given the components of the vectors $\vec{X}_i$ and $\vec{X}_{ij}$, $\vec{X}_j$ is computed. Then with this position j as known, and a known vector from an unknown k station to j, the coordinates of the unknown station $\vec{X}_k$ are computed (see Fig. 4.2-1). This is extended to include many unknown and known stations, along with many redundant observations thereby necessitating an adjustment.

Strictly speaking, pure optical or range data does not permit such a procedure to be literally followed; however, the adjustment framework (a form of collinearity) remains applicable.

The mathematical structure (equation 4.2 - 2) is linearized by a Taylor series expansion about the preliminary values of the ground stations and satellite positions, and the observed topocentric values of the range, declination and right ascension. The result is the following matrix equation

$$AX + BV + W = 0 \qquad 4.2 - 5$$

which represents the general linearized mathematical model.

In this equation, the design matrix A is composed of submatrices of the form

$$A_{ij} = \frac{\partial F_{ij}}{\partial \vec{X}_j, \partial \vec{X}_i} = \left[\begin{array}{ccc|ccc} 1 & 0 & 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & -1 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 \end{array}\right] = [+I_3 \,|\, -I_3] \qquad 4.2 - 6$$

and the unknown X vector is composed of subvectors of the form

$$X_{ij} = \begin{bmatrix} X_j \\ \hline X_i \end{bmatrix} \qquad 4.2 - 7$$

where

$$X_j = \begin{bmatrix} du_j \\ dv_j \\ dw_j \end{bmatrix}, \qquad X_i = \begin{bmatrix} du_i \\ dv_i \\ dw_i \end{bmatrix} \qquad \begin{array}{c} 4.2 - 8 \\ 4.2 - 9 \end{array}$$

are corrections to the preliminary values of the satellite positions and ground stations respectively. The design matrix B is composed of 3 x 3 submatrices of the form

$$B_{ij} = \frac{\partial F_{ij}}{\partial \delta_{ij}, \partial \alpha_{ij}, \partial r_{ij}} = S\, R_3(-\alpha_{ij})\, R_2(-90° + \delta_{ij}) \begin{bmatrix} 1 & 0 & 0 \\ 0 & -\cos\delta_{ij} & 0 \\ 0 & 0 & -1 \end{bmatrix} \qquad 4.2 - 10$$

where S is defined by equation 4.1 - 8; R_3 and R_2 are rotation matrices. The matrix

$$\begin{bmatrix} r_{ij} & 0 & 0 \\ 0 & r_{ij} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

is omitted from the expression for B_{ij} since it is multiplied into the vector of residuals V composed of the subvectors

$$V_{ij} = \begin{bmatrix} r_{ij}\delta\delta_{ij} \\ (r_{ij}\cos\delta_{ij})\,\delta\alpha_{ij} \\ \delta r_{ij} \end{bmatrix} \qquad 4.2 - 11$$

These are the residuals of the adjustment in units of meters ($\delta\delta_{ij}$ and $\delta\alpha_{ij}$ are in radians). Observe that $\delta\delta_{ij}$ is measured on the circle of radius r_{ij}, while $\delta\alpha_{ij}$ is measured on the circle of radius of $r_{ij}\cos\delta_{ij}$.

Finally, the misclosure vector W is composed of the subvectors

$$W_{ij} = \vec{X}^{o}_{j} - \vec{X}^{o}_{i} - \vec{X}^{b}_{ij} \qquad 4.2 - 12$$

where "o" designates "evaluated at preliminary values" and "b" designates "evaluated at observed values."

4.212 Weighting of Observations.

The observed quantities in the optical case are considered as the topocentric declinations (δ) and right ascensions (α). The corresponding accuracy estimates resulting from a photographic plate adjustment or some other a priori estimate are σ_{δ}^{2} and σ_{α}^{2}, the variances, and $\sigma_{\alpha\delta} = \sigma_{\delta\alpha}$, the covariance. All units are arc seconds squared.

It is important to note that the weighting of the declinations and right ascensions is made on the basis of the estimates of variances of

δ and α obtained from the plate adjustments and that it is assumed that the variance of δ and α do not vary according to the distance of the satellite from the particular observing ground station.

On the other hand, the weighted sum of squares of the residuals is conveniently chosen to have units of arc seconds squared; thus the weights are to have units of (arc sec)^2 m^{-2} since the units of the residuals have been stipulated (equation 4.2 - 11) to be meters. Therefore, it is necessary to transform σ_δ^2, σ_α^2, and $\sigma_{\delta\alpha}$ into linear units (meters) by the following formulas:

$$(\sigma_\delta)^2 = \left| r \frac{\sigma''_\delta}{\rho''} \right|^2 \qquad 4.2 - 13$$

$$(\sigma_\alpha)^2 = \left| r \frac{\sigma''_\alpha}{\rho''} \right|^2 \cos^2 \delta \qquad 4.2 - 14$$

$$\sigma_{\delta\alpha} = r^2 \frac{\sigma_{\delta\alpha}^{('')^2}}{(\rho'')^2} \cos \delta \qquad 4.2 - 15$$

where r is the approximate topocentric range and

$$\rho'' = \frac{1}{\sin 1''}$$

With the estimated accuracy in linear units the following variance-covariance matrix is formulated:

$$\Sigma_{\delta,\alpha,r} = \begin{bmatrix} \sigma_\delta^2 & \sigma_{\delta\alpha} & \sigma_{\delta r} \\ & \sigma_\alpha^2 & \sigma_{\alpha r} \\ \text{same as above diagonal} & & \sigma_r^2 \end{bmatrix}$$

where the new quantities σ_r^2, $\sigma_{\delta r}$, and $\sigma_{\alpha r}$ are the variance of the range, covariance between the declination and range, and the covariance between the right ascension and range respectively. If the correlation coefficients

$$\rho_{\delta r} = \frac{\sigma_{\delta r}}{\sigma_\delta \sigma_r} = 0$$

$$\rho_{\alpha r} = \frac{\sigma_{\alpha r}}{\sigma_\alpha \sigma_r} = 0$$

and

$$\sigma_r \to \infty$$

the weight matrix for a single direction is

$$P_{ij} = \sigma_0^2 \begin{bmatrix} \begin{bmatrix} \sigma_\delta^2 & \sigma_{\delta\alpha} \\ \sigma_{\alpha\delta} & \sigma_\alpha^2 \end{bmatrix}^{-1} & \begin{matrix} 0 \\ 0 \end{matrix} \\ \begin{matrix} 0 & 0 \end{matrix} & 0 \end{bmatrix} \qquad 4.2-16$$

where σ_0^2 is the a priori variance of unit weight.

Corresponding to P_{ij}, P denotes the weight matrix for the observed topocentric directions of the adjustment. P has the characteristic of containing non-zero 3 x 3 matrices only along the diagonal since the individual directions are assumed to be independent.

The topocentric range is needed in equations 4.2 - 13 to 4.2 - 15 to convert the estimated accuracy of the directions from arc units into linear (meters) units. Four significant figures are required in the topocentric range. Equation 4.2 - 13 shows that the range need have no more significant figures than σ''_δ or σ''_α.

The topocentric range from an arbitrary ground station i in a given simultaneous event j is computed from

$$r_{ij} = [(u_j^o - u_i^o)^2 + (v_j^o - v_i^o)^2 + (w_j^o - w_i^o)^2]^{\frac{1}{2}} \qquad 4.2 - 17$$

$i = 1, 2, \ldots, m$ (number of stations in the event). u_i^o, v_i^o, w_i^o are the preliminary rectangular coordinates of the i^{th} ground station and are computed from

$$\vec{X}_i^o = \begin{bmatrix} u_i^o \\ v_i^o \\ w_i^o \end{bmatrix} = \begin{bmatrix} (N+H) \cos\phi \ \cos\lambda \\ (N+H) \cos\phi \ \sin\lambda \\ [N(1-e^2) + H] \sin\phi \end{bmatrix} \qquad 4.2 - 18$$

ϕ, λ, H, N, being the geodetic latitude and longitude, the ellipsoidal height, and prime vertical radius of curvature at point i, respectively, while e is the eccentricity of the reference ellipsoid. u_j^o, v_j^o, w_j^o are the preliminary rectangular coordinates of the j^{th} satellite position and are computed (note that these are needed only for the purpose of getting the approximate topocentric range) as follows:

(1) The ground vector $\vec{X}_{ik}$ between the first two stations listed in the particular simultaneous event

$$\vec{X}_{ik} = \begin{bmatrix} u_k - u_i \\ v_k - v_i \\ w_k - w_i \end{bmatrix} \qquad 4.2 - 19$$

(2) The unit vector (direction) $\vec{X}_{ij}$ from the ground station i to the satellite position j is computed from

$$\vec{X}_{ij} = S \begin{bmatrix} \cos\delta_{ij} \cos\alpha_{ij} \\ \cos\delta_{ij} \sin\alpha_{ij} \\ \sin\delta_{ij} \end{bmatrix} \qquad 4.2 - 20$$

where S is the transformation matrix of the true celestial to the average terrestrial coordinate systems (section 4.13).

(3) In the same way the direction $\vec{X}_{kj}$ is computed.

(4) The angle A_k at ground station k is computed from

$$\cos A_k = \frac{\vec{X}_{ki} \cdot \vec{X}_{kj}}{|\vec{X}_{ki}||\vec{X}_{kj}|} \qquad 4.2 - 21$$

(5) The angle A_j at the satellite position is computed from

$$\cos A_j = \frac{\vec{X}_{ji} \cdot \vec{X}_{jk}}{|\vec{X}_{ij}||\vec{X}_{kj}|} \qquad 4.2 - 22$$

(6) Finally, the satellite position vector $\vec{X}_j^o$ to be used in equation 4.2 - 17 is computed from (see Fig. 4.2-1)

$$\vec{X}_j^o = \vec{X}_i^o + r_{ij} \vec{X}_{ij} = \begin{bmatrix} u_j^o \\ v_j^o \\ w_j^o \end{bmatrix} \qquad 4.2 - 23$$

where

$$r_{ij} = |\vec{X}_{ik}| \frac{\sin A_k}{\sin A_j} \qquad 4.2 - 24$$

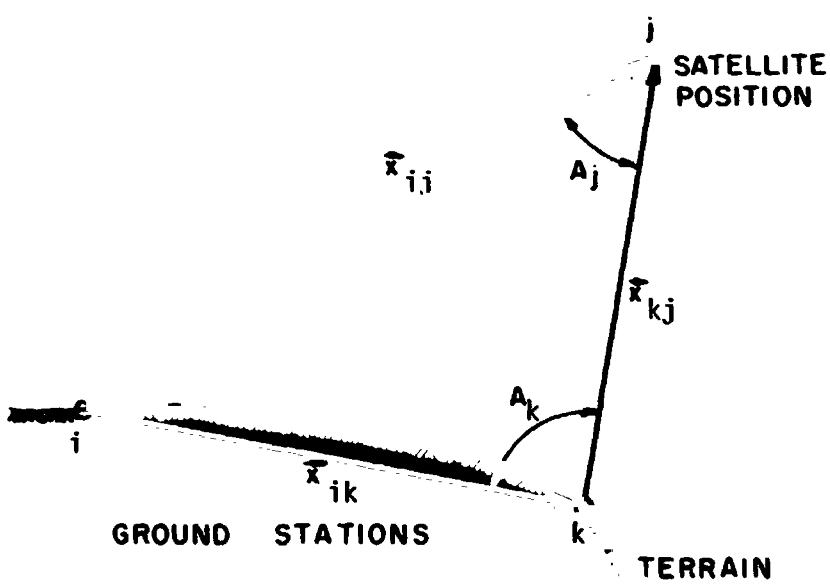


Fig. 4.2-2 The approximate satellite vector.

4.213 The Normal Equations.

The normal equations are derived by minimizing the quadratic form

$$V'PV + X'P_X X$$

subject to the relation (equation 4.2 - 5)

$$AX + BV + W = 0$$

Upon introduction of Lagrange multipliers K, the variation function is

$$\Phi = V'PV + X'P_X X - 2K'(AX + BV + W) \qquad 4.2\ -25$$

where

V is the vector of residuals corresponding to the α's and δ's

X is the vector of corrections to the preliminary ground and satellite positions

P is the weight matrix for the α's and δ's

P_X is the weight matrix for the ground and satellite positions

As described in section 4.211 A and B are the design matrices and W is the constant vector.

Upon the differentiation of equation 4.2 - 25 for the minimum condition [Uotila, 1967, p. 81], the expanded form of the normal equations becomes

$$\begin{bmatrix} -P_X & 0 & A' \\ 0 & -P & B' \\ A & B & 0 \end{bmatrix} \begin{bmatrix} X \\ V \\ K \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ W \end{bmatrix} = 0 \qquad 4.2\ -\ 26$$

By a row and column transformation, the residual vector V is eliminated and the normal equations become

$$\begin{bmatrix} BP^{-1}B' & A \\ A' & -P_X \end{bmatrix} \begin{bmatrix} K \\ X \end{bmatrix} + \begin{bmatrix} W \\ 0 \end{bmatrix} = 0 \qquad 4.2\ -\ 27$$

Next, the correlates are eliminated resulting in

$$[A'(BP^{-1}B')^{-1}A + P_x]X + A'(BP^{-1}B')^{-1}W = 0 \qquad 4.2 - 28$$

The following summation form of the non-zero 3 x 3 submatrices of the above equation is found by replacing the A, B, and P matrices with their expanded forms in terms of 3 x 3 submatrices (equations 4.2 - 6, 4.2 - 10, and 4.2 -16):

$$\left[\begin{array}{c|c} \sum_i (B_{ij}P_{ij}^{-1}B'_{ij})^{-1} + P_j & -(B_{ij}P_{ij}^{-1}B'_{ij})^{-1} \\ \hline -(B_{ij}P_{ij}^{-1}B'_{ij})^{-1} & \sum_j (B_{ij}P_{ij}^{-1}B'_{ij})^{-1} + P_i \end{array}\right] \left[\begin{array}{c} X_j \\ \hline X_i \end{array}\right] + \left[\begin{array}{c} U_j = \sum_i (B_{ij}P_{ij}^{-1}B'_{ij})^{-1} W_{ij} \\ \hline U_i = -\sum_j (B_{ij}P_{ij}^{-1}B'_{ij})^{-1} W_{ij} \end{array}\right] = 0 \qquad 4.2 - 29$$

where the non-zero 3 x 3 submatrices occur only on the diagonal and those ij 3 x 3 positions corresponding to a ground-to-satellite observation; $\sum_i$ indicates a summation over all ground stations observing satellite position j; $\sum_j$ indicates a summation over all satellite positions observed from ground station i. All summations contain only 3 x 3 and/or 3 x 1 matrices.

Elimination of X_j, the corrections to the satellite positions, from the above yields the following <u>reduced normal equations</u>:

$$N\,X + U = 0 \qquad 4.2 - 30$$

in which the X vector will always represent the unknown corrections to the preliminary rectangular coordinates of the ground stations only; U is the constant vector; N is the coefficient matrix.

The coefficient matrix N is made up of 3 x 3 matrices. By letting

$$M_{ij}^{-1} = (B_{ij}P_{ij}^{-1}B_{ij}')^{-1} \qquad 4.2-31$$

$$= (B_{ij}^{-1})' \, P_{ij}B_{ij}^{-1} \qquad 4.2-32$$

in equation 4.2 - 29 , the expression for the 3 x 3 diagonal matrix corresponding to the k^{th} ground station is given by [Krakiwsky and Pope, 1967]

$$N_{kk} = \sum_j M_{kj}^{-1} - \sum_j \{M_{kj}^{-1} \, (\sum_i M_{ij}^{-1})^{-1} \, M_{kj}^{-1}\} + P_k \qquad 4.2-33$$

Note the weight, P_j, for the j^{th} satellite position has been dropped in the second term of the above equation. The expression for the off-diagonal 3 x 3 matrix corresponding to the k^{th} and the ℓ^{th} ground stations is

$$N_{k\ell} = -\sum_j \{M_{kj}^{-1} \, (\sum_i M_{ij}^{-1})^{-1} \, M_{\ell j}^{-1}\} \qquad 4.2-34$$

where the summation $\sum_j$ is performed over all satellite events observed simultaneously from both ground stations k and ℓ.

The constant vector of the normal equations (equation 4.2 - 30) is made up of 3 x 1 vectors corresponding to each ground station. The vector U_k for the k^{th} ground station is given by

$$U_k = -(\sum_j M_{kj}^{-1} W_{kj}) + \sum_j \{M_{kj}^{-1} \, (\sum_i M_{ij}^{-1})^{-1} \, (\sum_i M_{ij}^{-1} W_{ij})\} \qquad 4.2-35$$

where, according to equation 4.2 - 12 ,

$$W_{ij} = \vec{X}_j^o - \vec{X}_i^o - \vec{X}_{ij}^b \qquad 4.2-36$$

or

$$W_{kj} = \vec{X}_j^o - \vec{X}_k^o - \vec{X}_{kj}^b \qquad 4.2-37$$

At first sight it seems that the preliminary coordinates of each satellite position are required; however, substitution of equations 4.2 - 36 and 4.2 - 37 into equation 4.2 - 35 results in the cancellation or dropping out of terms containing $\vec{X}_j^o$ and the observed vector $\vec{X}_{ij}^b$ or $\vec{X}_{kj}^b$. Specifically,

$$U_k = -\sum_j \{M_{kj}^{-1} (\vec{X}_j^o - \vec{X}_k^o - \vec{X}_{kj}^b)\} +$$

$$+ \sum_j \{M_{kj}^{-1} (\sum_i M_{ij}^{-1})^{-1} [\sum_i M_{ij}^{-1}(\vec{X}_j^o - \vec{X}_i^o - \vec{X}_{ij}^b)]\} \qquad 4.2 - 38$$

$$= -\sum_j \{M_{kj}^{-1}\vec{X}_j^o\} + (\sum_j M_{kj}^{-1}) \vec{X}_k^o + \sum_j \{M_{kj}^{-1}\vec{X}_{kj}^b\} +$$

$$+ \sum_j \{M_{kj}^{-1} (\sum_i M_{ij}^{-1})^{-1} (\sum_i M_{ij}^{-1}\vec{X}_j^o)\} -$$

$$-\sum_j \{M_{kj}^{-1} (\sum_i M_{ij}^{-1})^{-1} (\sum_i M_{ij}^{-1}\vec{X}_i^o)\} -$$

$$- \sum_j \{M_{kj}^{-1} (\sum_i M_{ij}^{-1})^{-1} (\sum_i M_{ij}^{-1}\vec{X}_{ij}^b)\} \qquad 4.2 - 39$$

Terms 1 and 4 in the above expression cancel (i.e., $\vec{X}_j^o$ satellite coordinates drop out) because $\vec{X}_j^o$ can be factored out of $\sum_i$ in term 4, i.e.,

$$\sum_j \{M_{kj}^{-1} (\sum_i M_{ij}^{-1})^{-1} (\sum_i M_{ij}^{-1}) \vec{X}_j^o\} = (\sum_j M_{kj}^{-1} \vec{X}_j^o) \qquad 4.2 - 40$$

which has an opposite sign to that of term 1. Terms 3 and 6 drop out because they are identically zero. This happens because both terms contain products like

$$B_{ij}^{-1} \vec{X}_{ij}^b \text{ or } B_{kj}^{-1} \vec{X}_{kj}^b$$

where (taking into consideration the orthogonality property of the rotation matrices and S)

$$B_{ij}^{-1} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1/\cos\delta_{ij} & 0 \\ 0 & 0 & -1 \end{bmatrix} R_2(90° - \delta_{ij})\, R_3(\alpha_{ij})\, S'$$

and after elementary matrix operations we have

$$B_{ij}^{-1}\vec{X}_{ij}^{b} = \begin{bmatrix} 0 \\ 0 \\ -1 \end{bmatrix} r_{ij}^{b}$$

Since in the optical adjustment, P_{ij} has the form

$$P_{ij} = \begin{bmatrix} \begin{bmatrix} * & * \\ * & * \end{bmatrix}^{-1} & \begin{matrix} 0 \\ 0 \end{matrix} \\ \begin{matrix} 0 & 0 \end{matrix} & 0 \end{bmatrix}$$

and using 4.2 - 32

$$M_{ij}^{-1}\vec{X}_{ij}^{b} = 0 \qquad 4.2 - 41$$

the final expression for the constant column becomes

$$U_k = \sum_j M_{kj}^{-1}\{\vec{X}_k^{o} - (\sum_i M_{ij}^{-1})^{-1}(\sum_i M_{ij}^{-1}\vec{X}_i^{o})\} \qquad 4.2 - 42$$

In summary, the normal equations in the optical adjustment are formed by equations 4.2 - 33, 4.2 - 36, and 4.2 - 42.

4.22 Correlated Events [193]

4.221 The Mathematical Model.

The theory and the mathematical model for a generalized least squares adjustment for simultaneous directions without correlation has been described (section 4.21). In that case each simultaneously observed satellite image was taken as an independent event, thus the correlation between satellite directions on the same plate was not considered. The following is a description of how the mathematical model is manipulated to take care of possible correlations between directions, such as in the case of the NGS BC-4 Type II data, where each given event consists of 7 fictitious directions (Greenwich hour angle h and declination δ relative to the 1900-1905 CIO mean pole) per station and the full 14 x 14 variance-covariance matrix associated with the set.

The basic geometric figure to begin the mathematical development is that of a single ground station observing one satellite position shown in Fig. 4.2-1. Using vector notation, the mathematical model as we know can be written

$$F_{ij_m} = \vec{X}_{j_m} - \vec{X}_i - \vec{X}_{ij_m} = 0 \qquad 4.2 - 43$$

where now m will identify a fictitious satellite image within the event j, i.e., $m = 1, 2 \ldots m_x$ (generally $4 \le m_x \le 7$).

The vector $\vec{X}_{ij_m}$ with this type of data takes the form

$$\vec{X}_{ij_m} = \begin{bmatrix} r_{ij_m} \cos\delta_{ij_m} \cos h_{ij_m} \\ -r_{ij_m} \cos\delta_{ij_m} \sin h_{ij_m} \\ r_{ij_m} \sin\delta_{ij_m} \end{bmatrix} \qquad 4.2 - 44$$

The linearized mathematical model can be written as follows

$$[A_1 \vdots A_2] \begin{bmatrix} X_j \\ \hdashline X_i \end{bmatrix} + BV + W = 0 \qquad 4.2 - 45$$

Since all the observations from one station to all fictitious satellite directions on a given plate are correlated, it is necessary to build up the model using all these satellite directions. Thus the design matrix A is divided in submatrices of the form

$$A_{ij_m} = \frac{\partial F_{ij_m}}{\partial \vec{X}_{j_m}, \partial \vec{X}_i} = \left[A_{1_{ij_m}} \vdots A_{2_{ij_m}}\right] = \begin{bmatrix} & \vdots & -I_3 \\ & \vdots & -I_3 \\ I_{3m_x} & \vdots & \vdots \\ & \vdots & -I_3 \end{bmatrix}_{3m_x \times 3m_x \quad 3m_x \times 3} \qquad 4.2 - 46$$

and the design matrix B is of the form:

$$
\underset{(3m_x \times 3m_x)}{B_{ij_m}} = \begin{bmatrix} \boxed{3x3} & & & & 0 \\ & \boxed{3x3} & & & \\ & & \boxed{3x3} & & \\ & & & \ddots & \\ 0 & & & & \boxed{3x3} \end{bmatrix} \qquad 4.2 - 47
$$

After minimizing V'PV under the condition 4.2 - 45, the vector of Lagrangian multipliers can be expressed as

$$
K = -(BP^{-1}B')^{-1} (A_1X_j + A_2X_i + W) \qquad 4.2 - 48
$$

and the normal equations will take the form:

$$
\begin{bmatrix} A_1'(BP^{-1}B')^{-1}A_1 & A_1'(BP^{-1}B')^{-1}A_2 \\ A_2'(BP^{-1}B')^{-1}A_1 & A_2'(BP^{-1}B')^{-1}A_2 \end{bmatrix} \begin{bmatrix} X_j \\ X_i \end{bmatrix} + \begin{bmatrix} A_1'(BP^{-1}B')^{-1}W \\ A_2'(BP^{-1}B')^{-1}W \end{bmatrix} = 0 \qquad 4.2 - 49
$$

4.222 The Weighting Technique Using the Full Variance-Covariance Matrix of the Observed Quantities.

Before proceeding further, it is necessary to explain how the above equations (4.2 - 48) are actually solved. For a particular station i and event j, the B matrix is dimensioned (21 x 21), but the original given P^{-1} matrix is (14 x 14). The P^{-1} matrix refers only to the actual observed quantities which are the Greenwich hour angle (h) and the declinations (δ) and therefore it has to be modified before it is substituted in equation 4.2 - 48. The easiest way to explain this is to look only at that part of B_{ij} that corresponds to observations on the first satellite position only:

$$
B_{ij_1} \equiv B_1 = \begin{bmatrix} \frac{\partial F_1}{\partial h_1} & \frac{\partial F_1}{\partial \delta_1} & \frac{\partial F_1}{\partial r_1} \\ \frac{\partial F_2}{\partial h_1} & \frac{\partial F_2}{\partial \delta_1} & \frac{\partial F_2}{\partial r_1} \\ \frac{\partial F_3}{\partial h_1} & \frac{\partial F_3}{\partial \delta_1} & \frac{\partial F_3}{\partial r_1} \end{bmatrix}_{i,j_1} \qquad 4.2 - 50
$$

The matrix P_1 (not P_1^{-1}) would have to be of the form

$$P_{ij_1} \equiv P_1 = \begin{bmatrix} \sigma^2_{h_1} & \sigma_{h_1\delta_1} & \sigma_{h_1r_1} \\ \sigma_{h_1\delta_1} & \sigma^2_{\delta_1} & \sigma_{\delta_1r_1} \\ \sigma_{h_1r_1} & \sigma_{\delta_1r_1} & \sigma^2_{r_1} \end{bmatrix}^{-1}_{i,j_1} \qquad 4.2 - 51$$

and for a single satellite image using 4.2 - 16 we can write

$$P_1 = \begin{bmatrix} \begin{bmatrix} \sigma^2_{h_1} & \sigma_{h_1\delta_1} \\ \sigma_{h_1\delta_1} & \sigma^2_{\delta_1} \end{bmatrix}^{-1} & \begin{matrix} 0 \\ 0 \end{matrix} \\ \begin{matrix} 0 & 0 \end{matrix} & 0 \end{bmatrix}_{i,j_1} \qquad 4.2 - 52$$

What is really needed is $(B_1P_1^{-1}B_1')^{-1}$, but $B_1P_1^{-1}B_1'$ is singular. However, *the matrix* B_1 *is square and nonsingular. Knowing this,* $(B_1P_1^{-1}B_1')^{-1}$ can be rearranged as follows:

$$(B_1P_1^{-1}B_1')^{-1} = (B_1')^{-1}P_1B_1^{-1} = (B_1^{-1})'P_1B_1^{-1} \qquad 4.2 - 53$$

where P_1 is defined by equation 4.2 - 52.

The preceding description applies to the case of one satellite position j_1. For the seven satellite positions the dimension of the P^{-1} matrix is (14 x 14). The matrix P_1 in equation 4.2 - 53 has to be of dimensions (21 x 21) and of the form of equation 4.2 - 52. The matrix P_{ij} for the BC-4 observations can be written as follows:

$$P_{ij} \underset{(14x14)}{=} \begin{bmatrix} \sigma^2_{h_1} & \sigma_{h_1\delta_1} & \cdots & & \sigma_{h_1\delta_7} \\ \cdot & \sigma^2_{\delta_1} & & & \cdot \\ \cdot & & \ddots & & \cdot \\ \cdot & & & \sigma^2_{h_7} & \cdot \\ \sigma_{h_1\delta_7} & & \cdots & & \sigma^2_{\delta_7} \end{bmatrix}^{-1}_{i,j} = \begin{bmatrix} \bar{w}_{1,1} & \bar{w}_{1,2} & \cdots & \bar{w}_{1,14} \\ \cdot & & & \cdot \\ \cdot & & & \\ \cdot & & & \cdot \\ \bar{w}_{14,1} & & \cdots & \bar{w}_{14,14} \end{bmatrix}_{i,j} \qquad 4.2 - 54$$

Now the (21 x 21) version of equation 4.2 - 52 will be

$$P_{ij} \underset{(21x21)}{=} \begin{bmatrix} \bar{w}_{1,1} & \bar{w}_{1,2} & 0 & \bar{w}_{1,3} & \bar{w}_{1,4} & 0 & \cdots & \bar{w}_{1,13} & \bar{w}_{1,14} & 0 \\ \bar{w}_{2,1} & \bar{w}_{2,2} & 0 & \bar{w}_{2,3} & \bar{w}_{2,4} & 0 & \cdots & \bar{w}_{2,13} & \bar{w}_{2,14} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & & \vdots & \vdots & \vdots \\ \bar{w}_{13,1} & \bar{w}_{13,2} & 0 & \bar{w}_{13,3} & \bar{w}_{13,4} & 0 & \cdots & \bar{w}_{13,13} & \bar{w}_{13,14} & 0 \\ \bar{w}_{14,1} & \bar{w}_{14,2} & 0 & \bar{w}_{14,3} & \bar{w}_{14,4} & 0 & \cdots & \bar{w}_{14,13} & \bar{w}_{14,14} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \end{bmatrix}_{i,j} \qquad 4.2 - 55$$

ith P defined considering 4.2 - 55, the matrix M^{-1} can be formed using he technique shown in equation 4.2 - 53.

$$M^{-1} = (B\ P^{-1}B')^{-1} \quad (B^{-1})'P\ B^{-1} \qquad 4.2 - 56$$

4.223 The Reduced Normal Equations.

Equation 4.2 - 49 can be referred to as the conventional normal equation, where the satellite position X_j is among the parameters. Since the satellite position is of no interest, it is eliminated from the solution. This is done by solving for X_j in terms of the other parameters and substituting this into the remaining equations. After elimination of X_j from 4.2 - 49, we will obtain the reduced normal equations. The (3 x 3) and (3 x 1) block elements of the coefficient matrix and constant vector respectively can be obtained by expressions similar to equations 4.2 - 33, 4.2 - 34 and 4.2 - 35. The only difference being that now the term P_k in equation 4.2 - 33 will drop out because now we are only minimizing V'PV.

4.3 The Range Adjustment [86, 140]

4.31 The Mathematical Model

Fig. 4.3-1 shows the average terrestrial coordinate system uvw (section 4.12) with a ground station i and a satellite position j. The observed quantity is the topocentric range r_{ij} from ground station i to satellite position j. The parameters u_i, v_i, w_i and u_j, v_j, w_j are the Cartesian coordinates of the ground station i and the satellite position j respectively.

From Fig. 4.3-1 it can easily be seen that the mathematical model can be written as

$$r_{ij} = [(u_j - u_i)^2 + (v_j - v_i)^2 + (w_j - w_i)^2]^{\frac{1}{2}} \qquad 4.3 - 1$$

or

$$F_{ij} = [(u_j - u_i)^2 + (v_j - v_i)^2 + (w_j - w_i)^2]^{\frac{1}{2}} - r_{ij} = 0 \qquad 4.3 - 2$$

The basic mathematical model above is extended to include simultaneous ranges from three or more ground stations. By increasing the number of simultaneous events along with the number of known and unknown ground stations, an adjustment is necessary.

The mathematical model (equation 4.3 - 2) is linearized by a Taylor series expansion about the preliminary values of the ground stations and satellite positions and the observed value of the topocentric range. The expression for the linearized mathematical model as in the optical case has the form

$$AX + BV + W = 0 \qquad 4.3 - 3$$

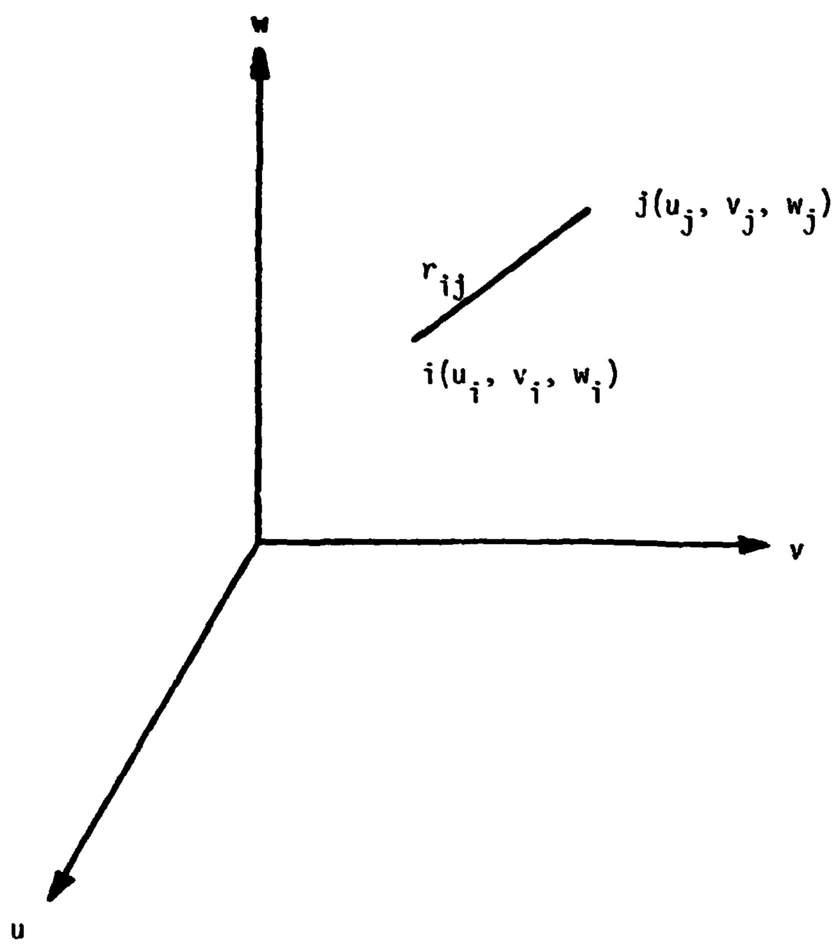


Fig. 4.3-1 The uvw coordinate system.

where now the design matrix B is a negative unit matrix and the design matrix A is formed by submatrices of the form

$$A_{ij} = \frac{\partial F_{ij}}{\partial \vec{X}_j^o, \partial \vec{X}_i^o} = \left[\frac{u_j^o - u_i^o}{r_{ij}^o}, \frac{v_j^o - v_i^o}{r_{ij}^o}, \frac{w_j^o - w_i^o}{r_{ij}^o} \;\vdots\; -\frac{u_j^o - u_i^o}{r_{ij}^o}, -\frac{v_j^o - v_i^o}{r_{ij}^o}, -\frac{w_j^o - w_i^o}{r_{ij}^o} \right]$$

$$= [a_{ij} \;\vdots\; -a_{ij}] \qquad 4.3 - 4$$

where r_{ij}^o is computed from 4.3 - 1 using the initial approximate values for the station and satellite coordinates, the latest coordinates resulting from a preliminary least squares adjustment (for each event j) with the coobserving stations held fixed.

The unknown vector X is made up of subvectors

$$X_{ij} = \begin{bmatrix} X_j \\ X_i \end{bmatrix} \qquad 4.3 - 5$$

where

$$X_i = \begin{bmatrix} du_i \\ dv_i \\ dw_i \end{bmatrix} \qquad 4.3 - 6$$

and

$$X_j = \begin{bmatrix} du_j \\ dv_j \\ dw_j \end{bmatrix} \qquad 4.3 - 7$$

The misclosure vector W is formed by the individual differences

$$W_{ij} = r^{o}_{ij}(\text{computed}) - r^{b}_{ij}(\text{observed}) \qquad 4.3 - 8$$

The residual vector V is composed of the individual residuals V_{ij} (in meters) corresponding to the observed ranges r^{b}_{ij}.

Giving consideration to the characteristic of the design matrices, the final equation for the linearized model in the range adjustment can be written as

$$AX - V + W = 0 \qquad 4.3 - 9$$

4.32 Weighting of Observed Ranges

The weighting of the observed topocentric range from ground station i to satellite position j is achieved by the following:

$$P_{ij} = \frac{\sigma_0^2}{\sigma_{ij}^2} \qquad 4.3 - 10$$

where σ_0^2 is the variance of unit weight and σ_{ij}^2 is the variance of the observed range in meters squared. P will denote the diagonal weight matrix containing all the independent weights P_{ij} to be considered in the adjustment.

4.33 The Normal Equations

The variation function for the range adjustment is similar to the optical case, namely,

$$\Phi = V'PV + X'P_X X - 2K'(AX - V + W) \qquad 4.3 - 11$$

where

V is the vector of residuals corresponding to the range observations

X is the vector of corrections to the preliminary ground and satellite positions*

P is the weight matrix for the ranges

P_X is the weight matrix for the ground and satellite positions

K is the vector of correlates

The differentiation of equation 4.3 - 11 for the minimum condition results in the following expanded form of the normal equations:

$$\begin{bmatrix} -P_X & 0 & A' \\ 0 & -P & -I \\ A & -I & 0 \end{bmatrix} \begin{bmatrix} X \\ V \\ K \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ W \end{bmatrix} = 0 \qquad 4.3 - 12$$

After the elimination of the correlates and residuals and the expansion of the A and P matrices, the following expression results

$$\left[\begin{array}{c:c} \sum_i a'_{ij}p_{ij}a_{ij} + P_j & -a'_{ij}p_{ij}a_{ij} \\ \hdashline -a'_{ij}p_{ij}a_{ij} & \sum_j a'_{ij}p_{ij}a_{ij} + P_i \end{array}\right] \left[\begin{array}{c} X_j \\ \hdashline X_i \end{array}\right] + \left[\begin{array}{c} U_j = \sum_i a'_{ij}p_{ij}W_{ij} \\ \hdashline U_i = -\sum_j a'_{ij}p_{ij}W_{ij} \end{array}\right] = 0 \qquad 4.3 - 13$$

*As in the case of the optical adjustment, satellite positions will be considered "nuisance" parameters and therefore eliminated from the solution.

Elimination of the corrections to the preliminary coordinates of the satellite position, namely X_j from equation 4.3 - 13, results in the following three expressions: The 3 x 3 diagonal matrix corresponding to the k^{th} ground station is given by

$$N_{kk} = (\sum_j a'_{kj}P_{kj}a_{kj}) - \sum_j \{a'_{kj}P_{kj}a_{kj}(\sum_i a'_{ij}P_{ij}a_{ij})^{-1} a'_{kj}P_{kj}a_{kj}\} + P_k \qquad 4.3 - 14$$

The 3 x 3 off-diagonal matrix corresponding to the k^{th} and the ℓ^{th} ground stations is given by

$$N_{k\ell} = - \sum_j \{a'_{kj}P_{kj}a_{kj}(\sum_i a'_{ij}P_{ij}a_{ij})^{-1} a'_{\ell j}P_{\ell j}a_{\ell j}\} \qquad 4.3 - 15$$

where the main summation $\sum_j$ is performed over all satellite positions observed simultaneously from both ground stations k and ℓ; the constant vector of the k^{th} ground station is

$$U_k = -(\sum_j a'_{kj}P_{kj}W_{kj}) + \sum_j \{a'_{kj}P_{kj}a_{kj}(\sum_i a'_{ij}P_{ij}a_{ij})^{-1} \sum_i a'_{ij}P_{ij}W_{ij}\} \qquad 4.3 - 16$$

In the above expressions, the weight matrix P_j of each satellite position was set equal to zero as there is no independent external source from which to get a priori variance estimates which could be used to derive weights.

The equivalent expression for the constant column U_k can be shown to have the following form:

$$U_k = - \sum_j a'_{kj}P_{kj}\bar{V}_{kj} \qquad 4.3 - 17$$

where $\bar{v}_{kj}$ is the residual of the particular observed range r_{kj} arising from a least squares adjustment of one simultaneous event with ground stations held fixed.

The quantities a_{kj} and $\bar{v}_{kj}$ needed in the formation of the reduced normal equations (equations 4.3 - 14, 4.3 - 15 and 4.3 - 17) are a side product of the preliminary adjustment of each simultaneous event. Specifically, a_{kj} is contained in the A matrix given by equation 3.2 - 3, and $\bar{v}_{kj}$ is an element of the $\bar{V}$ vector of equation 3.2 - 5.

4.4 Addition of Normal Equations

Independent sets of normal equations formed from two or more batches of optical and/or range data can be added together. The basic idea of the combination of the normal equations is simply the algebraic addition of their corresponding terms. Letting n sets of normal equations be represented by

$$\begin{aligned} N_1X + U_1 &= 0 \\ N_2X + U_2 &= 0 \\ &\vdots \\ N_nX + U_n &= 0 \end{aligned} \qquad 4.4 - 1$$

and their corresponding variances of unit weight as $\sigma_1^2, \sigma_2^2, \ldots, \sigma_n^2$; the addition is

$$(N_1 + p_{12}N_2 + \ldots + p_{1n}N_n)X + (U_1 + p_{12}U_2 + \ldots p_{1n}U_n) = 0 \qquad 4.4 - 2$$

In the above, the weights may be obtained as follows:

$$\begin{aligned} p_{12} &= \frac{\sigma_1^2}{\sigma_2^2} \\ &\vdots \\ p_{1n} &= \frac{\sigma_1^2}{\sigma_n^2} \end{aligned} \qquad 4.4 - 3$$

where $\sigma_1^2, \sigma_2^2, \ldots, \sigma_n^2$ must have the same a priori variance of unit weight (see sections 4.212 and 4.32).

The advantage of the above is obvious, namely, batches of observed data may be adjusted separately or as a part of a combined adjustment. The same holds for the addition of two or more independent sets of range normal equations and for the addition of optical and range normal equations to each other.

The weighting of the two or more different sets of normal equations (e.g., N_{11}, U_{11}, and N_{22}, U_{22}) is a function of the goodness of the observations involved and the geometry existing between the unknown parameters and the respective observables. The first item is taken care of by proper weighting as a function of the estimated variance-covariance matrix of the observations, and this weighting is reflected in the quantities N_{11}, N_{22}, U_{11}, and U_{22}. The geometry aspect is implicit in the coefficient matrices A and B which enter into N_{11}, and so forth.

4.5 Constraints' Contributions to the Normal Equations [86, 140, 148]

4.51 General

Since the coefficient matrix of normal equations is singular, a unique least squares solution is not possible. A minimal set of constraints to the normal equations provides a unique solution [Blaha, 1971].

Two alternative definitions exist for the term "constraints:" the absolute constraints represent certain conditions which have to be fulfilled exactly and with no uncertainties. The relative constraints (or weighted constraints) have the same characteristics as the observations.

In general the contribution of the functional constraint equation

$$G(X, L_C) = 0$$

to the reduced normal equations $\bar{N}X + \bar{U} = 0$ can be found by bordering the normal equation matrix

$$\begin{bmatrix} \bar{N} & C' \\ C & -P_C^{-1} \end{bmatrix} \begin{bmatrix} X \\ -K_C \end{bmatrix} + \begin{bmatrix} \bar{U} \\ W^C \end{bmatrix} = 0$$

where

$$C = \frac{\partial G}{\partial \vec{X}_i^{o}}$$

After elimination of K_C

$$K_C = -P_C(CX + W^C) \qquad 4.5 - 1$$

It is easy to find

$$[\bar{N} + C'P_C\, C]\, X + \bar{U} + C'P_C\, W^C = 0$$

or

$$[\bar{N} + N^C]\, X + \bar{U} + U^C = 0 \qquad 4.5 - 1a$$

where N^C and U^C are the contributions to the coefficient matrix and constant vector of the normal equation due to the application of constraints. The quantities $\bar{N}$ and $\bar{U}$ represent the original normal equations (without constraints).

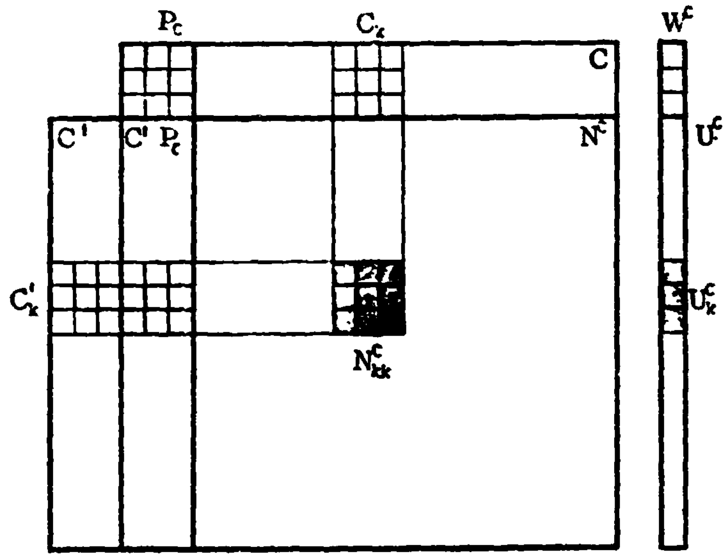
After the constraints are added the normal equations will take the usual form

$$N\,X + U = 0$$

and we are in the position to obtain the contribution from a new set of constraints.

Constraints can be applied between two stations k and ℓ or to a single station. The contribution of these constraints to the matrix (3 x 3 blocks) and $\bar{U}$ (3 x 1 blocks) can be schematically expressed in two different ways.

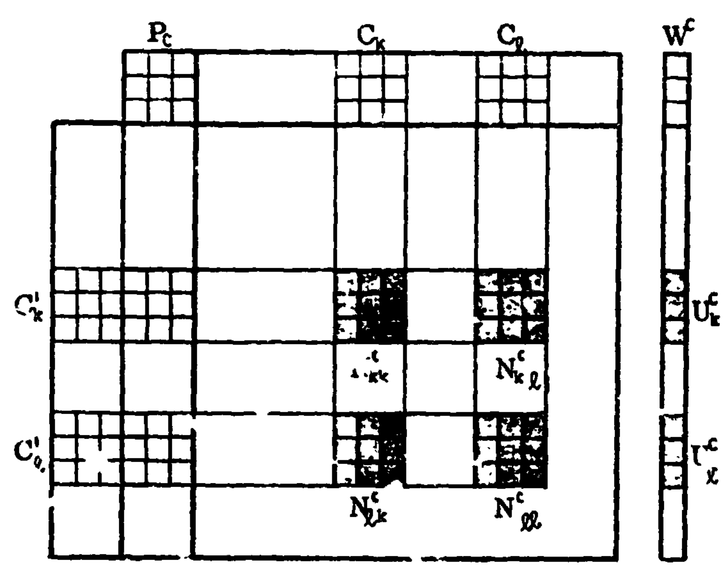
(a) Contribution to the normals due to the constraint applied to station k



$$N^c_{kk} = C'_k P_c C_k \qquad 4.5 - 2a$$

$$U^c_k = C'_k P_c W^c$$

(b) Contribution to the normals due to the constraint between stations k and ℓ



$$N^c_{kk} = C'_k P_c C_k; \quad N^c_{k\ell} = C'_k P_c C_\ell$$

$$N^c_{\ell\ell} = C'_\ell P_c C_\ell; \quad N^c_{\ell k} = C'_\ell P_c C_k$$

$$U^c_k = C'_k P_c W^c; \quad U^c_\ell = C'_\ell P_c W^c$$

4.5 - 2b

These blocks obtained as indicated above for the corresponding case will be the only ones computed and added to the original normal equations as expressed by formula 4.5 - 1.

4.52 Relative Position Constraints

Relative position constraints are used in order to combine the normal equations obtained from various satellite nets and to constrain "double" stations or closely situated stations of the same net. The expression for the combination of normals can be written as follows.

$$[\bar{N} + N^R]\, X + \bar{U} + U^R = 0$$

where N^R and U^R, computed from 4.5 - 2a, 4.5 - 2b, are the contribution to the original combined normal equations ($\bar{N}X + \bar{U} = 0$).

If the relative position ($\Delta u°$, $\Delta v°$, $\Delta w°$) of two stations is known, along with the standard deviation of these relative positions, the constraints can be formed. In this case the functional constraint equations are

$$u_k^\circ - u_\ell^\circ = \Delta u^\circ$$

$$v_k^\circ - v_\ell^\circ = \Delta v^\circ$$

$$w_k^\circ - w_\ell^\circ = \Delta w^\circ$$

Therefore

$$\underset{3\times3}{C_k^R} = \underset{3\times3}{I} \quad ; \quad \underset{3\times3}{C_\ell^R} = \underset{3\times3}{-I}$$

and

$$\underset{3\times1}{U_k^R} = 0 \quad ; \quad \underset{3\times1}{U_\ell^R} = 0 \text{ because } W^R = G^R(X^\circ, L_c^\circ) = 0$$

where

$$P_R = \begin{bmatrix} \frac{1}{\sigma^2_{\Delta u^\circ}} & 0 & 0 \\ 0 & \frac{1}{\sigma^2_{\Delta v^\circ}} & 0 \\ 0 & 0 & \frac{1}{\sigma^2_{\Delta w^\circ}} \end{bmatrix}$$

and

$$\underset{3\times 3}{N^R_{kk}} = I\ P_R\ I = \underset{3\times 3}{P_R}$$

$$\underset{3\times 3}{N^R_{\ell\ell}} = I\ P_R\ I = \underset{3\times 3}{P_R}$$

$$\underset{3\times 3}{N^R_{k\ell}} = \underset{3\times 3}{N^R_{\ell k}} = I\ P_R\ (-I) = \underset{3\times 3}{-P_R}$$

Thus, the diagonal elements of P_R are added to each element of the diagonal of the blocks kk and $\ell\ell$ of the coefficient matrix of the combined normals $\overline{N}$, and subtracted from the diagonal elements of the blocks $k\ell$ and ℓk of $\overline{N}$. There is no contribution to the vector $\overline{U}$.

4.53 Length (Chord) Constraints

Chord constraints are introduced when scalar information is available between ground stations (e.g., distances determined through high precision geodimeter traversing). The functional constraint equation in this case is

$$G^C(X, L_C) = 0$$

or

$$[(u_k - u_\ell)^2 + (v_k - v_\ell)^2 + (w_k - w_\ell)^2]^{\frac{1}{2}} = D_{k\ell} \qquad 4.5 - 3$$

$$C^C_k = \left[\frac{u^\circ_k - u^\circ_\ell}{D^\circ_{k\ell}}, \frac{v^\circ_k - v^\circ_\ell}{D^\circ_{k\ell}}, \frac{w^\circ_k - w^\circ_\ell}{D^\circ_{k\ell}}\right]$$

and

$$C^C_\ell = \left[-\frac{u^\circ_k - u^\circ_\ell}{D^\circ_{k\ell}}, -\frac{v^\circ_k - v^\circ_\ell}{D^\circ_{k\ell}}, -\frac{w^\circ_k - w^\circ_\ell}{D^\circ_{k\ell}}\right]$$

and

$$P_C = \frac{\sigma^2_o}{\sigma^2_{k\ell}} = \frac{\text{a priori variance of unit weight}}{\text{variance of the chord}}$$

Then the contribution to the normals are obtained by applying 4.5 - 2a and 4.5 - 2b

$$\underset{3\times 3}{N^C_{kk}} = (C^C_k)' \; P_C \; C^C_k$$

$$\underset{3\times 3}{N^C_{\ell\ell}} = (C^C_\ell)' \; P_C \; C^C_\ell$$

$$\underset{3\times 3}{N^C_{k\ell}} = (C^C_k)' \; P_C \; C^C_\ell$$

$$\underset{3\times 3}{U^C_k} = (C^C_k)' \; P_C \; W^C$$

$$\underset{3\times 3}{U^C_\ell} = (C^C_\ell)' \; P_C \; W^C$$

The first three expressions in the above are added respectively to the blocks $\overline{N}_{kk}$, $\overline{N}_{\ell\ell}$ and $\overline{N}_{k\ell}$ of $\overline{N}$; the last two expressions are added respectively to the constant subvectors $\overline{U}_k$ and $\overline{U}_\ell$ of $\overline{U}$.

4.54 Station Position Constraint

Station position constraint is used for the purpose of defining the origin of the coordinate system. If the station coordinates $(u^\circ_k, v^\circ_k, w^\circ_k)$ of station k are to be constrained and if the computed (known) variances of its approximate coordinates are $\sigma^2_{u^\circ_k}$, $\sigma^2_{v^\circ_k}$, $\sigma^2_{w^\circ_k}$, then the equations given in section 4.52 are valid by merely deleting the terms with index ℓ, then $\Delta u^\circ = u^\circ_k$, $\Delta v^\circ = v^\circ_k$, $\Delta w^\circ = w^\circ_k$. Then

$$\underset{3\times 3}{N^S_{kk}} = I \; P_S \; I = \underset{3\times 3}{P_S}$$

where

$$P_S = \begin{bmatrix} \frac{1}{\sigma^2_{u^\circ_k}} & 0 & 0 \\ 0 & \frac{1}{\sigma^2_{v^\circ_k}} & 0 \\ 0 & 0 & \frac{1}{\sigma^2_{w^\circ_k}} \end{bmatrix}$$

4.55 Height Constraints

If the geodetic (ellipsoidal) height of the station k is to be constrained, then

$$\underset{3\times 3}{N^H_{kk}} = (C^H_k)' \, P_H \, C^H_k$$

where

$$C^H_k = [\cos\phi^\circ_k \cos\lambda^\circ_k, \cos\phi^\circ_k \sin\lambda^\circ_k, \sin\phi^\circ_k]$$

and

$$P_H = \frac{1}{\sigma^2_{H_k}}$$

where ϕ°_k and λ°_k are the approximate geodetic coordinates and $\sigma^2_{H_k}$ is the variance of the height for station k.

The constant vector U^H_k can be computed from

$$U^H_k = (C^H_k)' \, P_H \, W^H$$

where

$$W^H = H_k - H^\circ_k$$

4.56 Directional Constraints

Directional constraints are introduced when the orientation of the coordinate system is not defined through the observations (e.g., in the case of a ranging network).

The directional constraint between two stations k and ℓ is accomplished by applying weights to two angles α° and β° defining the direction between them and computed from the approximate (u°, v°, w°) coordinates of the two stations as follows:

$$\alpha^\circ = \tan^{-1}\frac{\Delta v^\circ}{\Delta u^\circ}$$

$$\beta^\circ = \tan^{-1}\frac{\Delta w^\circ}{R^\circ}$$

where

$$\Delta u^\circ = u_k^\circ - u_\ell^\circ$$

$$\Delta v^\circ = v_k^\circ - v_\ell^\circ$$

$$\Delta w^\circ = w_k^\circ - w_\ell^\circ$$

and

$$R^\circ = (\Delta u^{\circ 2} + \Delta v^{\circ 2})^{\frac{1}{2}}$$

The matrix C^D of partial derivatives is then formed

$$C_k^D = \begin{bmatrix} \frac{\partial\alpha^\circ}{\partial\Delta u^\circ}\frac{\partial\Delta u^\circ}{\partial u_k^\circ} & \frac{\partial\alpha^\circ}{\partial\Delta v^\circ}\frac{\partial\Delta v^\circ}{\partial v_k^\circ} & \frac{\partial\alpha^\circ}{\partial\Delta w^\circ}\frac{\partial\Delta w^\circ}{\partial w_k^\circ} \\ \frac{\partial\beta^\circ}{\partial\Delta u^\circ}\frac{\partial\Delta u^\circ}{\partial u_k^\circ} & \frac{\partial\beta^\circ}{\partial\Delta v^\circ}\frac{\partial\Delta v^\circ}{\partial v_k^\circ} & \frac{\partial\beta^\circ}{\partial\Delta w^\circ}\frac{\partial\Delta w^\circ}{\partial w_k^\circ} \end{bmatrix}$$

where

$$\frac{\partial\alpha^\circ}{\partial\Delta u^\circ} = \cos^2\alpha^\circ \tan\alpha^\circ/\Delta u^\circ$$

$$\frac{\partial\alpha^\circ}{\partial\Delta v^\circ} = -\cos^2\alpha^\circ/\Delta u^\circ$$

$$\frac{\partial\alpha^\circ}{\partial\Delta w^\circ} = 0$$

$$\frac{\partial\beta^\circ}{\partial\Delta u^\circ} = \Delta u^\circ \cos^2\beta^\circ \tan^2\beta^\circ/R^{\circ 2}$$

$$\frac{\partial\beta^\circ}{\partial\Delta v^\circ} = \frac{\partial\beta^\circ}{\partial\Delta u^\circ}\tan\alpha^\circ$$

$$\frac{\partial\beta^\circ}{\partial\Delta w^\circ} = -\cos^2\beta^\circ/R^\circ$$

and clearly $C_\ell^D = -C_k^D$.

Then the matrix

$$N^D = (C^D)' P_D C^D \qquad 4.5 - 4$$

is formed according to 4.5 - 2b where P_D is the weight matrix estimated from the statistics of α° and β° in the customary way

$$P_D = \begin{bmatrix} \sigma^2_{\alpha^\circ} & \sigma_{\alpha^\circ\beta^\circ} \\ \sigma_{\alpha^\circ\beta^\circ} & \sigma^2_{\beta^\circ} \end{bmatrix}^{-1}$$

The matrix N^D is then added to the block elements of the reduced normal equations which correspond to each of the ground stations, i.e., its diagonal blocks will be added to $\bar{N}_{kk}$ and $\bar{N}_{\ell\ell}$ and subtracted from the off-diagonal elements $\bar{N}_{k\ell}$ and $\bar{N}_{\ell k}$.

4.57 Inner Constraints (Free Adjustment)

Even though the selection of a coordinate system is arbitrary in the case of a minimum constraint adjustment, e.g., in the case of ranging, the selection of the six coordinates (at more than two stations) to be constrained is very critical, since one set of constraints would give a different solution than another set. The "best" solution is arrived at in a coordinate system defined through the use of a set of constraint equations called "inner" constraints [Rinner et al., 1967]. In this sense, "best" means resulting in the smallest covariance matrix for the unknowns. Covariance matrices may be compared by means of their traces, and the inner constraint equations are characterized by the property that the trace of the covariance matrix obtained with their use is a minimum among those obtained by adjusting a given set of observations augmented by a minimal set of constraint equations. This property also implies that the mean square uncertainty of the unknowns is smaller when the inner adjustment equations are used. The resulting adjustment is called a "free" one. The functional inner constraints equations can be written as

$$C^I X = 0$$

where X is the set of corrections of the approximate coordinates of the unknown points and in the most general application when the "best" origin, orientation and scale are sought

$$C^I = \begin{bmatrix} C_1^I \\ \\ C_2^I \\ \\ C_3^I \end{bmatrix} = \left[\begin{array}{ccc:ccc:c} & \underset{3\times 3}{I} & & & \underset{3\times 3}{I} & & \cdots \\ \hdashline 0 & w_1^\circ & -v_1^\circ & 0 & w_2^\circ & -v_2^\circ & \\ -w_1^\circ & 0 & u_1^\circ & -w_2^\circ & 0 & u_2^\circ & \cdots \\ v_1^\circ & -u_1^\circ & 0 & v_2^\circ & -u_2^\circ & 0 & \\ \hdashline u_1^\circ & v_1^\circ & w_1^\circ & u_2^\circ & v_2^\circ & w_2^\circ & \cdots \end{array}\right]$$

The symbols $(u_i^\circ, v_i^\circ, w_i^\circ)$ denote the approximate coordinates of the i^{th} unknown point where both the ground points and the satellite positions are considered.

It is also possible to design a set of constraints that will result in the "best" solution for only a subset of the points. In the adjustments reported here we were only interested in the ground station unknowns implying that the trace of only that portion of the covariance matrix corresponding to the ground station unknowns should be minimized, while the variances of the satellite position unknowns should not be included in the minimum sum. The constraint equations that will produce such a solution have the same form as those producing the "best" solution for all the points; however, 3 x 3 blocks of zeros are inserted into those positions of C^I which correspond to unknowns whose variances are not to be included in the minimum sum.

The inner adjustment constraint equations can be given a geometrical interpretation that appeals to intuition. Let X_i° denote the set of approximate coordinates of the i^{th} unknown point, dX_i denote the corrections to these coordinates, and X_i^a denote the adjusted coordinates, i.e.,

$$X_i^a = X_i^\circ + dX_i$$

The first set of constraint equations, $C_1^I X = 0$, is then equivalent to the set of conditions

$$\sum_i dX_i = 0$$

The geometrical interpretation of these conditions is that the center of gravity of all the points will not change after adjustment, i.e.,

$$\sum_i X_i^a = \sum_i X_i^o$$

The second set of constraint equations, $C_2^I X = 0$, corresponds to the conditions

$$\sum_i X_i^o \times dX_i = 0$$

If the center of the system remains fixed, then the cross products $X_i^o \times dX_i$ reflect rotations of the points around the fixed center. These constraint equations insure that the sums of the rotations around all three coordinate axes are zero. The corresponding geometrical interpretation is that the mean orientation of the system of points will not change after adjustment either.

Thus, the respective equations $C_1^I X = 0$ and $C_2^I X = 0$ effectively specify the origin and the orientation of the adjustment coordinate system. A seventh "inner adjustment" equation $C_3^I X = 0$ specifies the scale of the system. However, this scale equation is only used when the observations themselves do not determine the scale.

A more complete description of the inner adjustment is described in [Blaha, 1971].

In summary, if the normal equations with the contribution of all the constraints (except inner constraints) are represented by

$$[\bar{N} + N^R + N^C + N^S + N^H + N^D]X + \bar{U} + U^R + U^C + U^S + U^H + U^D = 0 \qquad 4.5 - 5$$

or

$$NX + U = 0$$

then the inner adjustment can be obtained by bordering the coefficient matrix N of the normal equations as

$$\begin{bmatrix} N & (C^I)' \\ C^I & 0 \end{bmatrix} \begin{bmatrix} X \\ -K_I \end{bmatrix} = \begin{bmatrix} -U \\ 0 \end{bmatrix} \qquad 4.5 - 6$$

Upon the addition of any kind of constraint to the normal equations, it becomes necessary to consider also its contribution to $\Sigma V' PV$. The degrees of freedom change as well. In order to compute the proper variance of unit weight the latter must be taken into consideration.

4.6 Solution of Normal Equations and Formation of the Inverse Weight Matrix [86]

4.61 Introduction

The normal equations for the optical and range adjustments are given in the previous section. The general form of the normal equations is

$$NX + U = 0 \qquad 4.6 - 1$$

where N is the coefficient matrix, X is the vector of unknowns, and U is the constant vector.

The adjusted values of the Cartesian coordinates of the observing ground stations are obtained by adding the corrections X to the preliminary values X°, namely,

$$X^a = X^\circ + X \qquad 4.6 - 2$$

Section 4.7 deals with obtaining the precision estimate of X^a through the inverse matrix N^{-1}. For this reason the method of formation of N^{-1} will be dealt with in section 4.64 along with the method of solving for X.

The procedure used to solve the normal equations is a Gauss reduction (section 4.62) and back solution (section 4.63) and computation of the inverse by the method established by Banachiewicz (section 4.64).

Two features which are peculiar to the specific procedure used here are:

(1) The coefficient matrix N is broken down into 3 x 3 submatrices, and similarly the U vector is treated as composed of 3 x 1 vectors.

(2) The coefficient matrix N is compacted so that 3 x 3 zero submatrices are neither stored nor used in the computation.

The first feature is achieved rather naturally; it is because of the form of the expressions given in sections 4.2 - 4.6 which are used to build up N and U. On the other hand, the second feature is achieved through programming logic. Specifically, a first matrix L is used to tag each 3 x 3 nonzero submatrix of N with a row and column number. A second matrix F with a one-to-one correspondence to the first is then employed to tag the storage assigned to the particular 3 x 3 submatrix. The individual elements of the 3 x 3 submatrices are all stored in one large linear array E.

The reduced elements of N are stored in the locations previously created for elements in N. During reduction additional 3 x 3 matrices arise in locations where there were none originally in N; thus "drag storage" must be assigned. In doing so the guide matrix L and the storage tagging matrix F are updated to account for these additional matrices. Similar "drag storage" is also determined during the formation of the inverse N^{-1}.

Once the "drag storage" is determined, the reduction, back solution and inverse determinations are guided by L, the storage located by F, and the elements to be used in the computation found in E.

4.62 Reduction

The coefficient matrix of the normal equations is written as

$$N = SR \qquad 4.6 - 3$$

where S is a lower triangular matrix with 3 x 3 identity matrices along the diagonal, and R is an upper triangular matrix. All matrices and vectors presented in this discussion are stipulated to be composed of 3 x 3 submatrices and 3 x 1 subvectors respectively.

The reduction is accomplished by computing

$$S = I - T \qquad 4.6 - 4$$

from

$$N = R - TR \qquad 4.6 - 5$$

or

$$R = N + TR \qquad 4.6 - 6$$

where R and T (thus S) are built up simultaneously. The augmented matrix

$$[N,U] = \begin{bmatrix} n_{011} & n_{012} & n_{013} & \cdots & n_{01n} & u_{01} \\ n'_{012} & n_{022} & n_{023} & \cdots & n_{02n} & u_{02} \\ n'_{013} & n'_{023} & n_{033} & \cdots & n_{03n} & u_{03} \\ n'_{014} & & \cdot & & & u_{04} \\ \cdot & & & \cdot & & \cdot \\ \cdot & & & & \cdot & \cdot \\ n'_{01n} & & & & n_{0nn} & u_{0n} \end{bmatrix} \qquad 4.6 - 7$$

is first reduced according to the algorithms

$$n_{k,i,j} = n_{k-1,i,j} - n'_{k-1,k,i}\, n^{-1}_{k-1,k,k}\, n_{k-1,k,j} \qquad 4.6 - 8$$

$k = 1,2, \ldots, n - 1$

$i = k+1, k+2, \ldots, n$

$j = i, i+1, \ldots, n$

defining

$$R = \begin{bmatrix} n_{011} & n_{012} & \cdots & \cdots & n_{01n} \\ & n_{122} & n_{123} & \cdots & n_{12n} \\ & & \cdot & \cdot & \cdot \\ \text{zeros} & & & \cdot & \cdot \\ \text{below} & & & & \cdot \\ \text{diagonal} & & & & n_{n-1,n,n} \end{bmatrix}$$

and

$$u_{k,i} = u_{k-1,i} - n'_{k-1,k,i}\, n^{-1}_{k-1,k,k}\, u_{k-1,k}$$

$k = 1, 2, \ldots, n-1$

$i = k+1, \ldots, n$

defining

$$\bar{C} = \begin{bmatrix} u_{01} \\ u_{12} \\ u_{23} \\ \cdot \\ \cdot \\ \cdot \\ u_{n-1,n} \end{bmatrix} \qquad 4.6 - 9$$

A second algorithm (performed as part of equation 4.6 - 8) namely,

$$\bar{n}_{k-1,k,j} = n^{-1}_{k-1,k,k}\, n_{k-1,k,j} \qquad 4.6 - 10$$

$$\bar{n}_{k-1,k,k} = I \qquad 4.6 - 11$$

$$\bar{u}_{k-1,k} = n^{-1}_{k-1,k,k}\, u_{k-1,k} \qquad 4.6 - 12$$

$j = k+1, k+2, \ldots, n$

$k = 1, 2, \ldots, n-1$

results in the following reduced matrices:

$$S' = \begin{bmatrix} I & \bar{n}_{012} & \bar{n}_{013} & \cdots & \bar{n}_{01n} \\ 0 & I & \bar{n}_{123} & & \bar{n}_{12n} \\ 0 & 0 & I & & \\ \cdot & \cdot & \cdot & \ddots & \\ \cdot & \cdot & \cdot & & \\ \cdot & \cdot & \cdot & & \\ 0 & 0 & 0 & 0 & I \end{bmatrix} \qquad 4.6 - 13$$

$$-\bar{D} = \begin{bmatrix} \bar{u}_{01} \\ \bar{u}_{12} \\ \bar{u}_{23} \\ \cdot \\ \cdot \\ \cdot \\ \bar{u}_{n-1,n} \end{bmatrix} \qquad 4.6 - 14$$

(S' and D are used to obtain solution vector X--section 4.63)

$$R^{-1} = \begin{bmatrix} n_{011}^{-1} & & & \text{elements} \\ & n_{122}^{-1} & & \text{above} \\ & & n_{233}^{-1} & \text{diagonal} \\ \text{zeros} & & \cdots & \\ \text{below} & & & n_{n-1,n,n}^{-1} \\ \text{diagonal} & & & \end{bmatrix} \qquad 4.6 - 15$$

(used to obtain inverse--section 4.64)

4.63 Back Solution

The back solution involves the determination of the unknown vector X from elements of the reduced matrices S' and D. Without derivation [Uotila, 1967, p. 28],

$$X = T'X - \bar{D} \qquad 4.6 - 16$$

recall

$$T = I - S'$$

or in summation form

$$X_i = \sum_{j=i+1}^{n} \bar{n}_{i-1,i,j} X_j + \bar{u}_{i-1,i} \qquad 4.6 - 17$$

4.64 Formation of Inverse

The inverse matrix N^{-1} will be computed by the method associated with the name of Banachiewicz [Uotila, 1967, p. 31]. According to equation 4.6 - 3, N^{-1} can be computed from

$$N^{-1} = R^{-1} S^{-1} \qquad 4.6 - 18$$

However, it turns out that N^{-1} can be formed without the aid of S^{-1} and further only the diagonal elements of R^{-1} are needed.

The diagonal elements of R^{-1} are readily available since the inverse of an upper triangular matrix has as its diagonal elements the reciprocal of the diagonal elements of the triangular matrix itself and the same result holds if "elements" is taken to mean 3 x 3. The diagonal elements of

R^{-1} are computed by inverting the 3 x 3 diagonal matrices of R and for computer space saving reasons are stored along the diagonal of S' (equation 4.6 - 13).

From equation 4.6 - 18

$$R^{-1} = N^{-1}S \qquad 4.6 - 19$$

and further substituting in for S from equation 4.6 - 4

$$R^{-1} = N^{-1}(I - T) \qquad 4.6 - 20$$

$$= N^{-1} - N^{-1}T \qquad 4.6 - 21$$

and finally

$$N^{-1} = R^{-1} + N^{-1}T \qquad 4.6 - 22$$

The corresponding summation equation for computing any 3 x 3 matrix of N^{-1} is

$$n^{ij} = \sum_{k=i+1}^{n} \bar{n}_{i-1,i,k}\, n^{kj} + \delta_{ij}\, n^{-1}_{i-1,i,i} \qquad 4.6 - 23$$

where δ_{ij} is the Kronecker delta defined by

$$\delta_{ij} = \begin{cases} 1 & i = j \\ 0 & i \neq j \end{cases} \qquad 4.6 - 24$$

and

$$n^{ij} = (n^{ji})' \qquad 4.6 - 25$$

4.7 Statistical Evaluation (Precision of Ground Stations After Adjustment) [86]

4.71 Variance of Unit Weight

The variance of unit weight for the total adjustment is given by the following expression:

$$\sigma_0^2 = \frac{V'PV}{df} \qquad 4.7 - 1$$

where V'PV is the sum of the squares of the weighted residuals of all observed quantities and df is the number of degrees of freedom in the least squares adjustment.

4.711 Optical Adjustment.

Equation 4.7 - 1 will now be considered for the optical adjustment. The linearized mathematical structure according to section 4.2 was shown to be of the form

$$AX + BV + W = 0$$

The general expression for the computation of V'PV is

$$V_c'P_cV_c = -W'K - \sum^{c} (W^c)' K_c \qquad 4.7 - 3$$

where the first term is the contribution from equation 4.7 - 2 and the second term is the contribution from the c constraints applied. Without taking into consideration the constraints' contribution

$$V'PV = -W'K \qquad 4.7 - 4$$

and considering an expression for K and X from equations 4.2 - 27 and 4.2 - 28 respectively,

$$V'PV = W'(BP^{-1}B')^{-1} (AX + W) \qquad 4.7 - 5$$

and

$$X = -(A'M^{-1}A + P_x)^{-1}A'M^{-1}W \qquad 4.7 - 6$$

Denoting

$$M = BP^{-1}B' \qquad 4.7 - 6a$$

equation 4.7 - 5 with equations 4.2 - 29 and 4.7 - 6a gives

$$V'PV = W'M^{-1}W - [U_j' \ U_i'] \begin{bmatrix} X_j \\ X_i \end{bmatrix} \qquad 4.7 - 7$$

Let the partitioning of equation 4.2 - 29 be denoted as

$$\begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix} \begin{bmatrix} X_j \\ X_i \end{bmatrix} + \begin{bmatrix} U_j \\ U_i \end{bmatrix} = 0 \qquad 4.7 - 8$$

Then, using

$$\begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix}^{-1} = \begin{bmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{bmatrix} = \begin{bmatrix} N_{11}^{-1} + N_{11}^{-1} N_{12} E\, N_{21} N_{11}^{-1} & -N_{11}^{-1} N_{12} E \\ -E\, N_{21} N_{11}^{-1} & E \end{bmatrix} \qquad 4.7 - 9$$

where

$$E = (N_{22} - N_{21} N_{11}^{-1} N_{12})^{-1} \qquad 4.7 - 9a$$

equation 4.7 - 7 becomes

$$V'PV = W'M^{-1}W - [U_j' \; U_i'] \begin{bmatrix} Q_{11}U_j + Q_{12}U_i \\ Q_{21}U_j + Q_{22}U_i \end{bmatrix}$$

and after substituting the values from equation 4.7 - 9 and simplifying

$$V'PV = W'M^{-1}W - U_j'N_{11}^{-1}U_i + (U_i - N_{21}N_{11}^{-1}U_j)'\, E(U_i - N_{21}N_{11}^{-1}U_j) \qquad 4.7 - 10$$

but by elimination of X_j from 4.7 - 8 we get

$$X_i = -[N_{22} - N_{21}N_{11}^{-1}N_{12}]^{-1}\, [U_i - N_{21}N_{11}^{-1}U_j]$$

or, using the notation of 4.6 - 1,

$$X = -N^{-1}\, U$$

Thus we see that

$$E = N^{-1}$$

and

$$U = U_i - N_{21}N_{11}^{-1}U_j$$

and finally

$$V'PV = W'M^{-1}W - U_j'N_{11}^{-1}U_j + U'X \qquad 4.7 - 11$$

Denoting

$$Q = W'M^{-1}W - U_j'N_{11}^{-1}U_j \qquad 4.7 - 12$$

and considering equation 4.2 - 31 this becomes

$$Q = \sum_{ij} W_{ij}'M_{ij}^{-1}W_{ij} - \sum_j \{\sum_i M_{ij}^{-1}W_{ij}\}'\{\sum_i M_{ij}^{-1}\}^{-1}\{\sum_i M_{ij}^{-1}W_{ij}\} \qquad 4.7 - 13$$

Now using equations 4.2 - 38, 4.2 - 42 and factorization and cancellation analogous to that in equations 4.2 - 41 to 4.2 - 42, this becomes

$$Q = \sum_{ij} \vec{X}_i'M_{ij}^{-1}\vec{X}_i - \sum_j \{\sum_i M_{ij}^{-1}\vec{X}_i\}'\{\sum_i M_{ij}^{-1}\}^{-1}\{\sum_i M_{ij}^{-1}\vec{X}_i\} \qquad 4.7 - 14$$

which is easily shown to be identically equal to

$$Q = \sum_{ij} (\vec{X}_i - \vec{X}^\circ_j)' M^{-1}_{ij} (\vec{X}_i - \vec{X}^\circ_j)$$

with

$$\vec{X}^\circ_j = \{\sum_i M^{-1}_{ij}\}^{-1}\{\sum_i M^{-1}_{ij}\vec{X}_i\}$$

so that finally after the constraints are taken into consideration

$$V_c'P_cV_c = \sum_{ij} (\vec{X}_i - \vec{X}^\circ_j)' M^{-1}_{ij} (\vec{X}_i - \vec{X}^\circ_j) + U'X - \sum^{c} (W^c)' K_c \qquad 4.7 - 15$$

Note that the first term in the above is the quadratic form of all the residuals arising from all simultaneous event adjustments with ground stations held fixed and is computed and summed for each event by means of equation 3.2 - 1 for the purpose of blunder detection (section 3.222); the second term is found from

$$U'X = \overline{D}'\overline{C} \qquad 4.7 - 16$$

where the vectors $\overline{D}'$ and $\overline{C}$, a byproduct in the solution of the normal equations, are defined by equations 4.6 - 14 and 4.6 - 9 respectively. K_c is obtained from 4.5 - 1 where X is the solution of equation 4.5 - 6.

The total number of degrees of freedom, df, to be used in equation 4.7 - 1 is

$$df = \text{number of equations - number of unknowns}$$

$$df = (\sum_j 2n + n_c) - (3s + 3g) \qquad 4.7 - 17$$

where 2n is the number of equations resulting from one simultaneous event (n = number of ground stations in a particular event j and the summation is performed over all simultaneous events; n_c is the number of constraint equations; 3s is the number of unknowns due to s number of satellite positions; 3g is the number of unknowns due to g number of unknown ground stations.

In conclusion the "a posteriori" variance of unit weight for the optical adjustment will be

$$\sigma_o^2 = \frac{V_c' P_c V_c}{df} \qquad 4.7 - 18$$

4.712 Range Adjustment.

Equations 4.7 - 1 will now be discussed in the light of the range adjustment. Firstly, the expression for computing V'PV by an analogous argument to the optical case is

$$V'PV = \bar{V}'P\bar{V} - X'U \qquad 4.7 - 19$$

where $\bar{V}'P\bar{V}$ is the quadratic form of the residuals arising from the adjustment of simultaneous events--holding the ground stations fixed. The second term

$$X'U = \bar{D}'\bar{C} \qquad 4.7 - 20$$

is computed according to equations 4.6 - 14 and 4.6 - 9 respectively.

The degrees of freedom, df, in the range adjustment is as usual

df = number of equations - number of unknowns

$$= (\sum_j n + n_r) - (3s + 3g) \qquad 4.7 - 21$$

where n is the number of ground stations, thus observed ranges, in a particular simultaneous event and the summation is performed over all simultaneous events; n_r again is the number of constraint equations in the range adjustment; 3s and 3g are the number of unknowns due to s number of satellite positions and g number of unknown ground stations respectively.

In summary,

$$\sigma_o^2 = \frac{V'PV}{df} \qquad 4.7 - 22$$

4.72 Variances and Covariances of Ground Stations

4.721 Cartesian Coordinates.

The variance-covariance matrix giving the accuracy of the adjusted rectangular ground station coordinates is

$$\Sigma_{\substack{u\\v\\w}} = \sigma_0^2 \, N^{-1} \qquad 4.7 - 23$$

where σ_0^2 is the variance of unit weight arising from the adjustment (section 4.71) and N^{-1} is the coefficient matrix discussed in section 4.64.

The units for the variance-covariance matrix for the optical and range adjustments are meters squared.

The square root of the diagonal elements of the variance-covariance matrix yields the corresponding standard deviations in meters.

4.722 Geodetic (Curvilinear) Coordinates.

The propagation of variances and covariances from curvilinear coordinates (geodetic latitude ϕ and longitude λ and ellipsoidal height H) in meters to three dimensional rectangular coordinates (u,v,w) is achieved by the following matrix equation

$$\Sigma_{uvw} = G \, \Sigma_{\phi\lambda} \, G' \qquad 4.7 - 24$$

where

$$G = \begin{bmatrix} -\sin\phi \cos\lambda & -\cos\phi \sin\lambda & \cos\phi \cos\lambda \\ -\sin\phi \sin\lambda & \cos\phi \cos\lambda & \cos\phi \sin\lambda \\ \cos\phi & 0 & \sin\phi \end{bmatrix} \qquad 4.7 - 25$$

Reversing the transformation depicted by equation 4.7 - 24, the 3 x 3 variance-covariance matrix corresponding to ϕ, λ, H is

$$\Sigma_{\phi\lambda H} = G^{-1} \, \Sigma_{uvw} \, (G')^{-1}$$

$$= \begin{bmatrix} \sigma_{\phi}^2 & \sigma_{\phi\lambda} & \sigma_{\phi H} \\ \sigma_{\lambda\phi} & \sigma_{\lambda}^2 & \sigma_{\lambda H} \\ \sigma_{H\phi} & \sigma_{H\lambda} & \sigma_{H}^2 \end{bmatrix} \qquad 4.7 - 26$$

all in meters.

In order to obtain the units

$$\begin{array}{ll} \sigma_{\phi}^2 & (\text{arc sec})^2 \\ \sigma_{\lambda}^2 & '' \\ \sigma_{\phi\lambda} \equiv \sigma_{\lambda\phi} & '' \\ \sigma_{H}^2 & m^2 \end{array} \qquad 4.7 - 27$$

$\sigma_{\phi H} \equiv \sigma_{H\phi}$; $\sigma_{H\lambda} \equiv \sigma_{\lambda H}$, arc sec × meters the elements of equation 4.7 - 26 require the following modifications:

$$\sigma_{\phi}^{"2} = \left(\frac{\rho"}{R + H}\sigma_{\phi}\right)^2$$

$$\sigma_{\lambda}^{"2} = \left(\frac{\rho"}{R + H}\sigma_{\lambda}\right)^2$$

$$\sigma_{\phi\lambda} \equiv \sigma_{\lambda\phi} = \left(\frac{\rho"}{R + H}\right)^2 \sigma_{\phi\lambda} \qquad 4.7 - 28$$

$$\sigma_{H\phi} \equiv \sigma_{\phi H} = \frac{\rho"}{R + H}\sigma_{H\phi}$$

$$\sigma_{H\lambda} \equiv \sigma_{\lambda H} = \frac{\rho"}{R + H}\sigma_{H\lambda}$$

where

$$\rho" = \frac{1}{\sin 1"}$$

$$R = 6{,}370{,}000 \text{ m}$$

(Note: R replaces the radius of curvature N in the prime vertical plane in the rigorous case--justification for simplification is given by the fact that only three significant figures are meaningful in propagation of variances whose magnitudes in m^2 or (arc sec)^2 are in the units place.)

4.73 Correlation Between Ground Stations

The amount of correlation between the adjusted ground station coordinates is described in terms of the correlation coefficient. The correlation coefficient is defined as

$$\rho_{ij} = \frac{\sigma_{ij}}{\sigma_i \sigma_j} \qquad 4.7 - 29$$

where i and j represent any two quantities associated with a variance-covariance matrix such as that of equation 4.7 - 23; σ_{ij} is the covariance, namely, the off-diagonal term of equation 4.7 - 23; σ_i and σ_j are the standard deviations or square root of the i^{th} and j^{th} variances (diagonal terms) respectively.

4.74 Error Ellipsoid Computation

Error ellipsoid cor ıtation is made for each observing ground station considered as an unknown in the adjustment. The eigenvalues and eigenvectors are computed in a topocentric three-dimensional rectangular coordinate system with its origin at the particular ground station and its axes parallel to the mean terrestrial coordinate system (section 4.12). For each point there corresponds one eigenvalue (λ_{ii}) for each of the three mutually perpendicular axes of the ellipsoid; the direction of these three axes is given bv their corresponding eigenvector (T^i).

The actual computation is as follows. The particular 3 x 3 on-diagonal variance-covariance matrix Σ of equation 4.7 - 23 is subjected to an orthogonal transformation

$$T'\Sigma T = \Lambda \qquad 4.7 - 30$$

where Λ is a diagonal matrix and T is the orthogonal transformation matrix to be found which diagonalizes Σ. The transformation results in three homogeneous linear equations, namely,

$$[\Sigma - \lambda_{ii}I]\, T^i = 0 \qquad 4.7 - 31$$

which has a solution only if the determinant of the coefficient vanishes, i.e.,

$$|\Sigma - \lambda_{ii}I| = 0$$

or

$$\begin{vmatrix} \sigma_{11}^2 - \lambda_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22}^2 - \lambda_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33}^2 - \lambda_{33} \end{vmatrix} = 0 \qquad 4.7 - 32$$

Once the eigenvalues are obtained from equation 4.7 - 32, their corresponding eigenvectors are obtained from equation 4.7 - 31 after substitution of λ_{ii}.

The length of the axes of the error ellipsoid are the square-roots of the corresponding eigenvalues. The spherical coordinates (spherical latitude θ and longitude λ) which give the direction of each ellipsoidal axis are obtained from the components of the eigenvector

$$T^i = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \end{bmatrix}$$

namely

$$\tan \theta = \frac{t_3}{\sqrt{t_1^2 + t_2^2 + t_3^2}} \qquad 4.7 - 33$$

and

$$\tan \lambda = \frac{t_2}{t_1} \qquad 4.7 - 34$$

These angles can easily be converted to altitude and azimuth if so desired.

4.8 Computer Programming [87, 88, 190, 193]

Computer programs related to section 4 may be found in [Reilly et al., 1972] and in [Mueller et al., 1973a].

5. RESULTS (SOLUTION WN14) [187, 188, 193, 195, 196]

5.1 Reference Ellipsoid, Origin, Orientation and Scale

The least squares adjustment of the observations listed in Tables 3.2-3 is performed in terms of the Cartesian coordinates of the tracking stations. The results are also converted into geodetic coordinates (latitude, longitude, height) referenced to a rotational ellipsoid of the following parameters:

$$a = 6\ 378\ 155.00 \text{ m}$$

$$b = 6\ 356\ 769.70 \text{ m}$$

The corresponding flattening is

$$f = 1/298.2494985 = 0.003352897507$$

The origin of the coordinate system (or the center of the above reference ellipsoid) is free as determined through the "inner" constraints explained in section 4.57. The orientation of the system is inherent in the optical observations, through the star positions in the SAO catalog (referenced to the FK4 system) updated to their apparent positions at the epoch of the observation, and through UT1, x and y (coordinates of the true pole with respect to the CIO) as derived by the BIH. Thus the positive end of the axis u is in the direction of the Greenwich Mean Astronomical Meridian (and the zero geodetic meridian of the reference ellipsoid); the positive w axis passes through the Conventional International Origin (and coincides with the minor axis of the reference ellipsoid). The axis v completes the right-handed coordinate system in the direction of the 90° (E) meridian, and with the u axis defines the plane of the average terrestrial (geodetic) equator.

The scale in the solution is defined through the dominating nearly 30,000 SECOR range observations, through the lengths of eight EDM (Geodimeter or Tellurometer) and three C-Band baselines, and also through a special procedure using constrained ellipsoidal heights.

The SECOR observations have an a posteriori standard deviation of ±4.1 m or approximately one part per million [Mueller et al., 1973b]. The scale is propagated into the network through thirteen optical stations whose relative positions with respect to the nearby SECOR stations are maintained in the adjustment with their survey coordinate-differences entered as weighted constraints (see Table 3.3-2).

The available EDM and C-Band baselines are listed in Table 3.3-4. The chord distances shown are entered in the adjustment as weighted constraints with weights computed from their estimated a priori standard deviations as listed in the table. The reasons for rejecting the east-west Australian tellurometer line (6032-6060) are explained in [Mueller et al., 1973a]. Three C-Band lines were also rejected because of suspected errors in the survey coordinates of the terminal stations (Kauai (4742) in Hawaii and Pretoria (4050) in South Africa) needed to tie them to the nearest optical stations (9012 and 9002,respectively). Though these four lines were not constrained, at the end of the analysis two of them (6032-6060 and 4082-4050) compared well with the lengths computed from the adjusted coordinates (see Table 5.3-1). Thus the only station with survey coordinates in definite error is Kauai.

The use of geodetic (ellipsoidal) heights as weighted constraints as a contribution to the scale requires a more detailed explanation (Fig. 5.1-1). The height (H) above a <u>geocentric</u> reference ellipsoid has two

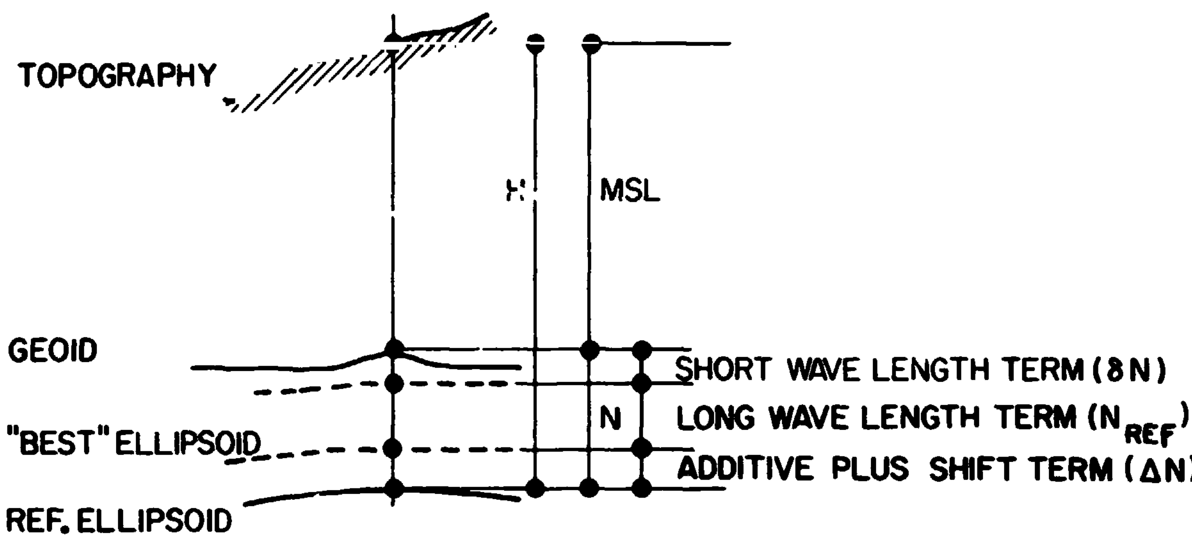


Fig. 5.1-1 Height components.

main components: the orthometric (mean sea level) height (MSL) and the geoid undulation (N). In this geocentric case, N consists of a long-wave-length component N_{REF}, a short-wave-length term δN, and an additive part Δa. The term N_{REF} generally corresponds to regional gravitational effects and can be computed, e.g., from a truncated spherical harmonic series. The short-wave-length part δN corresponds to local gravity or mass disturbances and is generally not contained in the spherical harmonic representation. The additive part Δa is the so-called zero-degree term which may exist due to the fact that the ellipsoid may not be of the same size (though it is of the same flattening) as the "best" (mean earth) level ellipsoid to which the undulation, N_{REF}, are referenced. Since the N_{REF} undulations are, within reasonable limits, insensitive to the semidiameter of the level ellipsoid, it is difficult to define a correct value for Δa. If the reference ellipsoid is nongeocentric, as is the case in this solution, an additional height term (dH) arises due to the "shift" of the origin (ellipsoidal center) with respect to the geocenter.

Thus the geodetic height may have the following components:

$$H = MSL + N \qquad 5.1-1$$

$$N = N_{REF} + \delta N + \Delta N \qquad 5.1-2$$

where [Heiskanen and Moritz, 1967, p. 207]

$$\Delta N = \Delta a + dH = \Delta a + u_o \cos\phi \cos\lambda + v_o \cos\phi \sin\lambda + w_o \sin\phi \qquad 5.1-3$$

Δa = a (level ellipsoid) - a (reference ellipsoid)

u_o, v_o, w_o are the coordinates of the geocenter with respect to the center of the reference ellipsoid (origin)

ϕ, λ are the geodetic coordinates of the station to which H refers

In practice at most satellite tracking stations, the quantity $MSL + N_{REF}$ is well known, and generally it constitutes the largest portion of the total height above the level ellipsoid. The additive + shift term, ΔN, can be determined empirically through an iterative interpolation procedure as described later. Since $MSL + N_{REF} + \Delta N$ constitute the largest portion of the total height above the reference ellipsoid, it seems reasonable not to ignore this, admittedly partial, information on the height of the station and to include it in the adjustment as a constraint ($H_{CONSTR} = MSL + N_{REF} + \Delta N$) with such a weight that the adjustment should be able to "pull out" the only remaining component, the short-wave-length term, δN, together with possible errors in H_{CONSTR}. In this solution the standard deviations used in computing the weights vary from ±2.5 m to ±8 m depending mostly on the location of the station, from the point of view of the extent of the available surface gravity observations in the area which was included in the spherical harmonic expansion for N_{REF} [Rapp, 1973]. Table 3.3-3 lists these standard deviations and the quantities H_{CONSTR} for all the stations.

In trying to determine the "best" scale for the solution or, which is the same, the "best" additive term Δa, the first step is to establish the relationship between them. This problem differently stated is the determination of the relationship between the additive term and the semi-diameter of the "best" level ellipsoid to which the quantity N_{REF} refers. The meaning of the term "best" will be elaborated on later in this section. This is accomplished empirically from a set of solutions with height constraints containing different additive terms, from Δa = 0 to 30 m. The shift term dH initially is estimated from comparisons with various dynamic solutions, resulting in the coordinates u_o, v_o and w_o needed in equations 5.1-3. These solutions result in sets of geodetic heights (H_{WNi}) above the reference ellipsoid and also in sets of undulations after subtracting the MSL:

$$N_{WNi} = H_{WNi} - MSL$$

These undulations thus refer to the reference ellipsoid of a = 6 378 155 m, whose origin is set by the inner constraint. Disregarding the short-wave-length term, the relationship between the undulations N_{WNi} and N_{REF} is given by equations 5.1-2 and 5.1-3, from where, for any station and for the solution WNi:

$$(N_{WNi} - N_{REF}) - (\Delta a_i + u_{oi} \cos\phi \cos\lambda + v_{oi} \cos\phi \sin\lambda + w_{oi} \sin\phi) = 0$$

Since the quantity $(N_{WNi} - N_{REF})$ is known at all stations, the parameters Δa_i, u_{oi}, v_{oi}, w_{oi} can be calculated (iterated) from least squares adjustments for each set "i." This is the same as determining the size (scale) and the origin of the level ellipsoid which fits best the geoid defined for a given set by the undulations N_{WNi}. Its size is

$$a_i = 6\ 378\ 155 + \Delta a_i$$

and its origin with respect to the origin of the reference ellipsoid is defined by the coordinates u_{oi}, v_{oi} and w_{oi}. After some iterations these coordinates hardly change from solution (set) to solution (set), regardless of the initial selection of Δa; thus the relationship between the input additive term and the resulting semidiameter, $a = f(\Delta a)$, becomes straightforward and linear.

This empirically determined relationship is shown in Fig. 5.1-2, as the dashed line drawn from the lower left corner towards the upper right. The corresponding ordinate is on the right-hand side of the diagram. The line now allows either to pick the correct initial additive term which when used in the height constraints would result in an a priori defined semidiameter (scale), or to determine which semidiameter (scale) would correspond to an a priori defined additive term. As an example, if the semidiameter of the level ellipsoid best fitting the geoid was to be 6 378 142 m, the WN solution would require height constraints computed with an additive term of -15 m.

The next question, of course, is just how big should this desired semidiameter be. Putting it differently, what criterion should be used to select the "best" scale? If the scale was to be determined only from the EDM and C-Band baselines and/or the SECOR observations, these questions would not arise since the scale would be inherently defined.

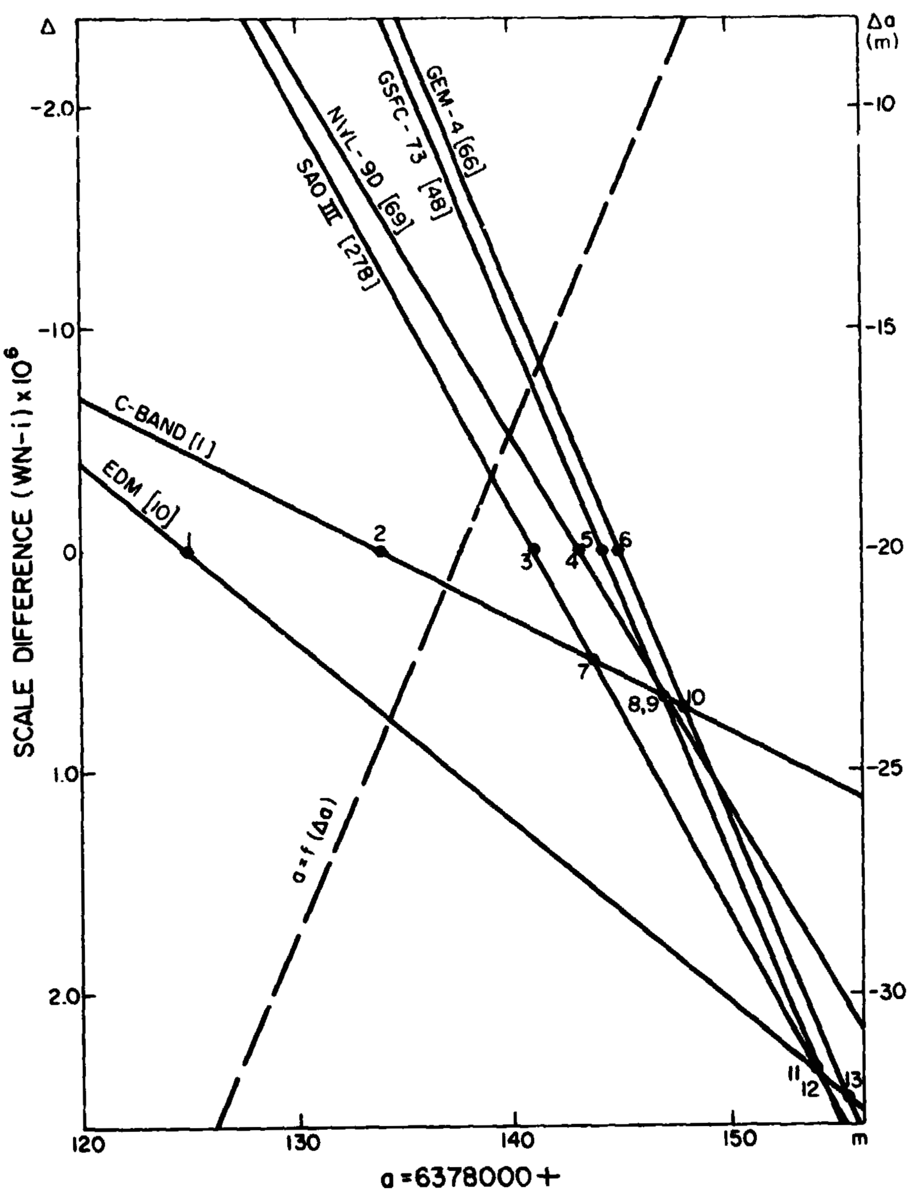


Fig. 5.1-2 Determination of scale.

The use of weighted height constraints, as explained above, provides a unique tool to select the scale to fit some criterion. There could be several noninclusive criteria, e.g.,

(1) The lengths of the EDM baselines as computed from the adjusted coordinates of the terminal stations should be (a) exactly the same as the given lengths in Table 3.3-4, or (b) their differences should be within the limit of one (average) standard deviation, or (c) within a certain limit, e.g.,1:1,000,000, etc.

(2) Same as (1) but for the C-Band baselines.

(3) The scale difference as determined from the station coordinates of the WN solution and from the same coordinates of some dynamic solution should be (a) exactly zero, (b) within the limit of one standard deviation of the scale difference factor, (c) within 1:1,000,000, etc.

(4) The scale difference as determined in (3) should be within a certain limit with respect to all the dynamic solutions.

(5) The scale difference should be within a certain limit with respect to all the dynamic solutions and the EDM and C-Band baselines.

In order to be able to enforce any of the above criteria, first the relationship between the scale difference factor and the semidiameter has to be established. This is accomplished again empirically by determining the scale differences between the different WNi solutions (used to determine the function $a = f(\Delta a)$) and the EDM and C-Band baselines and the dynamic solutions NWL-9D [Anderle, 1973], SAO III [Gaposchkin et al., 1973], GEM 4 [Lerch et al., 1972], GSFC 73 [Marsh et al., 1973]. The method of calculating the scale-difference factor is described in [Kumar, 1972], and the results are shown in Fig. 5.1-2 where, with the ordinate on the left-hand side, the scale differences are plotted against the semidiameters corresponding to the various Δa's used in the height constraints. The numbers on the lines indicate relative weights based on the uncertainties of the scale-difference determinations. It can be seen that the lines representing the geometric (EDM and C-Band) scale differences are much less well determined than the dynamic ones. As an example, the scale-difference factor, between the WNi solution computed with $\Delta a = -15$ m ($a = 6\ 378\ 142$ m), and the solutions NWL-9D is -0.18×10^{-6}; the GEM 4 is -0.68×10^{-6} (the dynamic scales are larger). Also, the lengths of the EDM baselines from the adjustment differ from their directly measured values by 1.38×10^{-6} (the measured values are smaller).

The diagram is used by recognising the importance of the various intersection points, marked by numbers. For example, point 1 illustrates the fact that if the semidiameter of the level ellipsoid was 6 378 125 m, the difference between the adjusted chord lengths and their given values would be zero; point 4 shows that with an a = 6 378 143 m there would be no scale difference between WNi and NWL-9D. Fourteen similar intersection points are listed in Table 5.1-1 with weights and interpretation.

From the table it is immediately clear that taking the weighted mean of the intersection points from the "geometric" scalars (points 1 and 2), the "best" semidiameter is 6 378 125.8 m, while from the "dynamic" lines (points 3 - 6) it is 6 378 142.0 m. The difference of some 16 m, or about 2.5 parts in a million, seems to be real but unexplained at this time. The combined weighted mean from points 1 - 6 is 6 378 141.7 m; while from all the points (1 - 14), it is 6 378 142.7 m.

Table 5.1-1

Determination of Scale

Point	Interpretation	Weight	a (m)	Weighted Mean a (m)
1	WN = EDM	10	6 378 125.0	
2	WN = C-Band	1	6 378 133.7	6 378 125.8 (from points 1 and 2)
3	WN = SAO III	278	6 378 140.8	
4	WN = NWL 9D	69	6 378 143.0	6 378 141.7 (from points 1 - 6)
5	WN = GSFC 73	66	6 378 144.9	6 378 142.0 (from points 3 - 6)
6	WN = GEM 4	48	6 378 144.1	
7	C-Band = SAO III	1	6 378 143.6	
8	C-Band = GSFC 73	1	6 378 146.8	6 378 142.7 (from points 1 - 14)
9	C-Band = NWL 9D	1	6 378 147.1	
10	C-Band = GEM 4	1	6 378 147.8	
11	EDM = SAO III	10	6 378 153.7	
12	EDM = GSFC 73	8	6 378 154.0	
13	EDM = GEM 4	9	6 378 155.2	
14	EDM = NWL 9D	9	6 378 160.5	

For the solution reported here (WN14), the criterion for the scale is (5) above, i.e., that the scale should correspond well to all geometric and dynamic information available at present. Based on the above numbers and on previously published parameters, a = 6 378 142 m was selected. This then requires an adjustment in which the scale is defined, in addition to the SECOR, EDM and C-Band observations, through height constraints with the initial additive constant $\Delta a = -15$ m. As can be seen from Fig. 5.1-2, at this semidiameter the maximum scale difference expected between WN14 and any of the dynamic solutions is about 0.8×10^{-6}, and with respect to the EDM about 1.4×10^{-6} or 1:700,000 which is about the average standard deviation of the EDM baselines. Using this scale the resulting geoid undulations

$$N = H_{WN14} - MSL - \Delta N \qquad 5.? - 4$$

with

$$\Delta N \text{ (meters)} = -13 - 23.2 \cos\phi \cos\lambda - 2.9 \cos\phi \sin\lambda + 2.7 \sin\phi$$

are consistent with dynamically computed ones when the following set of constants defining the gravity field of the level ellipsoid are used [Heiskanen and Moritz, 1967, p. 64]:

$f = 1/298.25$ (flattening)

$\omega = 0.72921151467 \times 10^{-4} \text{rad.sec}^{-1}$ (rotational velocity)

$a = 6\ 378\ 142$ m

$W_0 = 6\ 263\ 688.00$ kgal m (geopotential on the geoid)

Derived from these are the following parameters:

$k^2M = 3.98600922 \times 10^{14}\ m^3\ sec^{-2}$ (gravitational constant x earth mass)

γ_e 978.03226 cm sec^{-2} (equatorial normal gravity)

$J_2 = 1\ 082.6863 \times 10^{-6}$ (second-degree harmonic)

All the above constants are in good agreement with their current best estimates. The parameters in equation 5.1 - 4 ($\Delta a = -13 \pm 0.7$ m, $u_0 = -23.2 \pm 0.9$ m, $v_0 = -2.9 \pm 0.8$ m, $w_0 = 2.7 \pm 1.2$ m) are the result of fitting an ellipsoid to the WN14 geoid as explained earlier in this section, and they represent the size and the position of the best fitting level ellipsoid with respect to the reference ellipsoid (of the same flattening). In case of a good global station distribution the center of this level ellipsoid is the "geometric" center of the geoid. If this point is assumed to be identical with the center of mass than the above coordinates may be viewed as its coordinates with respect to the origin of the reference ellipsoid, and with opposite signs they can be used to shift the WN14 coordinates to the geocenter:

$$\begin{aligned} u\text{ (geocentric)} &= u_{WN14} + 23.2\text{ m} \\ v\text{ (geocentric)} &= v_{WN14} + 2.9\text{ m} \\ w\text{ (geocentric)} &= w_{WN14} - 2.7\text{ m} \end{aligned} \qquad 5.1 - 5$$

5.2 Cartesian and Geodetic Coordinates

The Cartesian and geodetic coordinates resulting from the WN14 solution are listed in Table 5.2-2. Standard deviations of both types of coordinates are also given together with the parameters of the error ellipsoid (see section 4.74). The first page of the table explains the format and the units used. Table 5.2-1 is a summary of the average standard deviations. The values are also broken down to the constituent networks. The notation is explained on the first page of Table 5.2-2, except for the average standard deviation which is $\sigma = \sqrt{(\sigma_u^2 + \sigma_v^2 + \sigma_w^2)/3}$. As can be seen, the weakest portion of the network is the MPS, and the strongest is the SECOR. The average standard deviation in a Cartesian coordinate is ±3.9 m. See Table 5.3-2 for comparison with solutions without the weighted height constraints.

The full variance-covariance matrix cannot be presented here due to lack of space; however, the correlation coefficients ρ_{ij} (see equation 4.7 - 29) between the u,v,w coordinates of stations i and j (the off-diagonal 3 x 3 matrices) are listed in Table 5.2-3 when $\rho_{ij} > 0.75$.

Table 5.2-1

Average Standard Deviations (Solution WN14)

Average Standard Deviations	Constituent Networks				WN14
	BC	SECOR	MPS	SA	
σ_u (m)	3.3	2.5	4.9	4.0	3.[illegible]
σ_v (m)	3.3	2.6	5.1	3.4	3.9
σ_w (m)	3.9	3.2	4.4	4.7	4.0
σ_ϕ (arcsec)	0.1	0.1	0.2	0.2	0.1
σ_λ (arcsec)	0.2	0.1	0.3	0.1	0.2
σ_H (m)	3.2	2.4	2.9	3.0	2.9
σ (m)	3.5	2.8	4.8	4.1	3.9

The 3 x 3 correlation coefficient matrices with any element greater than 0.925 are marked by asterisks. Comparison with Table 3.3-2 reveals that all of these station pairs have their relative positions constrained; thus such correlations are expected. Table 5.2-4 contains the correlation coefficients between the u,v,w coordinates of a given station, i.e., the 3 x 3 matrices along the diagonal of the full correlation coefficient matrix.

Table 5.2-2

Cartesian and Geodetic Coordinates (Solution WN14)

Sta. No	u	σ_u	v	σ_v	w	σ_w
	φ	σ_φ	λ	σ_λ	H	σ_H
		a_a	A_a	r_a		
		a_b	A_b	r_b		
		a_c	A_c	r_c		

u, v, w · Cartesian coordinates in meters (Orientation: u ≡ the Greenwich meridian as defined by the B.I.H.; v ≡ $\lambda = 90^\circ$ (E); w ≡ Conventional International Origin).

φ, λ Geodetic latitude and longitude in angular units (degrees, minutes and seconds of arc) computed from the Cartesian coordinates and referred to a rotational ellipsoid of a = 6378155.00 m and b = 6356769.70 m.

H Geodetic (ellipsoidal) height in meters referred to the same ellipsoid.

$\sigma_u, \sigma_v, \sigma_w$ Standard deviations of the Cartesian coordinates in meters.

$\sigma_\varphi, \sigma_\lambda$ Standard deviations of the geodetic coordinates in seconds of arc.

σ_H Standard deviations of the geodetic height in meters.

a_a, A_a, r_a Altitude (elevation angle), azimuth and magnitude of the major semi axis of the error ellipsoid, respectively. Angles in degrees, magnitude in meters. Altitude is positive above the horizon. Azimuth is positive east reckoned from the north (see section 4.74).

a_b, A_b, r_b Same as above for the mean axis of the error ellipsoid.

a_c, A_c, r_c Same as above for the minor axis of the error ellipsoid.

Table 5.2-2 (cont'd)

1021	1118023.12	2.84	-4876323.36	2.61	3942963.91	2.83
	38 25 49.56	0.10	282 54 48.07	0.12	-47.77	2.05
		0.08	16.31	3.25		
		-2.59	106.30	2.86		
		-87.41	-71.85	2.04		
1022	807851.91	2.25	-5651989.58	1.94	2833500.22	2.32
	26 32 52.94	0.08	278 8 3.56	0.08	-32.58	1.92
		6.37	-26.03	2.39		
		11.15	65.23	2.20		
		-77.12	34.75	1.90		
1030	-2357242.91	5.62	-4646338.51	3.30	3668306.76	3.24
	35 19 47.44	0.10	243 5 59.26	0.23	889.58	2.84
		-0.27	79.87	5.97		
		30.63	-9.97	3.16		
		-59.37	-10.59	2.71		
1032	2602688.61	39.33	-3419228.93	46.69	4697637.28	13.76
	47 44 28.60	0.65	307 16 41.12	2.84	60.96	4.05
		-0.33	73.10	61.68		
		-1.46	163.11	9.76		
		88.51	150.35	4.03		
1033	-2299282.59	6.92	-1445693.70	9.72	5751811.65	5.67
	64 52 17.50	0.24	212 9 35.93	0.74	170.23	5.15
		-1.11	-71.88	9.98		
		4.10	18.04	6.97		
		85.75	-146.80	5.14		
1034	-521704.47	3.09	-4242064.34	2.95	4718716.8[illegible]	2.69
	48 1 20.63	0.11	262 59 19.55	0.15	217.55	1.97
		0.01	138.01	3.88		
		1.65	48.01	2.57		
		88.35	-131.79	1.97		

Table 5.2-2 (cont'd)

1042	647497.49	2.77	-5177935.64	2.43	3656705.89	2.84
	35 12 7.07	0.09	277 7 40.08	0.11	863.40	2.42
		8.15	-32.33	2.99		
		21.12	60.84	2.66		
		-67.22	37.74	2.37		
3106	2881838.31	3.72	-5372164.61	3.32	1868538.63	4.25
	17 8 54.85	0.13	298 12 39.03	0.13	-58.68	3.35
		18.24	-31.23	4.45		
		17.20	64.62	3.62		
		-64.49	15.09	3.17		
3334	-84963.76	13.62	-5327974.93	6.79	3493428.28	8.96
	33 25 31.00	0.34	269 5 11.03	0.53	-2.60	3.90
		-2.81	71.02	13.96		
		0.27	-18.96	10.11		
		-87.18	-103.43	3.84		
3400	-1275207.22	9.06	-4798029.30	5.11	3994208.30	5.67
	39 0 21.73	0.23	255 6 58.20	0.38	2160.40	2.50
		-3.41	77.30	9.15		
		-1.14	-12.77	7.12		
		-86.41	-121.20	2.45		
3401	1513136.10	3.18	-4463576.80	3.44	4283055.82	2.99
	42 27 17.69	0.12	288 43 35.29	0.15	34.52	2.23
		-5.50	38.05	4.08		
		-0.81	128.13	3.07		
		84.44	46.50	2.20		
3402	167259.66	3.91	-5481970.99	2.81	3245036.99	3.46
	30 46 49.95	0.11	271 44 51.37	0.15	27.89	2.78
		10.37	74.47	3.96		
		9.33	-17.25	3.48		
		-75.98	31.59	2.71		

Table 5.2-2 (cont'd)

3404	642491.44	4.70	-6053940.27	3.73	1895688.60	4.89
	17 24 19.15	0.16	276 3 28.80	0.16	-1.41	3.78
		13.00	40.70	5.32		
		12.19	133.56	4.28		
		-72.03	85.31	3.64		
3405	1919482.89	3.30	-5621088.11	3.47	2315775.25	3.95
	21 25 48.55	0.13	288 51 14.23	0.12	-67.11	3.39
		16.02	4.06	3.96		
		-37.11	81.52	3.58		
		48.44	112.95	3.17		
3406	2251800.21	2.41	-5816912.95	2.07	1327191.09	3.37
	12 5 25.86	0.11	291 9 43.37	0.08	-37.08	2.02
		8.37	-21.06	3.51		
		-5.58	68.11	2.30		
		-79.92	-55.22	1.98		
3407	2979891.14	4.67	-5513530.88	3.36	1181129.32	5.25
	10 44 34.89	0.17	298 23 23.41	0.16	186.66	3.11
		7.22	-41.79	6.26		
		23.36	51.35	3.61		
		-65.42	32.14	2.91		
3413	5186348.44	2.15	-3654222.39	2.22	-653018.86	2.67
	- 5 54 57.54	0.09	324 49 55.40	0.08	-0.16	2.02
		-10.20	5.19	2.68		
		4.99	94.29	2.35		
		78.62	-21.40	2.00		
3414	4114977.82	7.65	-4554142.51	6.11	-1732153.99	7.24
	-15 51 37.38	0.24	312 5 59.86	0.28	1016.74	5.00
		1.84	51.81	9.40		
		0.35	-38.20	5.91		
		-88.12	41.00	4.99		

Table 5.2-2 (cont'd)

3431	3093045.37	7.59	-4870081.66	6.52	-2710823.02	10.84
	-25 18 57.42	0.38	302 25 12.37	0.27	145.11	5.06
		-2.01	12.62	11.79		
		-4.59	102.79	7.31		
		84.99	78.99	5.03		
3476	3623277.34	2.20	-5214210.74	2.03	601515.27	2.97
	5 26 52.73	0.10	304 47 41.50	0.07	-36.82	1.95
		1.89	-9.70	2.99		
		4.74	80.46	2.24		
		-84.90	58.64	1.94		
3477	1744650.18	10.18	-6114286.71	6.63	532208.62	9.56
	4 49 0.25	0.31	285 55 32.03	0.35	2555.03	5.51
		-2.04	49.78	13.43		
		-51.04	142.31	5.74		
		-38.88	-41.86	5.07		
3478	3185777.03	18.72	-5514585.85	14.46	-347703.19	35.12
	- 3 8 45.73	1.15	300 0 54.12	0.74	53.58	5.97
		0.31	-32.05	41.22		
		-25.68	57.80	8.05		
		64.32	58.59	5.37		
3499	1280834.24	3.59	-6250955.94	3.43	-10800.58	4.11
	- 0 5 51.49	0.13	281 34 47.08	0.12	2683.81	3.36
		22.05	-0.15	4.24		
		-15.59	83.36	3.69		
		-62.50	-39.06	3.14		
3648	832566.24	3.56	-5349540.70	2.49	3360585.27	3.62
	32 0 6.28	0.13	278 50 45.17	0.14	-36.10	1.67
		2.59	22.92	4.07		
		-5.52	112.67	3.57		
		-83.90	-42.00	1.64		

Table 5.2-2 (cont'd)

3657	1186787.14	3.14	-4785193.13	3.05	4032882.32	2.98
	39 28 19.01	0.11	283 55 44.44	0.14	-44.57	2.22
		-4.73	33.47	3.69		
		-2.52	123.68	3.09		
		84.64	61.63	2.20		
3861	961767.93	2.97	-5679156.55	2.33	2729883.49	2.61
	25 30 26.08	0.08	279 36 42.74	0.11	-43.47	2.50
		-9.63	116.13	3.08		
		56.43	40.95	2.58		
		-31.81	20.09	2.21		
3902	-1234700.68	8.59	-4651242.77	6.25	4174758.60	6.26
	41 7 57.30	0.27	255 8 0.09	0.37	1859.36	2.53
		-1.99	105.25	8.74		
		-3.73	15.12	8.35		
		-85.78	-136.72	2.46		
3903	1088989.74	12.11	-4843005.39	8.51	3991776.62	8.91
	38 59 34.10	0.36	282 40 21.55	0.50	110.47	5.67
		0.38	120.87	12.59		
		-5.48	30.91	10.42		
		84.51	26.96	5.60		
4050	5051608.05	3.18	2726603.28	3.18	-2774166.82	4.35
	-25 56 37.88	0.14	28 21 28.57	0.12	1575.91	2.91
		-9.93	1.93	4.46		
		-13.22	94.29	3.38		
		73.36	56.07	2.82		
4061	2881592.34	3.76	-5372523.89	3.47	1868024.39	4.35
	17 8 36.95	0.14	298 12 25.95	0.13	-18.85	3.49
		20.20	-26.66	4.48		
		11.03	67.45	3.76		
		-66.75	4.42	3.31		

Table 5.2-2 (cont'd)

4081	1920410.93	3.32	-5619417.80	3.57	2319128.45	4.00
	21 27 45.25	0.13	288 52 3.48	0.12	-33.03	3.47
		10.81	17.91	4.05		
		-47.10	96.05	3.64		
		40.87	117.42	3.18		
4082	910567.21	2.64	-5539113.24	2.36	3017965.30	2.80
	28 25 28.69	0.09	279 20 7.01	0.10	-35.47	2.25
		4.20	-14.50	2.91		
		1.40	75.60	2.62		
		-85.57	4.05	2.24		
4280	-2671873.84	3.83	-4521210.51	3.32	3607490.37	3.57
	34 39 56.78	0.13	239 25 6.35	0.16	85.34	2.65
		0.76	75.54	4.06		
		2.23	-14.49	3.87		
		-87.65	4.40	2.65		
4740	2308887.30	3.35	-4874298.20	3.14	3393082.09	3.77
	32 20 52.79	0.13	295 20 46.55	0.13	-40.55	2.60
		1.12	-14.90	4.19		
		-10.00	74.90	3.32		
		79.94	81.43	2.58		
5001	1088849.37	3.64	-4842948.67	3.00	3991840.18	3.69
	38 59 37.46	0.13	282 40 16.38	0.15	83.52	2.48
		12.35	37.45	4.41		
		13.94	130.56	3.36		
		-71.21	87.39	2.26		
5201	-2127802.21	2.28	-3785911.53	2.20	4656012.10	2.44
	47 11 5.15	0.08	240 39 45.48	0.11	341.28	2.14
		18.51	20.45	2.56		
		-4.92	-67.90	2.24		
		-70.81	36.41	2.08		

Table 5.2-2 (cont'd)

5410	-5618754.08	2.29	-258237.50	2.76	2997250.19	3.62
	28 12 43.31	0.12	182 37 53.25	0.10	21.73	2.38
		17.94	-6.80	3.68		
		12.06	-100.76	2.79		
		-68.14	-42.96	2.16		
5648	794691.02	3.59	-5360051.05	2.51	3353082.41	3.65
	31 55 18.82	0.13	278 26 0.03	0.14	-19.05	1.68
		2.34	23.32	4.11		
		-6.03	113.08	3.60		
		-83.53	-45.56	1.64		
5712	3623289.81	2.06	-5214188.02	1.95	601673.22	2.91
	5 26 57.88	0.10	304 47 42.25	0.07	-23.31	1.87
		1.26	-5.25	2.92		
		1.18	84.78	2.12		
		-88.27	37.82	1.87		
5713	4433637.78	1.98	-2268153.21	2.19	3971656.80	2.46
	38 45 36.52	0.08	332 54 24.11	0.10	91.71	1.82
		17.42	-22.37	2.58		
		6.62	69.72	2.27		
		71.29	179.77	1.72		
5715	5884468.78	1.60	-1853580.06	1.96	1612760.08	2.33
	14 44 39.23	0.08	342 30 56.94	0.07	31.00	1.52
		6.24	-7.11	2.35		
		4.07	83.34	2.01		
		82.54	-153.76	1.50		
5717	6023410.73	2.00	1617946.48	2.04	1331655.76	2.68
	12 7 52.22	0.09	15 2 7.09	0.07	284.13	1.96
		-3.82	-6.72	2.74		
		14.20	82.31	2.01		
		75.28	-82.00	1.95		

Table 5.2-2 (cont'd)

5720	4900749.06	2.03	3968252.96	2.06	966354.69	2.86
	8 46 13.32	0.09	38 59 52.49	0.07	1853.32	1.94
	2.64		-0.20	2.87		
	-0.51		89.78	2.14		
	87.31		168.84	1.94		
5721	2604404.77	2.05	4444122.35	2.13	3750344.33	2.65
	36 14 26.73	0.09	59 37 41.76	0.09	952.30	1.91
	11.32		-2.43	2.79		
	12.51		90.12	2.14		
	73.01		-133.34	1.85		
5722	1905127.03	3.49	6032287.50	4.05	-810716.17	4.30
	- 7 21 6.16	0.13	72 28 21.92	0.11	-91.66	4.23
	-46.43		5.87	4.79		
	32.30		54.23	3.66		
	25.81		-53.57	3.28		
5723	-941709.38	2.54	5967444.99	2.31	2039322.91	3.46
	18 46 11.15	0.11	98 58 3.96	0.09	252.51	2.48
	20.63		9.18	3.48		
	5.06		-82.73	2.53		
	68.70		174.16	2.30		
5726	-3361946.83	2.29	5365837.02	2.20	763627.83	3.16
	6 55 20.64	0.10	122 4 8.62	0.08	85.43	2.10
	14.84		-0.73	3.18		
	5.92		-92.31	2.44		
	73.97		156.56	1.99		
5730	-5858574.55	2.06	1394467.24	2.51	2093847.41	3.14
	19 17 29.46	0.10	166 36 41.38	0.09	24.96	2.22
	17.68		1.19	3.14		
	16.86		-94.35	2.51		
	-65.17		-45.28	2.05		

Table 5.2-2 (cont'd)

5732	-6099970.46	3.56	-997355.27	3.54	-1568570.89	4.15
	-14 19 53.84	0.13	189 17 8.85	0.12	38.64	3.64
		-24.28	33.76	4.47		
		-62.75	-175.08	3.46		
		-11.61	-61.56	3.23		
5733	-5885333.94	2.75	-2448380.44	2.91	221670.69	3.86
	2 0 18.39	0.13	202 35 16.75	0.09	25.88	2.77
		8.46	17.66	3.97		
		12.89	-74.29	2.77		
		-74.50	-39.91	2.74		
5734	-3851799.01	2.72	396409.29	3.31	5051342.05	3.90
	52 42 48.32	0.11	174 7 26.66	0.17	51.71	3.45
		35.90	29.49	4.03		
		42.09	-101.36	3.35		
		-27.04	-38.82	2.47		
5735	5186350.63	2.02	-3654223.69	2.06	-653018.90	2.54
	- 5 54 57.54	0.08	324 49 55.41	0.07	2.36	1.93
		-14.68	-5.18	2.55		
		2.64	84.13	2.16		
		75.06	-15.82	1.88		
5736	6118340.28	2.30	-1571761.88	2.25	-878553.62	2.74
	- 7 58 13.62	0.09	345 35 33.46	0.08	56.48	2.26
		-14.58	5.92	2.75		
		35.15	83.37	2.41		
		-51.08	112.70	2.11		
5739	4433629.32	1.98	-2268186.23	2.20	3971646.99	2.47
	38 45 36.11	0.08	332 54 22.73	0.10	91.43	1.83
		17.59	-22.26	2.58		
		6.31	69.75	2.29		
		71.24	178.75	1.73		

Table 5.2-2 (cont'd)

5744	4896437.74	1.82	1316125.03	2.16	3856626.21	2.28
	37 26 37.31	0.08	15 2 42.23	0.09	18.41	1.65
		3.13	-20.27	2.54		
		16.86	70.68	2.04		
		72.83	-120.48	1.60		
5907	-449417.54	4.17	-4600905.48	3.18	4380288.13	4.54
	43 38 57.03	0.17	264 25 15.72	0.18	444.85	2.26
		8.60	27.67	5.61		
		-11.78	115.86	3.54		
		-75.34	-27.02	2.04		
5911	2307991.25	2.56	-4873773.25	2.34	3394463.39	2.96
	32 21 45.57	0.09	295 20 24.17	0.10	-26.09	2.40
		21.55	33.67	3.18		
		28.27	135.92	2.42		
		-53.18	91.83	2.19		
5912	1142644.48	3.06	-6196109.11	3.45	988336.58	4.06
	8 58 26.82	0.14	280 26 55.35	0.10	-5.02	3.28
		-24.25	0.41	4.45		
		37.82	69.95	3.12		
		-42.44	114.73	2.88		
5914	2349456.86	10.50	-5576027.12	7.01	2010342.57	6.44
	18 29 39.35	0.24	292 50 53.18	0.37	-9.38	5.38
		4.84	88.74	10.84		
		-27.05	1.21	8.04		
		62.45	-10.60	4.33		
5915	-744091.08	3.84	-5465238.69	3.80	3192467.45	4.73
	30 13 45.90	0.19	262 14 48.71	0.14	170.93	2.25
		-8.00	11.70	5.83		
		-5.64	102.50	3.62		
		-80.19	-132.69	2.09		

Table 5.2-2 (cont'd)

5923	4363332.16	1.88	2862254.91	2.07	3655380.73	2.44
	35 11 30.32	0.09	33 15 50.54	0.08	170.07	1.77
		5.75	-9.41	2.63		
		15.87	82.23	1.96		
		73.07	-118.73	1.74		
5924	5093556.18	1.87	-565322.26	2.61	3784268.29	2.93
	36 37 36.90	0.09	353 40 0.45	0.10	19.25	1.99
		22.12	-10.48	3.00		
		1.36	80.07	2.60		
		67.83	173.41	1.76		
5925	6237366.27	2.27	-1140241.51	2.56	687740.16	3.01
	6 13 54.17	0.10	349 38 24.92	0.08	15.82	2.21
		-17.07	-2.36	3.15		
		-14.31	92.13	2.56		
		67.43	40.01	2.07		
5930	-1542549.36	2.61	6186956.66	2.67	151833.76	3.42
	1 22 23.73	0.11	103 59 58.99	0.09	18.73	2.57
		9.95	3.46	3.44		
		33.76	-93.28	2.86		
		-54.41	-72.35	2.37		
5931	-2423914.92	2.49	5388250.32	2.52	2394669.19	3.64
	22 11 55.70	0.11	114 13 14.49	0.09	140.80	2.91
		34.18	1.63	3.69		
		54.97	167.23	2.48		
		6.78	-93.00	2.47		
5933	-4071568.36	3.16	4714253.33	3.24	-1366528.34	3.75
	-12 27 15.12	0.12	130 48 58.51	0.10	76.62	3.28
		-15.03	4.38	3.75		
		66.67	-47.11	3.25		
		-17.41	-90.45	3.14		

Table 5.2-2 (cont'd)

5934	-5367663.14	2.46	3437869.92	2.55	-225415.97	3.28
	- 2 2 20.34	0.11	147 21 40.80	0.09	82.38	2.38
		8.39	6.55	3.31		
		3.83	-84.02	2.60		
		-80.76	-18.35	2.36		
5935	-5059825.71	2.08	3591185.96	2.22	1472762.50	2.84
	13 26 22.08	0.09	144 38 5.87	0.08	97.15	2.05
		9.68	9.47	2.86		
		7.47	-81.81	2.26		
		-77.73	-28.90	2.02		
5937	-4433463.64	2.22	4512930.31	2.23	809958.73	3.17
	7 20 40.34	0.10	134 29 27.89	0.08	135.86	2.06
		11.68	4.19	3.18		
		3.10	-86.45	2.42		
		-77.90	-11.10	2.00		
5938	-5915096.47	2.96	2146860.80	2.97	-1037909.46	3.49
	- 9 25 40.94	0.11	160 3 6.61	0.10	80.95	2.97
		-1.29	5.77	3.51		
		55.71	-82.34	3.00		
		-34.26	-85.11	2.90		
5941	-5467757.28	2.52	-2381246.70	2.79	2254033.75	3.78
	20 49 54.72	0.12	203 32 0.47	0.09	59.12	2.59
		11.30	7.83	3.83		
		-28.47	-75.95	2.79		
		-58.98	78.43	2.44		
6001	546568.68	2.57	-1389993.74	2.44	6180236.66	3.40
	76 30 4.71	0.07	291 27 56.08	0.38	211.60	3.39
		76.47	40.98	3.42		
		-11.64	72.10	2.84		
		-6.80	-19.31	2.10		

Table 5.2-2 (cont'd)

6002	1130764.85	2.04	-4830831.87	1.71	3994704.05	1.92
	39 1 39.35	0.07	283 10 27.05	0.08	-6.70	1.52
	3.64		-36.38	2.13		
	3.11		53.82	1.98		
	-85.21		4.20	1.51		
6003	-2127832.13	2.11	-3785862.99	2.[illegible]	4656037.23	2.30
	47 11 6.36	0.07	240 39 43.11	0.10	340.92	2.02
	23.12		23.42	2.41		
	-1.56		-65.92	2.07		
	-66.83		27.72	1.94		
6004	-3851797.46	2.74	396409.38	3.30	5051340.48	3.91
	52 42 48.33	0.11	174 7 26.64	0.17	49.54	3.45
	34.79		28.69	4.05		
	43.25		-102.14	3.37		
	-26.91		-40.66	2.45		
6006	2102927.39	2.36	721668.52	2.92	5958180.80	2.89
	69 39 45.17	0.09	18 56 27.07	0.25	111.31	2.81
	-18.55		137.52	3.14		
	68.66		106.71	2.79		
	10.18		-135.93	2.20		
6007	4433637.30	2.04	-2268151.36	2.17	3971655.01	2.49
	38 45 36.50	0.08	332 54 24.17	0.10	89.60	1.88
	17.05		-22.41	2.62		
	7.87		70.03	2.24		
	71.11		-176.12	1.78		
6008	3623241.00	2.13	-5214233.74	1.96	601536.05	2.93
	5 26 53.40	0.10	304 47 40.10	0.07	-36.69	1.89
	1.99		-8.96	2.95		
	4.43		81.19	2.17		
	-85.14		56.94	1.88		

Table 5.2-2 (cont'd)

6009	1280834.24	3.58	-6250955.94	3.41	-10800.59	4.10
	- 0 5 51.49	0.13	281 34 47.08	0.12	2683.81	3.36
		22.07	-0.16	4.24		
		-15.60	83.34	3.69		
		-62.48	-39.07	3.14		
6011	-5466018.63	3.02	-2404431.52	2.88	2242224.36	3.34
	20 42 26.97	0.10	203 44 38.68	0.11	3074.38	2.86
		8.35	42.07	3.79		
		-62.48	115.71	2.94		
		-26.02	-43.83	2.36		
6012	-5858569.26	2.14	1394508.74	2.60	2093820.34	3.17
	19 17 28.58	0.10	166 36 39.96	0.09	20.23	2.30
		18.21	3.06	3.17		
		17.08	-92.74	2.60		
		-64.60	-43.08	2.13		
6013	-3565892.77	3.28	4120713.58	4.43	3303428.26	4.93
	31 23 42.60	0.16	130 52 17.54	0.16	93.70	3.68
		9.78	33.58	5.53		
		56.25	-71.37	3.80		
		-31.94	-50.25	3.11		
6015	2604353.27	2.06	4444166.00	2.18	3750320.52	2.64
	36 14 25.88	0.09	59 37 44.42	0.09	947.60	1.91
		10.34	-3.33	2.79		
		15.69	89.61	2.19		
		71.06	-125.44	1.84		
6016	4896388.34	1.81	1316172.12	2.19	3856668.20	2.24
	37 26 39.09	0.08	15 2 44.60	0.09	15.77	1.66
		2.05	-24.93	2.51		
		17.19	65.71	2.05		
		72.68	-121.51	1.62		

Table 5.2-2 (cont'd)

6019	2280627.09	2.37	-4914543.17	2.71	-3355402.77	3.67
	-31 56 34.93	0.12	294 53 38.32	0.09	606.26	2.55
		-11.54	-1.78	3.81		
		-54.22	104.68	2.54		
		33.33	80.51	2.34		
6020	-1888614.27	5.37	-5354894.35	4.50	-2895749.01	5.53
	-27 10 35.94	0.16	250 34 22.07	0.18	217.23	5.41
		-58.94	24.67	5.79		
		-7.72	127.67	5.42		
		-29.88	-137.86	4.10		
6022	-6099961.67	3.42	-997362.18	3.56	-1568585.49	4.66
	-14 19 54.37	0.15	189 17 9.12	0.12	34.93	3.48
		-10.68	25.44	4.93		
		-77.02	170.33	3.42		
		-7.29	-65.94	3.18		
6023	-4955366.85	3.24	3842247.62	3.04	-1163847.43	3.97
	-10 35 2.97	0.13	142 12 40.14	0.11	120.39	2.64
		6.82	21.74	4.17		
		-5.41	-67.61	3.37		
		81.28	-119.52	2.60		
6031	-4313825.29	3.41	891333.91	3.91	-4597265.83	3.84
	-46 24 57.86	0.12	168 19 32.46	0.19	-0.11	3.43
		-11.19	-106.82	4.17		
		-37.93	-7.95	3.86		
		-49.86	149.61	3.06		
6032	-2375420.64	3.29	4875546.73	3.21	-3345411.07	3.90
	-31 50 25.25	0.12	115 58 33.09	0.13	-6.10	3.13
		-21.80	-2.12	3.93		
		13.36	-86.66	3.50		
		64.06	32.57	2.94		

Table 5.2-2 (cont'd)

6038	-2160980.91	2.52	-5642710.55	2.80	2035367.82	3.83
	18 43 58.27	0.13	249 2 41.03	0.09	-15.49	2.62
		6.05	-7.29	3.89		
		-42.31	-91.76	2.79		
		-47.05	76.18	2.43		
6039	-3724765.86	6.17	-4421237.60	5.42	-2686084.74	5.55
	-25 4 6.38	0.16	229 53 12.56	0.21	316.49	6.20
		-65.27	61.40	6.38		
		-15.82	-66.56	6.01		
		-18.50	-162.00	4.63		
6040	-741981.69	4.50	6190792.95	3.69	-1338546.30	4.16
	-12 11 43.94	0.13	96 50 3.98	0.15	-49.01	3.77
		1.81	-81.59	4.54		
		-32.17	7.28	4.23		
		57.76	11.28	3.57		
6042	4900750.71	2.04	3968252.68	2.08	966325.28	2.86
	8 46 12.37	0.09	38 59 52.45	0.07	1849.93	1.94
		2.48	-0.62	2.87		
		-1.20	89.33	2.17		
		87.25	153.48	1.94		
6043	1371375.89	3.30	-3614750.34	3.84	-5055927.83	4.77
	-52 46 52.54	0.17	290 46 33.27	0.16	71.89	3.52
		-17.66	5.08	5.36		
		-68.07	-137.21	3.29		
		-12.57	99.15	2.96		
6044	1098897.91	6.82	3684606.64	6.17	-5071873.13	7.78
	-53 1 9.71	0.25	73 23 35.89	0.38	24.18	5.98
		-25.82	17.19	8.32		
		-14.04	-79.76	7.05		
		60.10	-15.53	5.12		

Table 5.2-2 (cont'd)

6045	3223432.02	3.16	5045336.27	3.15	-2191805.72	3.94
	-20 13 53.35	0.13	57 25 32.73	0.11	114.46	3.13
		-19.28	1.28	3.94		
		-10.91	-92.59	3.30		
		67.63	-30.53	3.00		
6047	-3361976.90	2.37	5365811.89	2.30	763624.74	3.23
	6 55 20.56	0.10	122 4 9.88	0.08	79.76	2.21
		14.53	-1.10	3.25		
		6.31	-92.75	2.51		
		74.10	154.41	2.11		
6050	1192678.77	4.86	-2451015.64	6.15	-5747034.19	6.09
	-64 46 26.04	0.25	295 56 52.19	0.33	7.95	4.57
		16.30	-178.22	7.90		
		-24.63	99.49	4.39		
		-59.83	-118.43	4.10		
6051	1111336.13	4.89	2169262.66	3.72	-5874334.05	4.44
	-67 36 5.21	0.14	62 52 24.45	0.39	21.81	4.09
		-16.78	-47.12	5.12		
		-45.30	60.62	4.26		
		39.90	28.28	3.62		
6052	-902608.85	4.44	2409522.13	3.95	-5816551.79	5.45
	-66 16 45.03	0.14	110 32 9.56	0.34	-5.35	5.41
		-75.06	12.80	5.49		
		-11.85	-129.08	4.52		
		8.96	-40.97	3.81		
6053	-1310852.27	4.63	311257.54	4.53	-6213276.48	4.33
	-77 50 41.09	0.15	166 38 33.62	0.69	-51.41	4.19
		22.34	157.08	4.95		
		-11.26	-117.61	4.48		
		-64.71	127.48	4.02		

Table 5.2-2 (cont'd)

6055	6118334.19	2.35	-1571748.31	2.34	-878596.53	2.82
	- 7 58 15.04	0.09	345 35 33.84	0.08	53.25	2.29
		-12.50	3.22	2.82		
		31.06	85.55	2.51		
		-55.98	112.39	2.16		
6059	-5885333.51	2.71	-2448379.00	2.86	221671.07	3.84
	2 0 18.41	0.13	202 35 16.72	0.09	24.95	2.72
		8.72	16.80	3.94		
		18.01	-76.05	2.75		
		-69.86	-48.46	2.68		
6060	-4751649.95	3.27	2792058.10	3.27	-3200163.95	3.66
	-30 18 34.11	0.12	149 33 41.79	0.13	233.02	2.79
		-4.36	32.86	3.85		
		-15.01	-58.31	3.55		
		-74.34	138.63	2.72		
6061	2999915.62	3.66	-2219369.35	5.66	-5155245.98	5.32
	-54 17 1.10	0.15	323 30 20.06	0.31	-6.94	4.39
		13.73	125.85	6.13		
		-43.95	49.47	5.02		
		42.82	22.76	3.30		
6063	5884467.41	1.73	-1853495.77	2.05	1612855.09	2.46
	14 44 42.44	0.08	342 30 59.62	0.07	29.43	1.65
		6.88	-5.34	2.47		
		5.69	85.35	2.11		
		81.06	-145.36	1.63		
6064	6023386.68	2.73	1617931.85	2.59	1331733.18	3.24
	12 7 54.86	0.11	15 2 6.83	0.09	273.97	2.73
		-2.20	-0.39	3.27		
		80.49	76.34	2.73		
		-0.25	89.97	2.55		

Table 5.2-2 (cont'd)

6065	4213564.60	2.02	820829.99	2.44	4702784.39	2.35
	47 48 4.49	0.08	11 1 24.71	0.12	959.58	1.86
		8.80	-34.04	2.69		
		14.81	58.31	2.25		
		72.67	-153.77	1.80		
6066	-5858571.20	2.14	1394466.40	2.60	2093846.01	3.17
	19 17 29.45	0.10	166 36 41.39	0.09	21.23	2.30
		18.20	3.07	3.17		
		17.08	-92.72	2.60		
		-64.61	-43.07	2.14		
6067	5186397.12	2.08	-3653933.25	2.15	-654276.92	2.61
	- 5 55 38.70	0.09	324 50 4.00	0.07	3.57	1.96
		-10.64	5.08	2.62		
		5.06	94.12	2.28		
		78.19	-20.94	1.93		
6068	5084830.42	2.99	2670341.23	2.93	-2768095.23	4.18
	-25 52 59.53	0.14	27 42 23.71	0.11	1516.09	2.77
		-11.23	1.97	4.26		
		17.98	-84.34	3.13		
		68.59	61.55	2.64		
6069	4978421.74	6.50	-1086874.04	6.44	-3823167.78	8.08
	-37 3 53.78	0.26	347 41 4.53	0.27	18.79	6.22
		-16.86	-0.53	8.33		
		25.74	81.06	6.81		
		58.51	-60.86	5.76		
6072	-941702.05	5.74	5967455.05	3.96	2039311.64	4.25
	18 46 10.71	0.13	98 58 3.66	0.19	257.21	4.26
		-0.82	-73.76	5.83		
		59.89	14.83	4.46		
		30.10	-163.28	3.57		

Table 5.2-2 (cont'd)

6073	1905134.13	3.43	6032282.45	3.72	-810732.67	4.19
	- 7 21 6.70	0.14	72 28 21.65	0.12	-92.21	3.62
		-15.47	-13.67	4.23		
		44.62	60.49	3.76		
		41.30	-89.60	3.34		
6075	3602820.62	3.75	5238240.67	3.58	-515948.29	4.02
	- 4 40 14.71	0.13	55 28 48.41	0.12	518.71	3.77
		-29.52	-18.96	4.24		
		43.81	-76.08	3.77		
		31.83	50.46	3.30		
6078	-5952303.44	9.70	1231904.93	8.02	-1925972.50	12.38
	-17 41 31.46	0.46	168 18 25.18	0.26	79.53	7.18
		18.89	-8.89	15.06		
		-12.67	-94.48	7.43		
		-66.98	27.46	5.44		
6111	-2448853.28	2.56	-4667985.83	2.11	3582754.93	2.36
	34 22 54.30	0.08	242 19 5.62	0.11	2251.54	1.73
		5.18	77.41	2.75		
		7.60	-13.29	2.47		
		-80.79	21.41	1.70		
6123	-1881799.41	4.61	-812438.96	4.39	6019590.66	4.46
	71 18 47.70	0.14	203 21 5.60	0.50	4.04	4.21
		-1.38	62.03	5.25		
		53.91	-26.08	4.55		
		-36.05	-28.07	3.49		
6134	-2448907.01	2.56	-4668075.88	2.11	3582449.61	2.36
	34 22 44.21	0.08	242 19 5.40	0.11	2165.54	1.73
		5.18	77.46	2.75		
		7.59	-13.23	2.47		
		-80.79	21.45	1.71		

Table 5.2-2 (cont'd)

7036	-828486.97	3.47	-5657471.26	2.44	2816816.00	2.95
	26 22 46.30	0.09	261 40 7.52	0.13	34.35	2.53
		7.95	67.30	3.59		
		25.78	-26.56	2.81		
		-62.84	-6.90	2.43		
7037	-191291.02	2.88	-4967293.86	2.15	3983252.57	2.42
	38 53 35.51	0.09	267 47 40.64	0.12	232.83	1.82
		0.13	124.91	3.11		
		7.61	34.89	2.42		
		-82.39	35.87	1.81		
7039	2308213.41	3.31	-4873598.28	3.07	3394558.48	3.63
	32 21 49.28	0.13	295 20 34.72	0.13	-28.44	2.54
		1.38	-15.89	4.03		
		-8.95	73.90	3.32		
		80.94	82.79	2.52		
7040	2465049.46	3.69	-5534929.97	3.20	1985513.10	4.01
	18 15 28.38	0.13	294 0 23.01	0.13	-8.68	3.20
		15.92	-44.27	4.74		
		-73.82	-54.3	3.04		
		-2.82	44.92	2.87		
7043	1130708.65	2.05	-4831331.29	1.72	3994135.53	1.91
	39 1 15.36	0.07	283 10 20.04	0.09	3.15	1.52
		-2.98	141.75	2.14		
		2.53	51.88	1.99		
		-86.09	2.07	1.52		
7045	-1240470.24	4.15	-4760242.12	2.76	4048985.26	2.88
	39 38 47.63	0.10	255 23 38.90	0.18	1767.76	2.11
		-0.61	100.02	4.32		
		4.15	10.07	3.16		
		-85.80	1.71	2.11		

Table 5.2-2 (cont'd)

7072	976261.31	2.15	-5601399.89	1.82	2880241.91	2.26
	27 1 14.12	0.07	279 53 12.13	0.08	-30.55	1.75
		7.46	-28.42	2.39		
		-0.71	61.49	2.09		
		-82.50	-33.92	1.74		
7075	692620.68	3.74	-4347076.48	3.81	4600475.43	3.45
	46 27 20.82	0.15	279 3 10.28	0.18	230.94	2.27
		-2.83	13.39	4.61		
		-1.69	103.47	3.75		
		86.71	44.29	2.26		
7076	1384158.71	4.13	-5905362.00	4.44	1966545.66	5.31
	18 4 34.63	0.17	283 11 26.83	0.14	410.95	4.55
		19.91	-26.78	5.59		
		-67.02	4.56	4.42		
		11.01	67.26	3.76		
8009	3923397.43	8.48	299869.39	10.07	5002975.49	6.86
	52 0 6.51	0.34	4 22 14.44	0.52	44.12	3.84
		-0.72	139.13	11.46		
		-5.58	49.06	8.65		
		84.37	56.47	3.76		
8010	4331306.98	5.71	567490.82	8.28	4633108.30	5.44
	46 52 36.97	0.25	7 27 51.89	0.39	920.89	2.26
		-0.12	119.88	8.51		
		0.46	-150.12	7.30		
		89.52	43.97	2.26		
8011	3920153.49	8.86	-134804.48	14.27	5012734.75	6.95
	52 8 36.27	0.34	358 1 49.85	0.76	138.88	3.84
		-0.31	115.65	15.38		
		2.38	-154.37	8.90		
		87.60	32.94	3.83		

Table 5.2-2 (cont'd)

8015	4578322.11	4.19	457936.54	8.00	4403195.29	4.38
	43 55 57.85	0.19	5 42 42.79	0.35	679.03	2.23
		-0.72	109.93	8.21		
		-1.37	19.91	5.33		
		88.46	47.83	2.23		
8019	4579463.17	4.12	586573.52	7.91	4386419.17	4.31
	43 43 33.30	0.18	7 17 56.93	0.35	394.39	2.17
		0.08	110.52	8.11		
		-1.33	20.52	5.26		
		88.67	16.92	2.17		
8030	4205626.92	6.46	163683.38	9.66	4776540.59	5.80
	48 48 22.24	0.27	2 13 43.79	0.47	182.83	2.37
		-1.15	117.70	10.06		
		1.16	-152.32	7.88		
		88.35	72.00	2.35		
9001	-1535750.66	4.17	-5167014.38	2.81	3401039.43	2.70
	32 25 24.39	0.08	253 26 48.80	0.17	1623.61	2.65
		1.24	98.65	4.42		
		59.41	6.55	2.75		
		-30.56	9.38	2.33		
9002	5056108.42	3.01	2716508.67	2.98	-2775768.77	4.21
	-25 57 36.39	0.14	28 14 52.52	0.11	1536.20	2.77
		-10.82	2.06	4.31		
		-15.92	95.19	3.18		
		70.59	59.23	2.66		
9004	5105581.46	3.42	-555271.46	9.96	3769675.97	3.97
	36 27 46.88	0.15	353 47 34.93	0.40	51.52	2.82
		-6.73	87.80	9.97		
		-0.33	-2.24	4.54		
		83.26	84.99	2.58		

Table 5.2-2 (cont'd)

9005	-3946730.47	9.20	3366286.15	8.99	3698822.94	7.51
	35 40 22.02	0.27	139 32 17.28	0.45	94.06	5.29
		-1.55	-79.69	11.28		
		3.04	10.23	8.18		
		36.58	-142.70	5.27		
9006	1018164.52	12.37	5471108.70	5.48	3109625.60	5.96
	29 21 34.71	0.19	79 27 28.60	0.47	1861.67	4.96
		-2.35	-91.67	12.60		
		14.93	-2.29	6.00		
		74.88	-172.95	4.86		
9007	1942760.95	2.50	-5804088.24	2.88	-1796900.88	4.38
	-16 27 56.11	0.15	288 30 23.66	0.09	2469.27	2.72
		-2.85	-8.78	4.50		
		-78.35	95.21	2.72		
		11.28	80.65	2.48		
9008	3376875.17	6.75	4403976.17	6.11	3136257.32	6.09
	29 38 13.87	0.20	52 31 11.20	0.29	1553.30	4.75
		5.39	-74.43	7.81		
		8.26	16.35	6.08		
		80.12	162.78	4.69		
9009	2251810.73	2.40	-5816917.57	2.07	1327163.44	3.37
	12 5 24.93	0.11	291 9 43.64	0.08	-34.94	2.02
		8.42	-21.00	3.50		
		-6.32	68.06	2.29		
		-79.44	-58.40	1.97		
9010	976276.17	2.14	-5601402.23	1.81	2880234.50	2.26
	27 1 13.84	0.07	279 53 12.65	0.08	-29.59	1.74
		7.47	-27.81	2.38		
		0.22	62.16	2.07		
		-82.52	-29.48	1.73		

Table 5.2-2 (cont'd)

9014	2280575.30	2.37	-4914580.22	2.72	-3355383.71	3.70
	-31 56 34.20	0.12	294 53 35.94	0.09	606.19	2.56
		-11.45	-2.47	3.84		
		-54.53	104.05	2.55		
		33.04	79.96	2.34		
9012	-5466067.81	3.04	-2404312.68	2.92	2242188.45	3.35
	20 42 25.91	0.10	203 44 34.24	0.11	3059.03	2.87
		7.79	42.85	3.82		
		-62.21	117.81	2.96		
		-26.49	-43.24	2.38		
9021	-1936789.30	7.11	-5077714.74	5.34	3331922.70	5.30
	31 41 2.94	0.19	249 7 18.06	0.30	2349.90	3.25
		0.72	113.76	8.28		
		1.22	23.74	5.30		
		-88.58	54.04	3.25		
9028	4903726.56	2.06	3965206.29	2.10	963859.55	2.88
	8 44 51.11	0.09	38 57 33.76	0.07	1866.93	1.96
		2.55	-0.59	2.89		
		-0.88	89.37	2.18		
		87.31	160.38	1.95		
9029	5186441.45	2.14	-3653871.87	2.22	-654314.14	2.67
	- 5 55 39.91	0.09	324 50 6.46	0.08	8.29	2.02
		-10.14	5.92	2.68		
		4.56	95.10	2.34		
		78.86	-18.80	2.0[illegible]		
9031	1693797.28	8.28	-4112353.08	8.75	-4556621.98	11.18
	-45 53 11.72	0.43	292 23 8.87	0.33	177.97	6.32
		-6.68	10.74	13.68		
		8.70	99.71	6.73		
		-79.00	137.78	6.15		

Table 5.2-2 (cont'd)

9051	4606861.50	4.19	2029692.20	10.29	3903562.20	4.42
	37 58 37.26	0.18	23 46 38.43	0.41	192.42	3.34
		6.15	108.28	10.52		
		-2.74	18.58	4.72		
		83.26	-47.49	3.15		
9091	4595158.88	4.16	2039417.60	10.27	3912670.58	4.39
	38 4 45.20	0.18	23 55 57.16	0.41	471.05	3.31
		6.26	108.39	10.51		
		-2.72	18.69	4.69		
		83.17	-47.93	3.12		
9424	-1264831.95	4.75	-3466915.40	5.54	5185450.92	4.32
	54 44 33.04	0.21	249 57 23.60	0.27	669.87	2.39
		0.79	-7.27	6.60		
		-0.26	82.73	4.76		
		89.17	154.71	2.39		
9425	-2450012.65	2.64	-4624431.57	2.17	3635036.58	2.43
	34 57 50.43	0.08	242 5 7.68	0.11	752.76	1.78
		4.51	76.25	2.83		
		7.40	-14.34	2.56		
		-81.32	17.38	1.75		
9426	3121261.30	8.63	592605.66	9.36	5512722.95	5.77
	60 12 39.83	0.34	10 45 1.00	0.58	588.48	2.46
		-0.81	151.36	11.01		
		1.29	61.38	8.25		
		88.47	-150.80	2.44		
9427	-6007428.66	8.87	-1111852.47	19.80	1825733.94	8.62
	16 44 38.39	0.30	190 29 8.26	0.71	25.36	5.10
		4.74	-111.38	22.43		
		51.86	-15.32	5.30		
		-37.74	-25.05	3.72		

Table 5.2-2 (cont'd)

9431	3183897.57	12.32	1421426.70	9.36	5322814.69	7.01
	56 56 55.73	0.39	24 3 28.83	0.69	8.09	2.38
		-0.46	-137.19	14.53		
		-0.58	132.81	8.47		
		89.27	171.15	2.38		
9432	3907419.17	7.93	1602378.59	10.36	4763922.08	5.86
	48 38 2.34	0.27	22 17 52.28	0.55	202.70	2.44
		-0.06	75.84	11.46		
		-0.05	165.84	8.19		
		89.92	116.63	2.44		

Table 5.2-3

Station to Station Correlation Coefficients $\rho_{ij} > 0.75$
(Solution WN14)

*STA.NO.3106 WITH STA.NO.4061

0.952	0.143	-0.121
0.141	0.942	-0.130
-0.116	-0.128	0.963

*STA.NO.3406 WITH STA.NO.9009

0.971	0.156	-0.290
0.157	0.961	-0.057
-0.292	-0.058	0.985

*STA.NO.3413 WITH STA.NO.6067

0.962	0.157	-0.021
0.157	0.965	0.047
-0.022	0.048	0.976

STA.NO.3476 WITH STA.NO.5712

0.857	0.120	-0.103
0.119	0.838	-0.014
-0.088	0.008	0.923

*STA.NO.3499 WITH STA.NO.6009

1.000	0.107	0.063
0.107	1.000	-0.184
0.063	-0.184	1.000

*STA.NO.4050 WITH STA.NO.6068

0.910	-0.124	0.178
-0.125	0.908	0.139
0.175	0.138	0.952

STA.NO.4082 WITH STA.NO.9010

0.741	0.022	-0.113
0.020	0.662	0.159
-0.102	0.161	0.756

STA.NO.5001 WITH STA.NO.5907

0.844	0.307	0.313
-0.059	0.761	0.497
0.420	0.643	0.806

STA.NO.5001 WITH STA.NO.5915

0.767	0.306	0.395
-0.225	0.565	0.477
0.273	0.657	0.777

STA.NO.5410 WITH STA.NO.5730

0.778	0.133	0.098
-0.099	0.746	-0.064
0.129	-0.069	0.814

STA.NO.5410 WITH STA.NO.6012

0.695	0.116	0.091
-0.079	0.699	-0.066
0.114	-0.072	0.778

STA.NO.5712 WITH STA.NO.5912

0.686	-0.002	-0.118
-0.112	0.489	0.045
0.132	0.104	0.809

STA.NO.5713 WITH STA.NO.5715

0.591	0.189	-0.331
0.216	0.772	0.013
-0.340	0.075	0.651

*STA.NO.3405 WITH STA.NO.4081

0.939	0.119	0.029
0.119	0.946	0.037
0.041	0.034	0.957

STA.NO.3413 WITH STA.NO.5735

0.853	0.145	-0.040
0.138	0.861	0.038
-0.064	0.032	0.905

*STA.NO.3413 WITH STA.NO.9029

0.926	0.154	-0.019
0.153	0.930	0.047
-0.018	0.047	0.952

*STA.NO.3476 WITH STA.NO.6008

0.964	0.129	-0.107
0.129	0.958	-0.021
-0.107	-0.019	0.980

*STA.NO.3648 WITH STA.NO.5648

0.987	0.275	0.002
0.273	0.973	0.617
0.003	0.617	0.987

STA.NO.4050 WITH STA.NO.9002

0.931	-0.126	0.180
-0.127	0.930	0.140
0.180	0.142	0.963

*STA.NO.4740 WITH STA.NO.7039

0.940	0.060	-0.281
0.061	0.931	0.290
-0.275	0.283	0.951

STA.NO.5001 WITH STA.NO.5911

0.809	-0.055	0.314
0.108	0.857	0.273
0.237	0.320	0.784

STA.NO.5201 WITH STA.NO.6003

0.899	-0.019	0.156
-0.023	0.890	0.083
0.155	0.080	0.912

STA.NO.5410 WITH STA.NO.5941

0.716	-0.259	0.136
0.052	0.755	-0.016
0.253	-0.044	0.834

STA.NO.5410 WITH STA.NO.6066

0.695	0.116	0.091
-0.079	0.698	-0.066
0.113	-0.072	0.777

*STA.NO.5712 WITH STA.NO.6008

0.889	0.119	-0.088
0.121	0.875	0.008
-0.103	-0.012	0.941

*STA.NO.5713 WITH STA.NO.5739

0.994	0.206	-0.250
0.207	0.995	0.015
-0.250	0.016	0.996

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*ρ_{ij}>0.925

Table 5.2-3 (cont'd)

STA.NO.5713 WITH STA.NO.5924		
0.797	0.126	-0.275
0.329	0.565	-0.063
-0.272	0.067	0.491
STA.NO.5715 WITH STA.NO.5736		
0.412	0.240	0.121
0.145	0.765	-0.031
0.142	0.017	0.699
STA.NO.5715 WITH STA.NO.5925		
0.642	0.116	-0.022
0.131	0.722	0.020
-0.036	-0.023	0.784
STA.NO.5717 WITH STA.NO.5720		
0.649	-0.1[illegible]0	-0.032
0.019	0.751	0.015
0.029	-0.085	0.776
*STA.NO.5720 WITH STA.NO.6042		
0.932	-0.096	-0.062
-0.097	0.934	-0.054
-0.060	-0.056	0.965
STA.NO.5721 WITH STA.NO.5923		
0.855	0.133	-0.194
-0.128	0.814	-0.260
-0.194	-0.320	0.715
STA.NO.5723 WITH STA.NO.5726		
0.821	0.057	-0.000
0.300	0.713	0.027
0.008	0.035	0.782
STA.NO.5723 WITH STA.NO.5931		
0.897	-0.121	-0.057
0.186	0.863	0.018
-0.062	0.075	0.891
STA.NO.5726 WITH STA.NO.5930		
0.899	0.307	-0.024
0.044	0.773	0.127
-0.119	0.083	0.831
STA.NO.5726 WITH STA.NO.5933		
0.755	0.153	-0.118
0.234	0.710	0.149
-0.082	0.142	0.822
STA.NO.5726 WITH STA.NO.5935		
0.865	0.108	-0.093
0.291	0.751	0.004
-0.024	-0.072	0.831
*STA.NO.5726 WITH STA.NO.6047		
0.909	0.169	-0.056
0.171	0.903	0.101
-0.052	0.096	0.951
*STA.NO.5730 WITH STA.NO.6012		
0.890	-0.029	0.015
-0.023	0.926	-0.018
0.008	-0.016	0.950
STA.NO.5713 WITH STA.NO.6007		
0.886	0.190	-0.253
0.204	0.904	0.002
-0.244	0.014	0.921
STA.NO.5715 WITH STA.NO.5739		
0.593	0.215	-0.340
0.190	0.770	0.075
-0.330	0.015	0.650
STA.NO.5715 WITH STA.NO.6063		
0.838	0.194	-0.123
0.183	0.901	0.002
-0.117	-0.004	0.918
STA.NO.5717 WITH STA.NO.6042		
0.610	-0.176	-0.033
0.007	0.706	0.010
0.022	-0.082	0.751
*STA.NO.5720 WITH STA.NO.9028		
0.931	-0.095	-0.062
-0.095	0.934	-0.054
-0.060	-0.055	0.965
*STA.NO.5721 WITH STA.NO.6015		
0.892	-0.068	-0.151
-0.074	0.899	-0.256
-0.154	-0.246	0.931
STA.NO.5723 WITH STA.NO.5930		
0.817	0.191	-0.044
0.183	0.702	0.105
-0.039	-0.034	0.820
STA.NO.5723 WITH STA.NO.6047		
0.750	0.057	-0.001
0.278	0.646	0.025
0.004	0.031	0.745
STA.NO.5726 WITH STA.NO.5931		
0.838	0.179	0.002
0.149	0.711	-0.008
0.010	0.0[illegible]4	0.823
STA.NO.5726 WITH STA.NO.5934		
0.792	0.109	-0.126
0.337	0.762	0.051
-0.055	0.104	0.806
*STA.NO.5726 WITH STA.NO.5937		
0.962	0.132	-0.086
0.246	0.870	0.062
-0.050	0.044	0.893
STA.NO.5730 WITH STA.NO.5935		
0.772	0.129	0.084
-0.030	0.905	-0.112
0.033	-0.067	0.782
*STA.NO.5730 WITH STA.NO.6066		
0.869	-0.029	0.015
-0.023	0.925	-0.018
0.008	-0.017	0.950

Table 5.2-3 (cont'd)

STA.NO.5732 WITH STA.NO.5733

0.627	-0.199	0.084
0.003	0.780	-0.301
-0.160	-0.125	0.790

STA.NO.5732 WITH STA.NO.6059

0.582	-0.187	0.075
0.000	0.731	-0.294
-0.153	-0.129	0.764

*STA.NO.5733 WITH STA.NO.6059

0.933	-0.018	-0.000
-0.021	0.940	-0.217
-0.001	-0.219	0.966

STA.NO.5735 WITH STA.NO.5736

0.763	0.058	0.028
0.258	0.804	0.049
-0.029	-0.049	0.760

STA.NO.5735 WITH STA.NO.9029

0.853	0.136	-0.064
0.142	0.861	0.033
-0.038	0.040	0.905

STA.NO.5739 WITH STA.NO.5924

0.801	0.125	-0.274
0.329	0.564	-0.062
-0.271	0.067	0.491

STA.NO.5744 WITH STA.NO.5923

0.926	0.015	-0.291
0.158	0.932	-0.228
-0.307	-0.199	0.812

STA.NO.5744 WITH STA.NO.6016

0.868	0.132	-0.337
0.117	0.903	-0.167
-0.315	-0.168	0.909

STA.NO.5907 WITH STA.NO.5915

0.902	0.387	0.458
0.120	0.859	0.717
0.203	0.793	0.894

STA.NO.5912 WITH STA.NO.6008

0.600	-0.085	0.120
0.005	0.422	0.094
-0.127	0.019	0.762

STA.NO.5923 WITH STA.NO.6016

0.810	0.156	-0.306
0.036	0.849	-0.197
-0.275	-0.224	0.750

STA.NO.5930 WITH STA.NO.6047

0.816	0.044	-0.113
0.281	0.697	0.081
-0.022	0.115	0.792

STA.NO.5931 WITH STA.NO.5937

0.794	0.119	0.065
0.237	0.562	-0.034
0.006	-0.029	0.681

STA.NO.5732 WITH STA.NO.5938

0.750	0.043	-0.071
-0.298	0.814	-0.070
0.041	-0.276	0.760

STA.NO.5733 WITH STA.NO.5941

0.751	-0.061	0.146
-0.041	0.765	-0.231
-0.111	-0.060	0.886

*STA.NO.5734 WITH STA.NO.6004

0.934	-0.281	0.046
-0.287	0.954	-0.158
0.055	-0.153	0.967

*STA.NO.5735 WITH STA.NO.6067

0.887	0.139	-0.067
0.146	0.893	0.033
-0.043	0.041	0.928

*STA.NO.5736 WITH STA.NO.6055

0.911	0.137	-0.038
0.130	0.911	0.045
-0.037	0.038	0.938

STA.NO.5739 WITH STA.NO.6007

0.880	0.190	-0.253
0.203	0.899	0.002
-0.243	0.013	0.917

STA.NO.5744 WITH STA.NO.5924

0.849	0.155	-0.313
0.044	0.750	-0.074
-0.390	-0.110	0.624

STA.NO.5907 WITH STA.NO.5911

0.763	-0.202	0.425
0.236	0.608	0.573
0.250	0.409	0.599

STA.NO.5911 WITH STA.NO.5912

0.587	0.116	0.367
-0.329	0.273	0.150
-0.040	0.288	0.802

STA.NO.5923 WITH STA.NO.6015

0.793	-0.117	-0.195
0.107	0.746	-0.316
-0.204	-0.250	0.689

STA.NO.5930 WITH STA.NO.5937

0.822	0.102	-0.153
0.370	0.584	0.065
-0.015	0.075	0.708

STA.NO.5931 WITH STA.NO.5935

0.798	0.033	0.078
0.232	0.560	-0.063
-0.005	-0.085	0.645

STA.NO.5931 WITH STA.NO.6047

0.767	0.140	0.009
0.168	0.645	0.032
0.000	-0.005	0.782

Table 5.2-3 (cont'd)

STA.NO.5933 WITH STA.NO.5934		
0.645	-0.031	-0.179
0.174	0.837	0.005
-0.093	0.066	0.853
STA.NO.5933 WITH STA.NO.5938		
0.743	-0.118	-0.180
0.194	0.786	-0.048
-0.056	0.091	0.731
STA.NO.5934 WITH STA.NO.5935		
0.807	0.168	-0.133
0.155	0.816	0.018
-0.072	-0.052	0.899
STA.NO.5934 WITH STA.NO.5938		
0.905	-0.044	-0.149
0.107	0.925	-0.025
-0.102	0.052	0.893
STA.NO.5935 WITH STA.NO.5937		
0.920	0.187	-0.025
0.097	0.884	-0.076
-0.079	-0.025	0.881
STA.NO.5935 WITH STA.NO.6012		
0.682	-0.026	0.026
0.113	0.839	-0.072
0.057	-0.106	0.737
STA.NO.5935 WITH STA.NO.6066		
0.682	-0.026	0.026
0.113	0.839	-0.072
0.057	-0.106	0.737
STA.NO.5941 WITH STA.NO.6059		
0.709	-0.043	-0.107
-0.066	0.724	-0.065
0.135	-0.231	0.858
STA.NO.6011 WITH STA.NO.6059		
0.441	-0.254	0.002
-0.133	0.756	-0.158
0.037	-0.277	0.219
* STA.NO.6012 WITH STA.NO.6066		
0.999	-0.026	0.004
-0.025	0.999	-0.021
0.004	-0.021	0.999
* STA.NO.6019 WITH STA.NO.9011		
0.970	-0.027	0.120
-0.024	0.977	-0.254
0.117	-0.256	0.987
STA.NO.6031 WITH STA.NO.6060		
0.847	0.311	-0.166
0.385	0.605	-0.137
-0.108	0.021	0.634
STA.NO.6038 WITH STA.NO.6134		
0.808	-0.179	0.211
-0.052	0.293	-0.032
0.167	-0.112	0.233
STA.NO.5933 WITH STA.NO.5937		
0.754	0.141	-0.169
0.190	0.678	0.113
-0.110	0.079	0.783
STA.NO.5933 WITH STA.NO.6047		
0.682	0.212	-0.077
0.139	0.639	0.137
-0.102	0.138	0.782
STA.NO.5934 WITH STA.NO.5937		
0.856	0.216	-0.113
0.102	0.863	0.075
-0.124	0.015	0.857
STA.NO.5934 WITH STA.NO.6047		
0.718	0.304	-0.052
0.103	0.688	0.103
-0.108	0.052	0.765
STA.NO.5935 WITH STA.NO.5938		
0.583	0.099	-0.093
0.192	0.669	-0.047
-0.158	0.074	0.780
STA.NO.5935 WITH STA.NO.6047		
0.792	0.266	-0.023
0.103	0.682	-0.065
-0.079	0.009	0.789
STA.NO.5937 WITH STA.NO.6047		
0.876	0.225	-0.048
0.125	0.787	0.045
-0.074	0.060	0.849
* STA.NO.6002 WITH STA.NO.7043		
0.959	0.030	-0.116
0.031	0.943	0.264
-0.116	0.264	0.954
* STA.NO.6011 WITH STA.NO.9012		
0.981	-0.242	0.114
-0.242	0.980	-0.365
0.116	-0.365	0.985
STA.NO.6016 WITH STA.NO.6065		
0.697	0.106	-0.407
0.077	0.790	-0.227
-0.436	-0.240	0.685
STA.NO.6023 WITH STA.NO.6060		
0.829	0.329	-0.199
0.283	0.802	0.039
-0.267	-0.095	0.707
STA.NO.6028 WITH STA.NO.6111		
0.807	-0.180	0.211
-0.052	0.292	-0.031
0.167	-0.111	0.233
STA.NO.6038 WITH STA.NO.9425		
0.770	-0.177	0.208
-0.054	0.270	-0.025
0.162	-0.099	0.220

Table 5.2-3 (cont'd)

*STA.NO.6042 WITH STA.NO.9028

0.965	-0.102	-0.060
-0.102	0.966	-0.057
-0.060	-0.055	0.982

*STA.NO.6067 WITH STA.NO.9029

0.962	0.155	-0.022
0.154	0.965	0.049
-0.019	0.049	0.976

*STA.NO.6111 WITH STA.NO.6134

0.999	-0.312	0.157
-0.312	0.999	0.187
0.157	0.187	0.999

STA.NO.6134 WITH STA.NO.9425

0.953	-0.304	0.158
-0.308	0.932	0.191
0.159	0.195	0.945

STA.NO.8009 WITH STA.NO.8010

0.619	0.149	-0.610
0.047	0.794	-0.168
-0.593	-0.217	0.602

STA.NO.8009 WITH STA.NO.8019

0.551	0.173	-0.550
0.092	0.777	-0.242
-0.537	-0.232	0.564

STA.NO.8010 WITH STA.NO.8019

0.726	0.085	-0.682
0.079	0.936	-0.303
-0.701	-0.261	0.768

STA.NO.8015 WITH STA.NO.8030

0.591	0.125	-0.561
0.124	0.787	-0.186
-0.560	-0.273	0.592

STA.NO.8019 WITH STA.NO.8030

0.578	0.123	-0.551
0.118	0.779	-0.179
-0.553	-0.274	0.581

STA.NO.9004 WITH STA.NO.9051

0.551	0.197	-0.518
0.305	0.136	-0.224
-0.263	-0.433	0.812

STA.NO.9004 WITH STA.NO.9426

0.322	-0.003	-0.267
0.460	0.811	-0.538
-0.264	-0.131	0.277

*STA.NO.9051 WITH STA.NO.9091

0.990	-0.299	-0.208
-0.301	0.998	-0.383
-0.207	-0.381	0.991

STA.NO.9051 WITH STA.NO.9432

0.598	-0.196	-0.530
-0.470	0.809	0.047
-0.151	-0.334	0.371

STA.NO.9091 WITH STA.NO.9432

0.602	-0.196	-0.533
-0.471	0.810	0.047
-0.152	-0.335	0.374

STA.NO.6050 WITH STA.NO.6061

0.109	-0.358	0.106
0.222	0.840	-0.153
-0.116	-0.438	0.314

*STA.NO.6068 WITH STA.NO.9002

0.977	-0.125	0.175
-0.125	0.977	0.140
0.177	0.142	0.988

*STA.NO.6111 WITH STA.NO.9425

0.954	-0.304	0.158
-0.308	0.933	0.191
0.159	0.195	0.946

*STA.NO.7072 WITH STA.NO.9010

0.964	0.034	-0.140
0.035	0.949	0.156
-0.141	0.157	0.967

STA.NO.8009 WITH STA.NO.8015

0.545	0.182	-0.545
0.095	0.778	-0.236
-0.532	-0.242	0.559

STA.NO.8010 WITH STA.NO.8015

0.717	0.093	-0.679
0.083	0.931	-0.296
-0.695	-0.268	0.762

*STA.NO.8015 WITH STA.NO.8019

0.950	0.095	-0.707
0.098	0.986	-0.321
-0.709	-0.310	0.954

STA.NO.8015 WITH STA.NO.9004

0.593	0.386	-0.335
0.059	0.788	-0.313
-0.436	-0.532	0.556

STA.NO.8019 WITH STA.NO.9004

0.615	0.391	-0.328
0.064	0.786	-0.322
-0.437	-0.540	0.581

STA.NO.9004 WITH STA.NO.9091

0.555	0.198	-0.521
0.307	0.137	-0.225
-0.264	-0.433	0.818

STA.NO.9007 WITH STA.NO.9011

0.752	-0.080	0.167
-0.006	0.376	-0.049
0.058	0.051	0.512

STA.NO.9051 WITH STA.NO.9431

0.540	-0.152	-0.528
-0.523	0.826	0.283
-0.102	-0.354	0.250

STA.NO.9091 WITH STA.NO.9431

0.543	-0.152	-0.531
-0.523	0.828	0.283
-0.103	-0.355	0.252

STA.NO.9431 WITH STA.NO.9432

0.808	-0.451	-0.617
-0.373	0.847	-0.085
-0.750	0.180	0.721

Table 5.2-4

Station Correlation Coefficients $\rho_{ij} > 0.75$
(Solution WN14)

* STA.NO.1032		
1.000	0.967	0.779
0.967	1.000	0.880
0.779	0.880	1.000
STA.NO.3902		
1.000	-0.155	0.087
-0.155	1.000	0.813
0.087	0.813	1.000
STA.NO.8011		
1.000	0.408	-0.752
0.408	1.000	-0.382
-0.752	-0.382	1.000
STA.NO.9426		
1.000	0.230	-0.857
0.230	1.000	-0.353
-0.857	-0.353	1.000
STA.NO.9431		
1.000	-0.441	-0.870
-0.441	1.000	0.129
-0.870	0.129	1.000
STA.NO.3478		
1.000	0.875	-0.919
0.875	1.000	-0.837
-0.919	-0.837	1.000
STA.NO.8010		
1.000	0.027	-0.817
0.027	1.000	-0.206
-0.817	-0.206	1.000
STA.NO.8030		
1.000	0.139	-0.845
0.139	1.000	-0.241
-0.845	-0.241	1.000
STA.NO.9427		
1.000	-0.858	0.636
-0.858	1.000	-0.813
0.636	-0.813	1.000

*$\rho_{ij} > 0.925$

5.3 Comparisons with Geometric Information

In addition to solution WN14, two other adjustments were also performed with the same data. The only differences were that in one of them (WN12) the weighted height constraints were not applied; thus the scale is defined through the SECOR, EDM and C-Band data. In the other (WN16), the EDM and C-Band lengths were not entered as weighted constraints; thus the scale is through the SECOR and the weighted height constraints. Coordinates from solution WN16 are not given, only some revealing information in a summary form which can be compared to the WN14 results.

Table 5.3-1 contains the differences between the adjusted and given chord lengths (Table 3.3-4) from the three solutions. The lines originating

Table 5.3-1

Chord Length Comparisons (Solutions WN12, 14 and 16)

Type	Line	Adjusted - Given Length					
		WN12		WN14		WN16	
		m	ppM	m	ppM	m	ppM
EDM	6002 - 6003	8.3 ± 2.5	2.38	2.7 ± 2.3	0.78	5.9 ± 3.0	1.70
	6003 - 6111	2.7 ± 1.4	1.90	2.3 ± 1.4	1.60	11.4 ± 3.1	8.00
	6006 - 6065	7.7 ± 2.1	3.13	6.1 ± 2.0	2.47	19.9 ± 3.5	8.13
	6016 - 6065	- 2.8 ± 1.3	2.30	- 2.9 ± 1.3	2.47	-18.9 ± 3.4	15.87
	6006 - 6016	2.7 ± 2.2	0.77	1.3 ± 2.1	0.37	1.6 ± 3.3	0.46
	6063 - 6064	13.7 ± 2.4	3.94	10.6 ± 2.3	3.03	15.2 ± 2.8	4.37
	6023 - 6060	7.9 ± 3.1	3.42	5.9 ± 3.0	2.55	9.6 ± 3.8	4.16
	6032 - 6060*	- 2.4 ± 3.9	0.76	- 4.5 ± 3.6	1.42	- 2.9 ± 3.7	0.92
	3861 - 7043	2.2 ± 1.8	1.44	1.5 ± 1.8	0.99	7.6 ± 3.7	5.00
C-Band	4082 - 4050*	26.5 ± 6.9	2.42	- 5.2 ± 3.9	0.48	- 4.2 ± 4.0	0.39
	4082 - 4740	2.0 ± 2.7	1.25	1.3 ± 2.7	1.90	6.6 ± 5.0	4.13
	4082 - 4081	3.0 ± 2.3	2.40	2.3 ± 2.3	0.79	17.9 ± 6.2	14.49
	4082 - 4061	- 0.4 ± 3.6	0.19	- 1.5 ± 3.6	0.65	2.1 ± 6.1	0.93
Average	EDM		2.22		1.74		5.40
	C-Band		1.56		0.96		4.98
	All		2.02		1.50		5.27

*Not constrained in WN12 and WN14.

from Sta. 4742 (Kauai) are not listed for reasons explained earlier. Comparing solutions WN14 and WN12 the effect of including the heights is not very significant. The average length discrepancy decreases 0.48×10^{-6} in case of the EDM, and 0.60×10^{-6} in the C-Band case, both numbers being within the noise level. At first glance the difference between WN14 and WN16 seems to be significant since the average length discrepancy increases by about 4×10^{-6} or 1:250,000 for both types of observations. Close inspection, however, reveals that though the inclusion of the EDM and C-Band chords in the solution improves the positions of stations 6111 (Wrightwood I), 6065 (H. Peissenberg) and 4081 (Grand Turk), it does not otherwise contribute to the overall scale determination significantly. If the above-mentioned stations are left out from the comparison, the average length discrepancies in the WN16 solution decrease to 2.76×10^{-6} for the EDM and 1.81×10^{-6} for the C-Band, both within noise level from WN14 (about 1×10^{-6}).

The above conclusion is also strengthened by the content of Table 5.3-2 where the average standard deviations of the coordinates and the heights

Table 5.3-2

Standard Deviation Comparisons
(Solutions WN12, 14 and 16)

Solution	Constituent Networks								WN_i	
	BC		SECOR		MPS		SA			
	σ	σ_H	σ	σ_H	σ	σ_H	σ	σ_H	σ	σ_H
WN12	4.4	5.0	4.2	4.8	6.9	7.6	5.2	5.9	5.5	6.2
WN14	3.5	3.2	2.8	2.4	4.8	2.9	4.1	3.0	3.9	2.9
WN16	3.5	3.2	2.8	2.4	4.9	2.9	4.1	3.0	4.0	2.9

All units in meters.

are compared from the three solutions. It is seen that while the inclusion of the weighted heights decreases the standard deviations significantly, the exclusion of the geometric scalars hardly changes the results.

Table 5.3-3 shows the results of a coordinate transformation between solutions WN14 and WN16. Inspection of the residuals on the second and third pages of the table shows that they are insignificant except probably at the stations already mentioned, though even there the discrepancies are within or near the noise level. The fact that the chords 6003-6111 and 6016-6065 improve the positions of stations 6111 and 6065 (while the other chords have very little effect on their terminal stations) is not surprising once it is recognized that these lines are too short to be determined well from observations on PAGEOS.

Table 5.3-4 contains the results of the transformation between WN14 and WN12. The effect of the missing height constraints is well recognizable both in the scale and in the residuals.

In the tables the rotations ω, ψ and ε are about the w, v and u axes respectively. The unit in the variance-covariance matrix, for the elements corresponding to the rotations, is radian squared.

Table 5.3-3

Transformation: WN16 - WN14

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
0.08	0.57	0.04	0.06	0.00	-0.00	-0.01

VARIANCE - COVARIANCE MATRIX

σ_o^2= 0.22

0.642D-01	0.399D-04	-0.118D-03	-0.116D-10	0.633D-10	0.186D-09	-0.356D-11
0.399D-04	0.645D-01	0.194D-03	0.159D-10	0.728D-10	-0.361D-11	-0.194D-09
-0.118D-03	0.194D-03	0.930D-01	-0.219D-10	0.682D-11	-0.102D-09	-0.147D-09
-0.116D-10	0.159D-10	-0.219D-10	0.141D-16	0.638D-20	-0.583D-20	0.272D-19
0.633D-10	0.728D-10	0.682D-11	0.638D-20	0.993D-16	-0.114D-16	0.155D-17
0.186D-09	-0.361D-11	-0.102D-09	-0.583D-20	-0.114D-16	0.140D-15	-0.343D-17
-0.356D-11	-0.194D-09	-0.147D-09	0.272D-19	0.155D-17	-0.343D-17	0.134D-15

COEFFICIENTS OF CORRELATION

0.100D+01	0.619D-03	-0.153D-02	-0.122D-01	0.251D-01	0.621D-01	-0.121D-02
0.619D-03	0.100D+01	0.250D-02	0.167D-01	0.288D-01	-0.120D-02	-0.659D-01
-0.153D-02	0.250D-02	0.100D+01	-0.191D-01	0.224D-02	-0.282D-01	-0.416D-01
-0.122D-01	0.167D-01	-0.191D-01	0.100D+01	0.170D-03	-0.131D-03	0.623D-03
0.251D-01	0.288D-01	0.224D-02	0.170D-03	0.100D+01	-0.962D-01	0.134D-01
0.621D-01	-0.120D-02	-0.282D-01	-0.131D-03	-0.962D-01	0.100D+01	-0.249D-01
-0.121D-02	-0.659D-01	-0.416D-01	0.623D-03	0.134D-01	-0.249D-01	0.100D+01

Table 5.3-3 (cont'd)

RESIDUALS V

	V1(WN14)				V2(WN16)			V1 - V2		
3861	0.2	-0.9	-1.6	3861	-0.2	1.0	2.7	0.5	-1.8	-4.3
4061	0.4	-0.4	-1.0	4061	-0.7	0.4	1.4	1.1	-0.9	-2.4
4081	3.2	-0.2	-3.9	4081	-6.7	0.2	7.1	9.9	-0.4	-11.0
4082	-0.8	-0.5	-0.3	4082	1.0	0.5	0.4	-1.9	-1.0	-0.7
4740	1.3	0.4	-0.6	4740	-2.1	-0.5	0.6	3.3	0.9	-1.2
6001	-0.7	0.6	-0.1	6001	0.7	-0.7	0.1	-1.4	1.3	-0.1
6002	0.6	0.4	0.5	6002	-0.7	-0.4	-0.6	1.2	0.8	1.0
6003	-0.4	1.3	1.4	6003	0.5	-1.4	-1.6	-0.9	2.7	3.0
6004	-0.2	0.3	0.5	6004	0.2	-0.3	-0.6	-0.3	0.6	1.1
6006	-1.0	0.8	0.7	6006	1.2	-0.8	-0.8	-2.1	1.6	1.5
6007	-0.1	-0.3	0.4	6007	0.1	0.3	-0.4	-0.2	-0.6	0.8
6008	0.1	-0.1	0.4	6008	-0.1	0.1	-0.4	0.1	-0.3	0.9
6009	0.1	-0.1	0.2	6009	-0.1	0.1	-0.2	0.2	-0.2	0.4
6011	-0.7	0.3	-0.5	6011	0.7	-0.3	0.5	-1.4	0.5	-0.9
6012	0.2	0.1	0.2	6012	-0.2	0.1	-0.2	0.3	0.2	0.4
6013	0.2	-0.1	0.3	6013	-0.2	0.1	-0.3	0.4	-0.2	0.6
6015	0.2	0.2	0.4	6015	-0.2	-0.2	-0.4	0.3	0.3	0.9
6016	-0.5	0.0	1.1	6016	0.6	-0.0	-1.3	-1.1	0.1	2.4
6019	0.0	-0.4	0.5	6019	-0.0	0.4	-0.5	0.1	-0.9	0.9
6020	-0.7	-0.2	0.5	6020	0.7	0.2	-0.5	-1.3	-0.4	1.0
6022	-0.1	-0.0	0.6	6022	0.1	0.0	-0.6	-0.1	-0.0	1.2
6023	-0.1	-0.1	1.4	6023	0.1	0.1	-1.6	-0.3	-0.1	3.1
6031	-0.1	-0.4	0.1	6031	0.1	0.4	-0.1	-0.3	-0.8	0.3
6032	0.3	-0.1	0.2	6032	-0.3	0.1	-0.2	0.6	-0.1	0.4
6038	-1.0	0.1	-0.1	6038	1.1	-0.1	0.1	-2.0	0.2	-0.1
6039	-0.5	0.0	0.6	6039	0.5	-0.0	-0.6	-1.0	0.0	1.3
6040	0.3	-0.2	0.6	6040	-0.3	0.2	-0.6	0.6	-0.4	1.1
6042	-0.3	-0.1	0.5	6042	0.3	0.1	-0.5	-0.5	-0.2	0.9
6043	-0.0	-0.3	0.3	6043	0.0	0.3	-0.3	-0.1	-0.7	0.7
6044	0.0	0.0	0.5	6044	-0.0	-0.0	-0.5	0.1	0.0	1.0
6045	0.0	-0.2	0.8	6045	-0.0	0.2	-0.8	0.1	-0.4	1.6
6047	0.4	-0.3	0.3	6047	-0.4	0.3	-0.3	0.7	-0.5	0.6
6050	-0.0	-0.4	0.4	6050	0.0	0.4	-0.4	-0.0	-0.8	0.7
6051	0.1	-0.1	0.5	6051	-0.1	0.1	-0.5	0.1	-0.2	1.0
6052	0.1	-0.3	0.3	6052	-0.1	0.3	-0.3	0.2	-0.5	0.7
6053	-0.0	-0.4	0.3	6053	0.0	0.4	-0.3	-0.0	-0.8	0.7
6055	-0.3	-0.5	0.5	6055	0.3	0.6	-0.5	-0.7	-1.1	1.0

Table 5.3-3 (cont'd)

RESIDUALS V

	V1(WN14)				V2(WN16)			V1 - V2		
6059	-0.2	0.2	0.6	6059	0.2	-0.2	-0.6	-0.4	0.5	1.3
6060	-0.1	-0.7	-0.1	6060	0.1	0.7	0.1	-0.1	-1.5	-0.2
6061	0.0	-0.4	0.4	6061	-0.0	0.4	-0.4	0.0	-0.7	0.8
6063	-0.4	-0.7	0.6	6063	0.4	0.7	-0.7	-0.8	-1.4	1.3
6064	-0.1	1.3	0.6	6064	0.1	-1.6	-0.6	-0.1	2.9	1.2
6065	2.5	2.5	-4.3	6065	-3.3	-2.9	7.3	5.8	5.4	-11.6
6066	0.2	0.1	0.2	6066	-0.2	-0.1	-0.2	0.3	0.2	0.4
6067	-0.1	-0.5	0.6	6067	0.1	0.5	-0.6	-0.1	-0.9	1.3
6068	-0.2	0.4	1.2	6068	0.2	-0.4	-1.2	-0.4	0.7	2.3
6069	-0.1	-0.6	0.4	6069	0.1	0.6	-0.4	-0.2	-1.2	0.9
6072	0.3	-0.3	0.3	6072	-0.3	0.3	-0.3	0.6	-0.5	0.7
6073	0.1	-0.3	0.7	6073	-0.1	0.3	-0.7	0.2	-0.6	1.3
6075	-0.0	-0.2	0.6	6075	0.0	0.2	-0.6	-0.1	-0.5	1.3
6078	-0.2	-0.3	1.2	6078	0.2	0.4	-1.2	-0.5	-0.7	2.3
6111	-0.9	-1.1	-1.8	6111	0.9	1.3	2.6	-1.8	-2.4	-4.5
6123	-0.5	0.6	0.0	6123	0.5	-0.6	-0.0	-1.0	1.2	0.1
6134	-0.9	-1.1	-1.8	6134	0.9	1.3	2.6	-1.8	-2.4	-4.5
7043	0.6	0.4	0.5	7043	-0.7	-0.5	-0.6	1.2	0.9	1.1

Table 5.3-4

Transformation: WN12 - WN14

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
-1.02	1.87	-4.53	1.94	0.04	0.05	0.05

VARIANCE - COVARIANCE MATRIX

σ_o^2 = 0.68

0.246D+00	0.652D-04	-0.285D-03	-0.175D-09	0.284D-09	0.757D-09	-0.155D-10
0.652D-04	0.270D+00	0.416D-03	0.187D-09	0.255D-09	-0.139D-10	-0.705D-09
-0.285D-03	0.416D-03	0.384D+00	-0.320D-09	0.289D-10	-0.382D-09	-0.499D-09
-0.175D-09	0.187D-09	-0.320D-09	0.215D-15	0.622D-19	-0.677D-19	0.346D-18
0.284D-09	0.255D-09	0.289D-10	0.622D-19	0.378D-15	-0.472D-16	0.611D-17
0.757D-09	-0.139D-10	-0.382D-09	-0.677D-19	-0.472D-16	0.534D-15	-0.140D-16
-0.155D-10	-0.705D-09	-0.499D-09	0.346D-18	0.611D-17	-0.140D-16	0.523D-15

COEFFICIENTS OF CORRELATION

0.100D+01	0.253D-03	-0.927D-03	-0.241D-01	0.294D-01	0.661D-01	-0.137D-02
0.253D-03	0.100D+01	0.129D-02	0.246D-01	0.252D-01	-0.116D-02	-0.593D-01
-0.927D-03	0.129D-02	0.100D+01	-0.353D-01	0.240D-02	-0.267D-01	-0.352D-01
-0.241D-01	0.246D-01	-0.353D-01	0.100D+01	0.218D-03	-0.200D-03	0.103D-02
0.294D-01	0.252D-01	0.240D-02	0.218D-03	0.100D+01	-0.105D+00	0.137D-01
0.661D-01	-0.116D-02	-0.267D-01	-0.200D-03	-0.105D+00	0.100D+01	-0.265D-01
-0.137D-02	-0.593D-01	-0.352D-01	0.103D-02	0.137D-01	-0.265D-01	0.100D+01

Table 5.3-4 (cont'd)

RESIDUALS V

	V1(WN14)				V2(WN12)			V1 - V2		
3861	-0.2	-1.5	2.7	3861	0.3	4.0	-5.4	-0.5	-5.5	8.0
4061	-0.5	-2.8	3.8	4061	0.6	5.1	-5.0	-1.0	-7.9	8.8
4081	-1.0	0.1	1.2	4081	1.2	-0.2	-1.9	-2.2	0.3	3.2
4082	0.7	-2.5	2.4	4082	-0.9	6.3	-4.2	1.6	-8.8	6.7
4740	-0.2	-2.4	2.2	4740	0.3	7.2	-4.0	-0.5	-9.6	6.2
6001	-0.3	-0.2	-0.7	6001	0.3	0.2	1.2	-0.5	-0.4	-2.0
6002	-0.7	0.2	0.3	6002	0.8	-0.6	-0.9	-1.5	0.8	1.3
6003	-0.4	1.0	-1.4	6003	0.6	-1.7	3.2	-1.0	2.7	-4.6
6004	0.1	1.0	-1.1	6004	-0.1	-1.3	1.7	0.2	2.3	-2.8
6006	0.5	0.5	-1.9	6006	-0.7	-0.7	4.4	1.2	1.3	-6.3
6007	3.5	-1.3	3.4	6007	-6.4	2.0	-7.9	9.9	-3.3	11.3
6008	3.2	1.5	-0.[illegible]	60[illegible]	-8.2	-4.1	0.0	11.4	5.5	-0.1
6009	-0.3	0.0	-1.0	[illegible]	0.3	-0.0	1.2	-0.7	0.0	-2.2
6011	-2.6	1.5	0.5	6011	5.7	-2.0	-0.7	-8.3	3.6	1.2
6012	1.0	0.7	-0.3	6012	-1.9	-1.0	0.4	2.8	1.7	-0.6
6013	-0.3	-0.6	-0.5	6013	0.5	0.8	0.7	-0.8	-1.4	-1.2
6015	-0.6	-2.8	-0.4	6015	1.0	4.5	0.6	-1.6	-7.6	-1.0
6016	-0.5	-0.1	-0.4	6016	0.9	0.2	0.8	-1.3	-0.3	-1.2
6019	0.1	1.5	-2.0	6019	-0.1	-2.7	4.0	0.2	4.2	-6.0
6020	-1.1	1.7	-1.6	6020	1.4	-3.1	2.5	-2.5	4.7	-4.1
6022	-0.6	1.8	0.3	6022	1.3	-2.2	-0.3	-1.9	4.0	0.6
6023	1.7	-0.7	0.4	6023	-3.4	1.1	-0.5	5.1	-1.8	0.9
6031	1.0	1.7	0.9	6031	-1.7	-2.0	-1.7	2.7	3.6	2.6
6032	-0.7	0.1	-0.3	6032	0.8	-0.2	0.5	-1.5	0.3	-0.8
6038	-0.9	0.2	-0.0	6038	1.3	-0.4	0.0	-2.2	0.7	-0.0
6039	-0.4	3.6	-0.1	6039	0.7	-6.3	0.1	-1.1	9.8	-0.2
6040	-1.6	-1.0	-0.9	6040	1.7	1.7	1.1	-3.3	-2.7	-2.0
6042	-2.7	-2.2	-1.6	6042	4.8	4.2	2.3	-7.5	-6.4	-3.9
6043	-0.8	2.8	-2.0	6043	0.9	-3.4	4.4	-1.7	6.2	-6.5
6044	-1.2	1.4	-4.0	6044	1.2	-1.6	8.2	-2.4	3.0	-12.2
6045	-1.7	-1.1	-1.3	6045	2.1	1.9	1.8	-3.8	-3.0	-3.2
6047	0.0	-1.3	0.4	6047	-0.1	2.7	-0.5	0.1	-4.0	0.9
6050	-0.9	3.3	-1.0	6050	0.9	-3.5	2.7	-1.8	6.9	-3.7
6051	-1.0	1.4	-1.4	6051	1.0	-1.8	3.8	-2.0	3.3	-5.2
6052	-0.8	1.2	-0.6	6052	0.9	-1.5	1.1	-1.8	2.9	-1.7
6053	-0.3	2.0	-0.3	6053	0.4	-2.2	0.8	-0.7	4.3	-1.1
6055	1.5	0.6	-0.2	6055	-3.0	-0.9	0.3	4.5	1.5	-0.5

Table 5.3-4 (cont'd)

RESIDUALS V

	V1(WN14)				V2(WN12)			V1 - V2		
6059	-1.2	2.6	-1.0	6059	3.0	-3.8	1.5	-4.1	6.5	-2.5
6060	1.3	0.2	0.8	6060	-2.4	-0.3	-1.4	3.7	0.5	2.2
6061	-0.0	3.5	-2.6	6061	0.0	-3.7	5.5	-0.1	7.2	-8.1
6063	0.8	0.6	1.2	6063	-1.6	-1.0	-2.0	2.4	1.7	3.2
6064	-1.1	-0.8	-0.3	6064	1.6	1.1	0.3	-2.7	-1.9	-0.6
6065	-0.2	-0.0	-0.9	6065	0.3	0.0	2.3	-0.4	-0.1	-3.2
6066	1.0	0.7	-0.3	6066	-1.9	-1.0	0.4	2.8	1.7	-0.6
6067	2.6	1.3	-0.1	6067	-6.8	-2.2	0.1	9.4	3.5	-0.2
6068	-1.1	-0.0	-1.9	6068	2.1	0.0	3.0	-3.2	-0.1	-4.9
6069	-0.0	2.4	-3.7	6069	0.1	-2.6	6.1	-0.1	5.0	-9.7
6072	-1.7	-2.4	-0.8	6072	1.8	3.9	1.1	-3.5	-6.3	-1.9
6073	-1.7	-1.2	-1.2	6073	1.9	2.0	1.4	-3.6	-3.2	-2.6
6075	-1.3	-1.3	-1.6	6075	1.7	2.1	2.0	-3.0	-3.5	-3.6
6078	1.4	0.4	-0.5	6078	-5.9	-0.6	0.8	7.3	1.0	-1.3
6111	-0.9	-0.2	0.5	6111	1.3	0.5	-1.2	-2.2	-0.7	1.7
6123	-0.9	0.8	0.5	6123	1.0	-0.8	-1.4	-1.9	1.6	2.0
6134	-0.9	-0.2	0.5	6134	1.3	0.5	-1.2	-2.2	-0.7	1.7
7043	-0.7	0.2	0.4	7043	0.8	-0.5	-0.9	-1.5	0.7	1.3

Table 5.3-5 is a height analysis computed for the purpose of inspecting the height residuals from solution WN14 which, according to the explanation offered in section 5.1, are mostly the short-wave-length components (δN) of the geoid undulation. In the table, NOSUGC denotes the quantity H_{WN14} - MSL - dH, where dH is computed with u_0 = -23.2 m, v_0 = -2.9 m and w_0 = 2.7 m. In case of a uniform global station distribution, the average value of NOSUGC - N_{REF} should be equal to the additive terms from the best fit, Δa = -13 m. As it is seen on the last page of the table, this number is -12.94 m. The root mean square value of the residuals is ±6.42 m. The respective numbers from the WN12 solution (no weighted height constraints) are -1.24 and ±13.45 m. From this it seems that the semidiameter of the level ellipsoid best fitting the geoid (defined through the N_{WN12} undulations) is 6 378 153.8 ±13.5 m, opposed to the WN14 solution's 6 378 142.1 ±6.4 m. The proximity of these values and their noise level are only indications that the "best" semidiameter of the level ellipsoid still needs to be determined; at the present time it can only be <u>defined to fit some criteria</u> as in section 5.1.

Table 5.3-6 contains the results of an independent height comparison where undulations (N) from the WN14 solution referenced to the defined level ellipsoid are compared with those from [Vincent et al., 1972] (N_V). The quantity

$$N = H_{WN14} - MSL - \Delta N = NOSUGC - \Delta a \quad .$$

The average difference N - N_V taken over the stations where N_V is available is -0.3 m, and the rms of the residuals is ±6.1 m. Similar comparisons with the WN12 solution show an average difference of -0.2 m and the rms of the residuals of ±16.1 m.

Table 5.3-5

Height Residuals (Solution WN14)

STN. NO.	NOSUGC	N REF	NOSUGC-N REF	RESIDUALS
1021	-53.33	-37.32	-16.01	-3.07
1022	-38.20	-31.58	-6.62	6.33
1030	-51.74	-30.00	-21.74	-6.79
1032	-2.12	11.57	-13.69	-0.75
1033	-3.91	9.11	-13.02	-0.08
1034	-40.84	-25.47	-15.37	-2.42
1042	-47.53	-34.38	-13.15	-0.20
3106	-53.30	-49.83	-3.47	9.47
3334	-45.79	-31.54	-14.25	-1.30
3400	-32.19	-18.42	-13.77	-0.82
3401	-46.81	-30.59	-16.22	-3.28
3402	-48.34	-29.04	-19.30	-6.36
3404	-43.00	-6.69	-36.31	-23.36
3405	-65.84	-49.77	-16.07	-3.12
3406	-38.89	-29.19	-9.70	3.24
3407	-60.27	-38.57	-21.70	-8.76
3413	-19.55	-12.03	-7.52	5.43
3414	-27.84	-9.88	-17.96	-5.02
3431	5.59	11.98	-6.39	6.56
3476	-44.50	-28.31	-16.19	-3.25
3477	0.51	10.71	-10.20	2.74
3478	-20.75	-7.17	-13.58	-0.64
3499	3.87	16.73	-12.86	0.09
3648	-48.91	-35.70	-13.21	-0.26
3657	-49.62	-36.55	-13.07	-0.13
3861	-43.88	-33.70	-10.18	2.76
3902	-31.19	-16.53	-14.66	-1.72
3903	-57.45	-36.87	-20.58	-7.63
5001	-44.20	-36.87	-7.33	5.62
5201	-39.05	-17.65	-21.40	-8.46
5410	-6.20	-4.13	-2.07	10.88
5648	-47.90	-35.07	-12.83	0.12
5712	-44.22	-28.31	-15.91	-2.97
5713	49.11	54.00	-4.89	8.05
5715	23.59	27.20	-3.61	9.33

Table 5.3-5 (cont'd)

STN. NO.	NCSUGC	N REF	NOSUGC-N REF	RESIDUALS
5717	7.70	10.35	-2.65	10.30
5720	-16.89	-5.78	-11.11	1.84
5721	-32.25	-20.67	-11.58	1.37
5722	-87.78	-73.64	-14.14	-1.19
5723	-59.91	-40.39	-19.52	-6.58
5726	61.98	62.16	-0.18	12.76
5730	-4.72	13.75	-18.47	-5.53
5732	8.67	27.35	-18.68	-5.73
5733	-0.23	16.07	-16.30	-3.35
5734	-3.56	6.22	-9.78	3.17
5735	-19.53	-12.03	-7.50	5.45
5736	4.41	16.26	-11.85	1.10
5739	48.73	54.00	-5.27	7.67
5744	23.35	37.43	-14.08	-1.14
5907	-42.61	-28.11	-14.50	-1.56
5911	-43.33	-43.44	0.11	13.05
5912	-13.16	6.16	-19.32	-6.38
5914	-67.99	-50.08	-17.91	-4.97
5915	-41.79	-26.32	-15.47	-2.52
5923	22.05	24.64	-2.59	10.35
5924	23.49	54.48	-30.99	-18.04
5925	26.11	33.75	-7.64	5.31
5930	9.73	8.28	1.45	14.39
5931	-28.03	2.32	-30.35	-17.40
5933	48.80	50.66	-1.86	11.09
5934	58.59	74.75	-16.16	-3.22
5935	42.62	48.15	-5.53	7.42
5937	51.60	69.93	-18.33	-5.38
5938	49.03	59.97	-10.94	2.01
5941	4.87	2.05	2.82	15.76
6001	4.33	11.66	-7.33	5.61
6002	-50.76	-36.90	-13.86	-0.92
6003	-39.23	-17.65	-21.58	-8.64
6004	-3.23	6.22	-9.45	3.50
6006	11.02	27.06	-16.04	-3.09

Table 5.3-5 (cont'd)

STN. NO.	NOSUGC	N REF	NOSUGC-N REF	RESIDUALS
6007	49.70	54.00	-4.30	8.64
6008	-44.48	-28.31	-16.17	-3.23
6009	3.57	16.73	-13.16	-0.21
6011	3.20	1.75	1.45	14.40
6012	-4.85	13.75	-18.60	66
6013	15.27	34.27	-19.00	.06
6015	-33.55	-20.67	-12.88	0.07
6016	23.27	37.43	-14.16	-1.22
6019	5.60	22.80	-17.20	-4.25
6020	-21.60	-4.75	-16.85	-3.90
6022	7.62	27.35	-19.73	-6.78
6023	44.08	67.94	-23.86	-10.92
6031	-14.32	8.68	-23.00	-10.05
6032	-37.42	-30.51	-6.91	6.03
6038	-49.95	-35.47	-14.48	-1.54
6039	-37.29	-16.68	-20.61	-7.66
6040	-52.86	-38.11	-14.75	-1.81
6042	-17.34	-5.78	-11.56	1.39
6043	-3.29	15.60	-18.89	-5.95
6044	28.18	36.61	-8.43	4.52
6045	-20.02	-6.07	-13.95	-1.00
6047	60.22	62.17	-1.95	10.99
6050	-2.81	15.70	-18.51	-5.56
6051	18.02	29.20	-11.18	1.76
6053	-72.38	-56.10	-16.28	-3.33
6055	4.24	16.26	-12.02	0.93
6059	-0.41	16.07	-16.48	-3.53
6060	7.28	27.33	-20.05	-7.10
6061	0.96	11.28	-10.32	2.62
6063	23.02	27.20	-4.18	8.76
6064	0.64	10.35	-9.71	3.23
6065	30.04	44.23	-14.19	-1.24
6066	-5.65	13.74	-19.39	-6.45
6067	-19.55	-12.03	-7.52	5.43
6068	13.16	24.65	-11.49	1.45

Table 5.3-5 (cont'd)

STN. NO.	NOSUGC	N REF	NOSUGC-N REF	RESIDUALS
6069	13.23	25.52	-12.29	0.66
6072	-63.61	-40.39	-23.22	-10.28
6073	-86.13	-73.64	-12.49	0.46
6075	-54.59	-44.40	-10.19	2.75
6078	44.05	63.10	-19.05	-6.10
6111	-45.28	-33.18	-12.10	0.85
6123	-14.02	-1.40	-12.62	0.33
6134	-45.38	-33.19	-12.19	0.75
7036	-31.99	-19.78	-12.21	0.73
7037	-44.47	-33.87	-10.60	2.34
7039	-54.88	-43.43	-11.45	1.49
7040	-52.74	-50.55	-2.19	10.75
7043	-50.11	-36.91	-13.20	-0.26
7045	-30.24	-18.10	-12.14	0.81
7072	-44.94	-36.04	-8.90	4.04
7075	-52.35	-39.20	-13.15	-0.21
7076	-33.40	-26.62	-6.78	6.16
8009	31.67	42.33	-10.66	2.28
8010	31.46	44.77	-13.31	-0.37
8011	37.72	47.43	-9.71	3.23
8015	34.99	46.38	-11.39	1.55
8019	32.00	45.91	-13.91	-0.97
8030	30.64	44.64	-14.00	-1.06
9001	-37.07	-22.93	-14.14	-1.19
9002	12.89	24.27	-11.38	1.56
9004	42.32	54.57	-12.25	0.69
9005	19.87	30.20	-10.33	2.62
9006	-60.51	-48.12	-12.39	0.56
9007	22.60	31.82	-9.22	3.73
9008	-31.19	-10.91	-20.28	-7.34
9009	-38.62	-29.19	-9.43	3.51
9010	-44.91	-36.04	-8.87	4.07
9011	5.71	22.80	-17.09	-4.14
9012	2.98	1.76	1.22	14.17
9021	-42.84	-27.00	-15.84	-2.89

Table 5.3-5 (cont'd)

STN. NO.	NOSUGC	N REF	NOSUGC-N REF	RESIDUALS
9028	-39.07	-5.78	-33.29	-20.34
9029	-19.54	-12.03	-7.51	5.44
9031	-2.31	13.43	-15.74	-2.80
9051	20.50	32.81	-12.31	0.64
9091	19.99	32.84	-12.85	0.10
9424	-43.09	-26.21	-16.88	-3.93
9425	-44.00	-32.39	-11.61	1.34
9426	21.80	36.39	-14.59	-1.64
9427	-2.77	8.83	-11.60	1.34
9431	10.01	25.67	-15.66	-2.71
9432	26.58	39.71	-13.13	-0.12

AVERAGE	SIGMA
-0.1294D+02	0.6420D+01

SEMI-MAJOR AXIS

6378142.06

Table 5.3-6

Undulation Comparison (Solution WN14)

Sta.	N_{REF}	MSL	-dH	H_{WG84}	N	N_V	Diff.
1021	-37.32	5.76	0.20	-47.77	-40.39	-34.50	-5.89
1022	-31.58	4.81	-0.81	-32.58	-25.25	-29.50	4.25
1030	-30.00	929.10	-12.22	889.58	-38.79	-31.90	-6.89
1032	11.57	69.00	5.92	60.96	10.82	12.50	-1.68
1034	-25.47	252.58	-5.81	217.55	-27.89	-26.70	-1.19
1042	-34.38	909.40	-1.53	863.40	-34.58	-30.30	-4.28
3106	-49.83	1.90	7.28	-58.68	-40.36	-54.80	14.44
3334	-31.54	39.00	-4.19	-2.60	-32.84	-28.70	-4.14
3400	-18.42	2184.10	-8.49	2160.40	-19.24	-17.50	-1.74
3401	-30.59	83.00	1.67	34.52	-33.87	-28.40	-5.47
3402	-29.04	73.00	-3.23	27.89	-35.40	-30.40	-5.00
3405	-49.77	2.20	3.47	-67.11	-52.89	-53.30	0.41
3406	-29.19	6.83	5.02	-37.08	-25.95	-35.50	9.55
3407	-38.57	254.80	7.87	186.66	-47.33	-46.20	-1.13
3648	-35.70	12.00	-0.81	-36.10	-35.96	-31.70	-4.26
3657	-36.55	5.50	0.45	-44.57	-36.68	-33.90	-2.78
3861	-33.70	0.20	-0.21	-43.47	-30.94	-31.00	0.06
3902	-16.53	1882.20	-8.35	1859.36	-18.25	-16.40	-1.85
3903	-36.87	168.00	0.08	110.47	-44.50	-34.00	-10.50
5001	-36.87	127.80	0.08	83.52	-31.25	-34.00	2.75
5201	-17.65	368.92	-11.41	341.28	-26.11	-20.90	-5.21
5648	-35.07	27.90	-0.95	-19.05	-34.95	-30.90	-4.05
5715	27.20	27.30	19.89	31.00	36.53	25.50	11.03
5739	54.00	56.10	13.40	91.43	61.67	60.30	1.37
5744	37.43	11.80	16.74	18.41	36.29	40.80	-4.51
5907	-28.11	481.90	-5.56	444.85	-29.67	-27.90	-1.77
5911	-43.44	22.00	4.76	-26.09	-30.39	-39.20	8.81
5912	6.16	9.10	0.96	-5.02	-0.22	1.10	-1.32
5914	-50.08	63.80	5.19	-9.38	-55.05	-55.90	0.85
5915	-26.32	206.20	-6.52	170.93	-28.84	-27.10	-1.74
5924	54.48	12.40	16.64	19.25	36.44	48.60	-12.16
6002	-36.90	44.30	0.24	-6.70	-37.82	-34.00	-3.82
6003	-17.65	368.74	-11.41	340.92	-26.29	-20.90	-5.39
6006	27.06	105.70	5.41	111.31	23.97	26.00	-2.03
6007	54.00	53.30	13.40	89.60	62.64	60.30	2.34
6016	37.43	9.24	16.74	15.77	36.21	40.80	-4.59
6023	67.94	60.50	-15.81	120.39	57.02	71.30	-14.28
6032	-30.51	26.30	-5.02	-6.10	-24.48	-21.50	-2.98
6060	27.33	211.08	-14.66	233.02	20.23	31.60	-11.37
6063	27.20	26.30	19.69	29.43	35.96	25.50	10.46
6065	44.23	943.20	13.66	959.58	42.99	44.50	-1.51
6111	-33.18	2284.30	-12.52	2251.54	-32.33	-34.50	2.17
7036	-19.78	59.59	-6.75	34.35	-19.05	-24.00	4.95
7037	-33.87	272.68	-4.62	232.83	-31.53	-32.30	0.77
7040	-50.55	49.70	5.64	-8.68	-39.80	-52.30	12.50
7045	-18.10	1789.63	-8.37	1767.76	-17.29	-18.40	1.11
7072	-36.04	14.20	-0.19	-30.55	-32.00	-36.30	4.30
7075	-39.20	281.90	-1.39	230.94	-39.41	-36.90	-2.51
7076	-26.62	445.90	1.55	410.95	-20.46	-32.00	11.54
9001	-22.93	1651.33	-9.35	1623.61	-24.12	-22.80	-1.32
9004	54.57	25.90	16.70	51.52	55.26	48.40	6.86
9009	-29.19	8.70	5.02	-34.94	-25.68	-35.70	10.02
9010	-36.04	15.13	-0.19	-29.59	-31.97	-36.30	4.33
9021	-27.00	2382.00	-10.74	2349.90	-29.89	-28.10	-1.79
9051	32.81	187.90	15.98	192.42	33.45	40.60	-7.15
9091	32.64	467.00	15.94	471.05	32.94	40.60	-7.66

Table 5.3-6 (cont'd)

Sta.	N_{RE7}	MSL	-dH	H_{WGS4}	N	N_v	Diff.
9424	-26.21	704.60	-8.36	669.87	-30.14	-20.20	-9.94
9425	-32.39	784.23	-12.53	752.76	-31.05	-33.90	2.85
9426	36.39	575.92	9.24	588.48	34.75	36.60	-1.85
6134	-33.19	2198.40	-12.52	2165.54	-32.44	-34.50	2.06
8009	42.33	24.70	12.25	44.12	44.61	41.60	3.01
8010	44.77	903.44	14.01	920.89	44.40	46.10	-1.70
8011	47.43	113.20	12.04	138.88	50.66	47.00	3.66
8015	46.38	647.00	14.96	679.03	59.93	49.30	10.63
8019	45.91	377.42	15.03	394.39	44.94	47.30	-2.36
8030	44.64	165.50	13.31	182.83	43.58	43.60	-0.02
9431	25.67	8.00	9.92	8.09	22.96	16.80	6.16
9432	39.71	189.00	12.88	202.70	39.52	41.10	-1.58

5.4 Comparisons with Dynamic Solutions

Table 5.4-1 is a compilation of transformation parameters between the WN coordinates and those from the dynamic solutions NWL-9D, SAO III, GEM-4 and GSFC-73. The method of computing the parameters is described in [Kumar, 1972]. In the table the positive angles ω, ψ and ε are counter-clockwise rotations about the w, v and u axes respectively, as viewed from the end of the positive axis. The scale difference factor Δ is in units of ppM. In the transformations the variances of both sets of the coordinates are taken into account. Taking the variances of the WN solutions as standard, those of the dynamic solutions are scaled by the weight factors indicated. These numbers are also indicative of the overoptimism over the quality of some of the published solutions. For example, a weight factor of 25 would indicate that the published standard deviations of a given solution need to be multiplied by $\sqrt{25} = 5$.

Tables 5.4-2 to 5.4-5 contain the variance-covariance matrices, the correlation coefficients, and the residuals after transformation for the solutions mentioned above.

It can be observed that there is a good agreement between the translational elements Δu-s and Δv-s of the main (all stations inclusive) dynamic solutions and a discrepancy of about 8.5 ± 1.7 m with respect to the geometric values (see equation 5.1 - 5). The largest discrepancy occurs in the Δw components, where there seems to be a 12.3 ± 2.1 m difference between the SAO III and the GEM-4 solutions. Eliminating the SAO III value, all Δw's, including the geometric one, are within the noise level. The weighted mean shifts from the main dynamic solutions (excluding Δw from SAO III), or the coordinates of the geocenter

Table 5.4-i

Relationships Between Various Dynamic and the WN Systems
(Dynamic - WN14)

Solution	NWL-9D **			SAO III **			GEM-4 **	GSFC-73**
S.H. Considered	5000	6000	all	6000	9000	all	all	all
No. Stations	12	22	32	47	22	73	30	26
Weight Factor*	1.5	7.75	∿ 4	2	2	2	50	22
Δu (m)	15.6 ±1.6	16.8 ±1.1	16.9 ±1.0	16.8 ±1.5	10.7 ±2.1	13.9 ±1.3	14.5 ±1.6	13.7 ±1.5
Δv (m)	13.1 ±1.5	9.6 ±1.1	10.3 ±1.0	12.8 ±1.5	13.6 ±2.2	13.6 ±1.3	11.6 ±1.6	12.9 ±1.4
Δw (m)	- 7.8 ±2.0	- 3.2 ±1.1	- 3.4 ±1.1	- 5.2 ±1.5	-15.7 ±2.3	-10.4 ±1.3	1.9 ±1.7	- 1.7 ±1.9
$\Delta (10^{-6})$	0.74±0.15	0.26±0.05	0.29±0.04	- 0.50±0.05	0.74±0.15	- 0.17±0.04	0.93±0.11	0.96±0.11
ω (″)	0.73±0.03	0.70±0.01	0.71±0.01	0.51±0.02	0.26±0.03	0.37±0.01	- 0.02±0.02	- 0.38±0.02
ψ (″)	- 0.11±0.04	- 0.15±0.01	- 0.15±0.01	0.15±0.02	0.08±0.04	0.15±0.01	0.12±0.03	0.19±0.03
ϵ (″)	0.23±0.07	- 0.17±0.01	- 0.14±0.01	- 0.18±0.02	0.07±0.03	- 0.03±0.01	0.17±0.02	0.24±0.03
σ_0^2	0.65	0.91	0.87	0.83	1.20	1.14	1.11	1.09

*Weight Factor = $\sigma_{0,i}^2 / \sigma_{0,WN14}^2$

**See p. 118 for references.

Table 5.4-2

Transformation: NWL 9D - WN14

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
15.89	10.27	-3.38	0.29	0.71	-0.15	-0.14

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 =$ 0.87

0.957D+00	-0.812D-03	-0.133D-02	0.958D-10	0.151D-08	0.433D-08	0.502D-09
-0.812D-03	0.955D+00	0.127D-02	0.109D-08	-0.877D-09	-0.248D-09	-0.603D-08
-0.133D-02	0.127D-02	0.112D+01	-0.293D-08	-0.205D-09	-0.708D-09	-0.196D-08
0.958D-10	0.109D-08	-0.293D-08	0.185D-14	-0.436D-18	0.277D-17	-0.530D-18
0.151D-08	-0.877D-09	-0.205D-09	-0.436D-18	0.285D-14	-0.592D-16	0.446D-15
0.433D-08	-0.248D-09	-0.708D-09	0.277D-17	-0.592D-16	0.289D-14	0.167D-15
0.502D-09	-0.603D-08	-0.196D-08	-0.530D-18	0.446D-15	0.167D-15	0.394D-14

COEFFICIENTS OF CORRELATION

0.100D+01	-0.849D-03	-0.129D-02	0.228D-02	0.289D-01	0.823D-01	0.817D-02
-0.849D-03	0.100D+01	0.123D-02	0.260D-01	-0.168D-01	-0.472D-02	-0.983D-01
-0.129D-02	0.123D-02	0.100D+01	-0.646D-01	-0.363D-02	-0.125D-01	-0.296D-01
0.228D-02	0.260D-01	-0.646D-01	0.100D+01	-0.190D-03	0.120D-02	-0.196D-03
0.289D-01	-0.168D-01	-0.363D-02	-0.190D-03	0.100D+01	-0.207D-01	0.133D+00
0.823D-01	-0.472D-02	-0.125D-01	0.120D-02	-0.207D-01	0.100D+01	0.494D-01
0.817D-02	-0.983D-01	-0.296D-01	-0.196D-03	0.133D+00	0.494D-01	0.100D+01

Table 5.4-2 (cont'd)

RESIDUALS V

	V1(WN14)				V2(NWL 9D)			V1 - V2		
5410	0.2	-0.1	-0.3	700	-13.2	3.8	10.5	13.4	-3.9	-10.9
5648	0.1	0.0	0.6	708	-1.6	-1.4	-17.7	1.7	1.5	18.3
5713	0.0	0.4	-0.0	713	-3.1	-21.4	0.0	3.1	21.8	-0.0
5733	-6.7	5.0	-4.3	733	3.0	-1.3	1.1	-9.7	6.3	-5.4
5915	2.1	0.5	4.5	709	-19.1	-2.9	-33.4	21.2	3.4	37.9
5923	-0.3	-0.4	0.1	719	11.6	8.8	-1.[illegible]	-11.9	-9.3	1.7
5924	0.1	0.6	0.0	740	-11.6	-20.3	-0.5	11.8	20.9	0.6
5933	0.3	-0.8	0.3	727	-11.8	18.7	-10.1	[illegible].1	-19.5	10.5
5934	-0.0	-0.1	-0.3	729	0.7	1.9	12.1	-0.7	-1.9	-12.4
5935	0.3	0.0	0.2	728	-21.2	-1.5	-8.0	21.4	1.5	8.2
6001	0.8	0.1	-2.8	18	-2.0	-0.2	3.9	2.9	0.3	-6.6
6002	-0.1	0.2	1.1	742	0.5	-1.1	-4.9	-0.6	1.3	6.0
6003	0.7	-0.4	-0.1	738	-2.6	1.5	0.4	3.3	-1.9	-0.6
6004	3.7	-5.4	-5.5	739	-8.1	8.1	5.9	11.8	-13.6	-11.4
6006	0.6	-2.3	1.3	818	-1.8	4.5	-2.5	2.5	-6.8	3.7
6008	1.4	-0.8	2.9	815	-5.2	3.5	-5.4	6.7	-4.3	8.2
6011	-0.7	0.3	-4.3	811	1.3	-0.6	6.3	-2.0	0.[illegible]	-10.7
6012	0.0	0.0	-0.5	708	-0.2	-0.8	6.1	0.2	0.8	-6.6
6015	-1.1	-1.0	-1.1	817	4.4	3.5	2.6	-5.5	-4.5	-3.7
6016	0.7	1.5	0.1	812	-3.5	-5.0	-0.5	4.1	6.5	0.6
6022	-1.8	0.8	-1.9	117	2.5	-1.1	1.4	-4.2	1.9	-3.3
6023	-0.3	0.4	1.1	744	0.4	-0.8	-1.2	-0.7	1.2	2.3
6031	-0.2	2.7	3.3	809	0.3	-2.9	-3.6	-0.5	5.5	6.9
6038	-0.2	-0.1	-0.2	831	2.3	0.9	0.9	-2.5	-1.0	-1.1
6043	-1.5	-4.5	6.7	847	2.2	4.8	-4.8	-3.7	-9.1	11.4
6053	-2.0	1.7	1.0	19	1.5	-1.4	-0.8	-3.5	3.1	1.8
6055	1.4	-0.1	-0.5	722	-4.1	0.3	1.0	5.5	-0.4	-1.5
6060	-0.1	-0.4	0.8	805	1.1	4.8	-6.7	-1.2	-5.3	7.4
6064	-0.7	2.2	-1.3	822	1.4	-5.4	2.1	-2.1	7.6	-3.4
6065	-0.3	-0.7	-0.2	830	1.4	1.8	0.7	-1.7	-2.5	-1.0
6068	0.0	-0.1	1.3	115	-0.1	1.2	-9.7	0.1	-1.2	11.1
6075	-0.1	0.4	0.3	717	0.2	-0.5	-0.3	-0.3	1.0	0.5

Table 5.4-3

Transformation: SAO III - WN14

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
13.93	13.62	-1[illegible] 5	-0.17	0.37	0.15	-0.03

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 = 1.14$

0.155D+01	-0.247D-04	-0.818D-03	-0.382D-08	0.357D-08	0.355D-08	0.310D-09
-0.247D-04	0.167D+01	0.118D-02	0.288D-08	0.473D-08	-0.579D-09	-0.329D-08
-0.818D-03	0.118D-02	0.167D+01	-0.300D-08	0.342D-09	-0.584D-08	-0.491D-08
-0.382D-08	0.288D-08	-0.300D-08	0.190D-14	-0.693D-18	-0.100D-17	0.301D-17
0.357D-08	0.473D-08	0.342D-09	-0.693D-18	0.274D-14	-0.152D-15	-0.474D-16
0.355D-08	-0.579D-09	-0.584D-08	-0.100D-17	-0.152D-15	0.300D-14	0.304D-15
0.310D-09	-0.329D-08	-0.491D-08	0.301D-17	-0.474D-16	0.304D-15	0.306D-14

COEFFICIENTS OF CORRELATION

0.100D+01	-0.153D-04	-0.509D-03	-0.704D-01	0.548D-01	0.521D-01	0.450D-02
-0.153D-04	0.100D+01	0.705D-03	0.511D-01	0.699D-01	-0.819D-02	-0.459D-01
-0.509D-03	0.705D-03	0.100D+01	-0.534D-01	0.507D-02	-0.826D-01	-0.688D-01
-0.704D-01	0.511D-01	-0.534D-01	0.100D+01	-0.304D-03	-0.421D-03	0.125D-02
0.548D-01	0.699D-01	0.507D-02	-0.304D-03	0.100D+01	-0.530D-01	-0.164D-01
0.521D-01	-0.819D-02	-0.826D-01	-0.421D-03	-0.530D-01	0.100D+01	0.100D+00
0.450D-02	-0.459D-01	-0.688D-01	0.125D-02	-0.164D-01	0.100D+00	0.100D+01

Table 5.4-3 (cont'd)

RESIDUALS V

	V1(WN14)				V2(SAO III)			V1 - V2		
6002	1.7	-2.9	4.3	6002	-3.4	8.1	-9.6	5.1	-11.0	13.8
6003	0.0	0.1	0.4	6003	-0.7	-1.6	-8.2	0.7	1.7	8.6
6004	0.2	0.0	0.1	6004	-14.4	-2.4	-4.7	14.5	2.5	4.8
6006	0.0	-0.3	0.0	6006	-1.6	6.8	-0.5	1.6	-7.1	0.6
6007	-0.1	0.2	-0.3	6007	6.2	-9.7	10.0	-6.3	9.9	-10.3
6008	0.1	-0.0	0.2	6008	-6.2	2.1	-6.0	6.3	-2.2	6.1
6009	0.1	0.2	-0.3	6009	-3.5	-5.5	6.5	3.6	5.7	-6.8
6011	-0.6	1.0	0.4	6011	6.8	-12.3	-4.2	-7.4	13.3	4.7
6012	0.3	0.0	-0.4	6012	-26.6	-1.3	15.3	26.9	1.3	-15.7
6013	0.9	-0.1	0.1	6013	-24.8	1.8	-1.0	25.7	-1.9	1.0
6015	-0.1	-0.4	0.1	6015	4.2	16.0	-4.0	-4.3	-16.4	4.2
6016	-0.1	-0.3	0.2	6016	3.3	7.8	-5.4	-3.4	-8.1	5.6
6019	0.3	-0.3	-3.0	6019	-3.4	3.2	16.8	3.6	-3.5	-19.8
6020	0.3	0.4	-0.2	6020	-7.8	-14.7	4.4	8.1	15.1	-4.6
6022	0.2	0.8	0.2	6022	-4.8	-19.5	-3.0	5.0	20.2	3.2
6023	1.2	-0.0	0.2	6023	-19.7	0.8	-2.5	20.8	-0.9	2.7
6031	0.8	1.0	0.1	6031	-13.2	-12.4	-1.9	14.0	13.3	2.1
6032	1.3	0.1	1.4	6032	-29.0	-2.9	-22.3	30.3	3.1	23.7
6038	-0.1	-0.0	0.0	6038	2.2	0.1	-0.1	-2.3	-0.2	0.1
6039	0.3	0.7	-0.1	6039	-6.4	-20.1	3.6	6.7	20.8	-3.8
6040	1.0	-0.2	0.2	6040	-17.6	4.1	-4.7	18.6	-4.3	4.9
6042	-0.5	-0.7	1.2	6042	13.7	16.5	-16.0	-14.2	-17.1	17.1
6043	0.1	0.1	-1.4	6043	-4.2	-2.8	20.0	4.3	2.9	-21.4
6044	0.4	1.1	0.6	6044	-7.5	-27.4	-9.7	7.9	28.4	10.3
6045	-0.1	-0.4	1.1	6045	1.9	6.4	-12.1	-2.0	-6.8	13.1
6047	0.5	-0.1	0.2	6047	-34.2	7.4	-8.7	34.7	-7.5	9.0
6050	0.1	1.1	-1.1	6050	-4.0	-20.2	21.1	4.1	21.2	-22.2
6051	0.5	0.3	0.0	6051	-7.2	-7.1	-0.9	7.7	7.4	0.9
6052	1.1	0.6	0.1	6052	-20.0	-13.7	-1.6	21.1	14.3	1.7
6053	1.1	0.9	-0.1	6053	-17.2	-14.7	2.7	18.3	15.6	-2.8
6055	-0.3	0.2	-0.2	6055	9.8	-5.8	3.6	-10.1	6.0	-3.7
6059	-0.1	0.7	0.2	6059	2.5	-20.0	-2.9	-2.5	20.7	3.1
6060	2.2	1.2	0.3	6060	-14.7	-8.0	-1.8	16.9	9.3	2.1
6061	0.3	0.8	-0.9	6061	-10.9	-11.0	13.9	11.2	11.9	-14.8
6063	-1.3	0.5	-0.4	6063	21.0	-5.2	3.1	-22.3	5.7	-3.5
6064	-0.5	-0.2	0.4	6064	9.7	4.8	-4.6	-9.2	-5.1	5.0
6065	-0.1	-1.1	-1.4	6065	1.3	7.8	11.2	-1.5	-8.9	-12.6

Table 5.4-3 (cont'd)

RESIDUALS V

	V1(WN14)				V2(SAO III)			V1 - V2		
6067	0.9	0.5	-0.1	6067	-12.2	-6.3	1.3	13.1	6.8	-1.4
6068	-0.2	-0.8	-0.3	6068	0.4	1.4	0.3	-0.7	-2.2	-0.6
6069	0.1	0.3	0.3	6069	-2.1	-8.0	-5.8	2.2	8.3	6.1
6072	1.0	-0.6	0.3	6072	-10.7	13.8	-5.3	11.7	-14.4	5.5
6073	0.1	-0.6	0.7	6073	-1.3	12.5	-11.9	1.4	-13.2	12.6
6075	-0.3	-0.6	0.8	6075	4.7	11.5	-12.2	-5.0	-12.0	13.0
6078	-0.8	0.9	5.6	6078	10.0	-15.5	-40.4	-10.8	16.3	46.0
6111	-0.4	-0.0	0.7	6111	2.8	0.0	-5.5	-3.3	-0.0	6.1
6123	0.3	0.0	0.3	6123	-7.3	-0.6	-8.0	7.6	0.6	8.3
6134	-0.4	-0.0	0.7	6134	2.8	0.1	-5.5	-3.2	-0.1	6.2
8010	-9.2	13.4	0.0	8010	7.2	-5.0	-0.0	-16.4	18.3	0.0
8011	-2.1	39.2	-5.1	8011	2.1	-14.9	8.2	-4.1	54.1	-13.3
8015	-5.7	20.6	-3.5	8015	3.1	-3.1	1.7	-8.8	23.7	-5.2
8019	-1.3	14.8	-1.5	8019	5.6	-17.0	5.8	-6.9	31.8	-7.4
9001	-3.2	0.9	0.8	9001	13.5	-9.3	-7.7	-16.7	9.2	8.5
9002	-0.3	-1.1	-0.9	9002	0.3	1.1	0.4	0.7	-2.2	-1.3
9004	-3.1	20.1	-8.7	9004	4.2	-3.2	8.7	-7.4	23.3	-17.5
9005	4.5	-1.5	2.9	9005	-16.6	5.8	-15.8	21.1	-7.3	18.6
9006	11.1	-1.8	1.9	9006	-9.9	8.2	-7.2	21.0	-10.0	9.1
9007	1.8	-4.0	-8.5	9007	-3.5	6.0	5.6	5.3	-10.1	-14.1
9008	0.9	-1.8	-1.0	9008	-3.3	7.9	4.4	4.2	-9.7	-5.4
9009	0.5	-0.2	-1.5	9009	-6.1	3.7	9.7	6.6	-3.9	-11.2
9010	0.4	0.1	0.4	9010	-6.3	-1.2	-5.5	6.7	1.3	5.8
9011	0.2	-0.3	-3.1	9011	-3.2	3.1	16.7	3.4	-3.4	-19.8
9012	-0.6	1.0	0.5	9012	7.0	-12.4	-4.2	-7.6	13.5	4.7
9021	1.0	-3.3	0.2	9021	-0.6	3.6	-0.3	1.7	-6.9	0.5
9028	0.1	-0.2	1.5	9028	-2.1	3.8	-19.2	2.1	-3.9	20.7
9029	1.0	0.5	-0.2	9029	-12.2	-6.2	1.2	13.2	6.7	-1.4
9031	-0.4	0.2	-7.0	9031	1.6	-0.7	16.8	-2.0	0.9	-23.7
9091	-1.2	15.2	-1.5	9091	12.9	-26.1	14.2	-14.1	41.3	-15.7
9424	-4.4	2.0	1.5	9424	8.2	-2.7	-3.4	-12.6	4.8	5.0
9425	-0.1	-0.0	0.2	9425	3.6	0.6	-7.0	-3.7	-0.6	7.2
9426	1.2	3.2	-2.6	9426	-5.7	-12.4	27.0	6.9	15.5	-29.6
9427	1.1	-12.9	2.9	9427	-4.8	11.0	-12.9	5.9	-23.9	15.8
9431	-11.2	6.9	-0.5	9431	28.4	-30.4	3.8	-39.6	37.3	-4.3
9432	-0.2	2.1	-0.4	9432	6.7	-51.3	32.3	-6.8	53.4	-32.7

Table 5.4-4

Transformation: GEM 4 - WN14

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
14.52	11.64	1.91	0.93	-0.02	0.12	0.17

VARIANCE - COVARIANCE MATRIX

σ_o^2 = 1.11

0.268D+01	-0.378D-01	-0.116D-01	-0.932D-08	0.235D-07	0.392D-07	0.510D-08
-0.378D-01	0.251D+01	0.761D-02	0.364D-07	0.709D-08	-0.110D-07	-0.345D-07
-0.116D-01	0.761D-02	0.291D+01	-0.305D-07	0.612D-08	-0.212D-07	-0.395D-07
-0.932D-08	0.364D-07	-0.305D-07	0.111D-13	-0.437D-16	-0.536D-17	0.402D-16
0.235D-07	0.709D-08	0.612D-08	-0.437D-16	0.999D-14	-0.204D-14	-0.166D-14
0.392D-07	-0.110D-07	-0.212D-07	-0.536D-17	-0.204D-14	0.176D-13	0.387D-14
0.510D-08	-0.345D-07	-0.395D-07	0.402D-16	-0.166D-14	0.387D-14	0.127D-13

COEFFICIENTS OF CORRELATION

0.100D+01	-0.146D-01	-0.414D-02	-0.540D-01	0.144D+00	0.180D+00	0.277D-01
-0.146D-01	0.100D+01	0.282D-02	0.218D+00	0.448D-01	-0.523D-01	-0.193D+00
-0.414D-02	0.282D-02	0.100D+01	-0.170D+00	0.359D-01	-0.939D-01	-0.205D+00
-0.540D-01	0.218D+00	-0.170D+00	0.100D+01	-0.415D-02	-0.384D-03	0.338D-02
0.144D+00	0.448D-01	0.359D-01	-0.415D-02	0.100D+01	-0.154D+00	-0.147D+00
0.180D+00	-0.523D-01	-0.939D-01	-0.384D-03	-0.154D+00	0.100D+01	0.259D+00
0.277D-01	-0.193D+00	-0.205D+00	0.338D-02	-0.147D+00	0.259D+00	0.100D+01

Table 5.4-4 (cont'd)

RESIDUALS V

	V1(WN14)				V2(GEM 4)			V1 - V2		
1021	-0.1	-0.2	0.1	1021	2.3	5.3	-2.1	-2.4	-5.5	2.2
1022	0.4	-0.1	0.4	1022	-3.2	0.4	-3.0	3.5	-0.5	3.4
1030	-4.3	-0.9	1.0	1030	4.5	1.8	-3.3	-8.8	-2.6	4.3
1032	45.0	63.5	7.1	1032	-8.7	-10.0	-10.6	53.7	73.5	17.7
1034	-1.1	0.5	0.3	1034	9.9	-5.3	-3.8	-10.9	5.8	4.0
1042	1.8	-0.6	0.1	1042	-12.2	3.7	-0.9	14.0	-4.3	1.1
7036	-1.9	1.3	-0.1	7036	8.1	-7.8	0.4	-10.0	9.1	-0.5
7037	-0.7	1.0	0.6	7037	3.7	-6.2	-4.5	-4.4	7.1	5.1
7039	-1.1	-0.7	1.7	7039	6.3	5.3	-10.2	-7.3	-6.0	11.9
7040	-0.1	0.5	1.4	7040	0.3	-2.1	-4.7	-0.4	2.7	6.1
7043	-0.2	-0.0	-0.0	7043	7.9	1.9	0.9	-8.1	-2.0	-0.9
7045	-3.7	1.0	-0.7	7045	9.0	-4.5	3.6	-12.7	5.5	-4.3
7072	0.2	0.0	-0.1	7072	-5.1	-0.9	3.1	5.4	0.9	-3.2
7075	-1.0	-0.5	0.3	7075	9.6	4.7	-2.9	-10.7	-5.2	3.2
7076	-1.0	-3.0	-0.7	7076	5.1	10.4	2.4	-6.1	-13.3	-3.1
9001	-0.9	0.8	0.8	9001	1.2	-2.0	-3.4	-2.1	2.8	4.2
9002	0.6	0.7	-1.1	9002	-1.6	-2.3	1.7	2.2	3.0	-2.8
9004	-1.7	30.2	-3.4	9004	2.3	-5.8	5.4	-4.0	35.9	-8.8
9005	13.0	-11.9	9.1	9005	-7.9	7.9	-10.0	20.8	-19.9	19.1
9006	13.0	-9.6	1.7	9006	-2.2	6.5	-1.5	15.2	-16.1	3.2
9008	-2.4	2.1	2.1	9008	2.9	-3.0	-4.4	-5.3	5.2	6.5
9009	1.3	-0.4	-0.6	9009	-12.0	6.1	3.1	13.3	-6.5	-3.7
9010	0.9	-0.9	-0.3	9010	-5.4	6.4	2.2	6.3	-7.3	-2.5
9012	1.5	0.8	-1.3	9012	-3.3	-2.0	3.1	4.8	2.8	-4.5
9021	2.6	-0.4	-1.6	9021	-5.0	1.3	6.5	7.6	-1.7	-8.2
9028	1.0	-0.2	0.3	9028	-13.7	2.4	-2.2	14.8	-2.6	2.5
9031	-5.6	1.8	-20.9	9031	5.2	-2.3	10.7	-10.9	4.1	-31.5
9091	-4.1	17.8	-2.4	9091	10.3	-7.3	7.4	-14.4	25.1	-9.8
9425	-0.1	-0.4	-0.4	9425	1.5	8.6	7.5	-1.6	-8.9	-7.9
9427	2.1	-32.0	2.2	9427	-4.6	9.9	-5.2	6.7	-41.9	7.4

Table 5.4-5

Transformation: GSFC 73 - WN14

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
13.73	12.86	-1.70	0.96	-0.38	0.19	0.24

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 = 1.09$

0.218D+01	-0.646D-01	-0.166D-01	-0.125D-07	0.265D-07	0.500D-07	0.629D-08
-0.646D-01	0.203D+01	0.449D-01	0.508D-07	0.113D-07	-0.190D-07	-0.542D-07
-0.166D-01	0.449D-01	0.362D+01	-0.369D-07	0.132D-07	-0.343D-07	-0.648D-07
-0.125D-07	0.508D-07	-0.369D-07	0.123D-13	-0.133D-15	-0.537D-16	0.132D-15
0.265D-07	0.113D-07	0.132D-07	-0.133D-15	0.111D-13	-0.380D-14	-0.308D-14
0.500D-07	-0.190D-07	-0.343D-07	-0.537D-16	-0.380D-14	0.223D-13	0.595D-14
0.629D-08	-0.542D-07	-0.648D-07	0.132D-15	-0.308D-14	0.595D-14	0.179D-13

COEFFICIENTS OF CORRELATION

0.100D+01	-0.308D-01	-0.592D-02	-0.761D-01	0.170D+00	0.227D+00	0.318D-01
-0.308D-01	0.100D+01	0.166D-01	0.321D+00	0.753D-01	-0.894D-01	-0.284D+00
-0.592D-02	0.166D-01	0.100D+01	-0.174D+00	0.660D-01	-0.121D+00	-0.254D+00
-0.761D-01	0.321D+00	-0.174D+00	0.100D+01	-0.113D-01	[illegible]	0.989D-02
0.170D+00	0.753D-01	0.660D-01	-0.113D-01	0.100D+01	-0.241D+00	-0.218D+00
0.227D+00	-0.894D-01	-0.121D+00	-0.323D-02	-0.241D+00	0.100D+01	0.297D+00
0.318D-01	-0.284D+00	-0.254D+00	0.889D-02	-0.218D+00	0.297D+00	0.100D+01

Table 5.4-5 (cont'd)

RESIDUALS V

	V1(WN14)				V2(GSFC 73)			V1 - V2		
1021	0.2	-0.3	-0.3	1021	-1.3	2.7	3.5	1.5	-3.0	-3.8
1022	0.9	0.2	0.0	1022	-3.8	-0.6	-0.3	4.7	0.8	0.3
1030	-4.7	-0.6	1.1	1030	2.7	0.7	-4.5	-7.4	-1.2	5.5
1034	-1.1	1.3	0.7	1034	2.5	-2.3	-4.2	-3.6	3.6	4.9
1042	3.7	-1.0	-0.3	1042	-10.0	2.2	1.9	13.7	-3.2	-2.2
7036	-2.9	2.0	-0.1	7036	6.2	-5.4	0.9	-9.1	7.4	-1.0
7037	0.2	1.5	0.5	7037	-0.4	-4.0	-3.4	0.6	5.5	3.8
7039	0.2	-2.1	1.8	7039	-0.5	5.3	-8.1	0.7	-7.5	9.9
7040	0.6	0.7	0.3	7040	-1.2	-1.5	-1.1	1.8	2.3	1.4
7045	-3.9	0.6	-0.1	7045	4.7	-1.3	0.8	-8.7	1.9	-0.9
7072	0.7	-0.3	-0.3	7072	-7.9	4.6	4.4	8.6	-4.9	-4.7
7075	-2.0	-0.5	0.6	7075	4.5	0.9	-2.6	-6.5	-1.4	3.1
7076	-1.8	-5.7	-3.3	7076	3.5	7.4	7.8	-5.3	-13.0	-11.1
9001	-2.0	0.1	0.1	9001	3.7	-0.4	-0.7	-5.7	0.5	0.8
9002	1.1	-0.9	0.8	9002	-1.9	2.6	-1.8	3.0	-3.6	2.6
9004	-1.8	25.5	-2.1	9004	1.7	-5.0	4.7	-3.5	30.5	-6.8
9005	5.9	-4.8	3.6	9005	-11.2	23.7	-13.1	17.0	-29.4	16.7
9006	11.1	-5.4	0.2	9006	-7.7	15.3	-0.7	18.9	-20.9	0.9
9008	-2.2	-0.1	0.6	9008	14.3	0.6	-6.2	-16.5	-0.6	6.8
9009	0.6	-0.2	-0.0	9009	-17.2	9.6	1.0	17.8	-9.8	-1.1
9012	1.6	-0.2	0.3	9012	-5.7	0.8	-1.9	7.2	-0.9	2.2
9021	2.1	-3.3	-3.1	9021	-1.6	2.8	6.7	3.7	-6.2	-9.8
9028	0.6	-0.2	0.9	9028	-10.1	3.1	-9.9	10.7	-3.3	10.7
9031	-9.8	5.1	-14.7	9031	9.0	-5.3	10.4	-18.8	10.4	-25.1
9091	-3.2	24.9	-1.8	9091	4.4	-7.1	5.0	-7.6	32.0	-6.9
9425	-0.0	-0.5	-0.2	9425	0.4	5.8	2.9	-0.4	-6.3	-3.0

with respect to the WN14 origin, are listed in Table 5.4-6.

Table 5.4-6

Shifts to the Geocenter (Solution WN14)

Source	u_0 (m)	v_0 (m)	w_0 (m)	r_0 (m)
1. Dynamic Comparison	14.8 ±1.4	11.8 ±1.3	-1.8 ±1.6	18.9 ±1.9
2. Geometric Fit (section 5.1)	23.2 ±0.9	2.9 ±0.8	-2.7 ±1.2	23.4 ±1.2
3. Weighted Mean of 1 & 2	20.7 ±1.2	5.3 ±1.1	-2.4 ±1.4	21.4 ±1.6
4. JPL/DSN				25.9 ±2.5

The quantity $r_0 = \sqrt{u_0^2 + v_0^2}$ is distance of the WN14 origin from the rotation axis of the earth. Calculating the same number from the JPL-LS 37 coordinates of the Deep Space Network (stations DSN1 = 4711, DSN2 = 4712, DSN4 = 4714, DSN6 = 4742 and DSN7 = 4751) as published in [Gaposchkin et al., 1973], one gets r_0 = 25.9 ±2.5 m, which value is nearest to the one calculated from the geometric fit.

The differences in scale between the dynamic solutions are significant (see Fig. 5.1-2 for comparison). The largest discrepancy is between the SAO III and GSFC-73 with $\Delta = (1.13 \pm 0.12) \times 10^{-6}$, which is larger than what one would expect from the noise. The other dynamic scales are within near noise level and, on the average, differ from the scale of the WN14 solution by

$$\Delta = (0.12 \pm 0.08) \times 10^{-6}$$

or about one part in 8.3 million.

The largest discrepancies occur in the orientation of the various dynamic systems with respect to each other and to WN14. In the rotation about the w axis (ω), the largest difference occurs between the NWL-9D and the GSFC-73 solutions, where $\omega = 1''.1$, or about 34 m on the equator (Fig. 5.4-1). The other differences are smaller but are significant. These rotations may be partly due to the definition of the zero meridian in the case of purely electronic systems (e.g., Doppler), partly to the various definitions of the vernal equinox in the star catalogs used, and also to its motion with respect to inertial space, in case of optical observations. The latter alone requires a correction to the FK4 right ascensions amounting to $+0''.65$ at 1960.0,changing with a rate of $+1''.36$ per century [Martin and Van Flandern, 1970].

The rotations about the axes u and v are even more confusing. Fig. 5.4-2 illustrates the situation at the pole. The weighted means of the dynamic solutions are $\psi = 0''.02 \pm 0''.02$ and $\varepsilon = -0''.04 \pm 0''.02$. The discrepancy between the poles as determined separately from the SAO III 6000 stations and then from the 9000 stations is unexplained at this time. It is interesting to note that the weighted mean pole and zero meridian positions computed from the dynamic solutions hardly differ from those of the WN14 solution.

The only general conclusion that one can draw from the rotation parameters is that the coordinate systems used in the dynamic solutions need to be more carefully defined and conditions enforcing these definitions more strongly applied than evidenced from the solutions discussed.

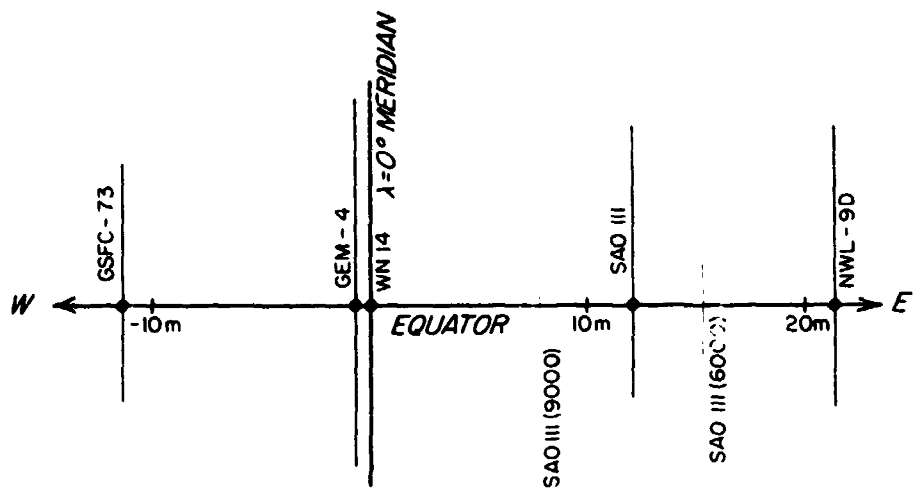

Fig. 5.4-1 Dynamic zero meridians relative to the WN14 zero meridian.

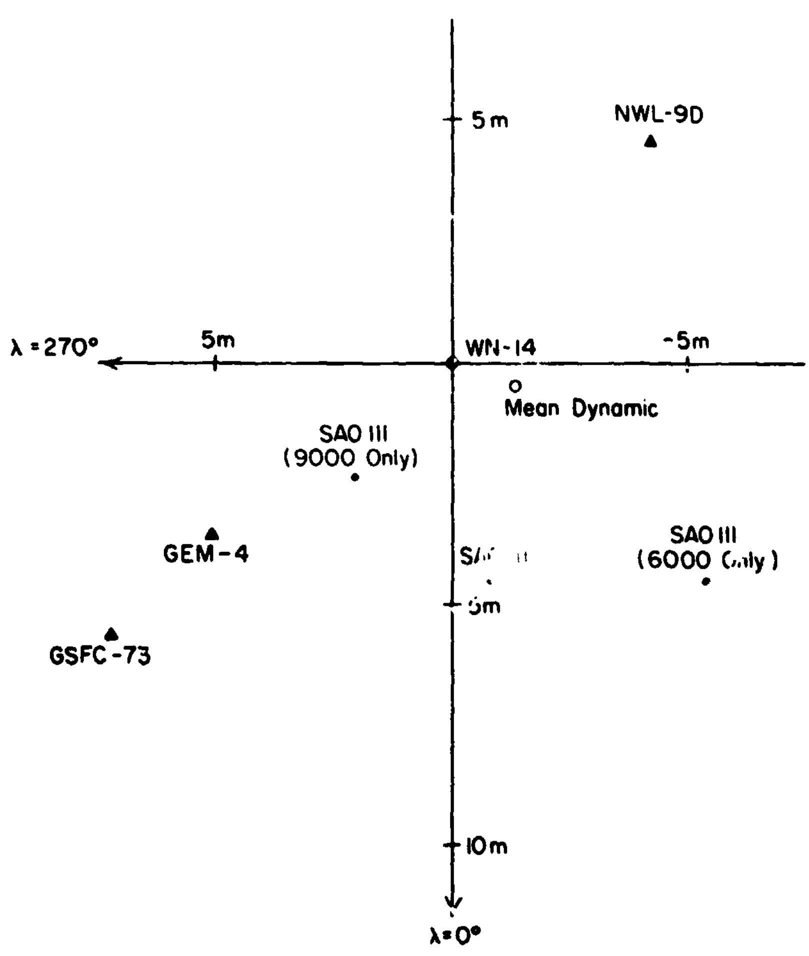

Fig. 5.4-2 Dynamic pole positions relative to the WN14 pole.

5.5 Comparisons with Geodetic Datums

In a planning document prepared in 1966 it was shown that the various ountries in the world use or have used 90 different geodetic datums in their mapping activities [Mueller, 1966]. Since many of these datums have been tied together with ground survey, it is possible to combine them into about 20 large and/or independent datum blocks (Fig. 5.5-1). The original OSU goal, outlined in section 1, called for at least three well-distributed tracking stations on each of these datum blocks. As of the writing of this report this goal has been accomplished only on the following datums:

Australian (3 stations)
European 50 (16 stations but marginal accuracy)
North American 1927 (21 stations)
South American 1969 (10 stations)

On the Tokyo Datum there are also several stations, but only one of them is independently determined in the WN14 solution. In order to meet the original requirement additional stations or observations will have to be included in future solutions in the following general areas in order of preference: Europe, Soviet Union, India, Japan, Philippines, Cape (South Africa), Madagascar, New Zealand, North Africa. Observations have already been taken and will become available within reasonable time in Europe and North Africa.

Relationships between the geodetic datums and the WN14 coordinate system, as reflected from the data included, are summarized in Table 5.5-1. Coordinates given only to the nearest meter represent estimated values, while the other parameters are the results of regular seven parameter transformations. In order to reduce the correlations between these parameters, the rotations and the scale are determined first from respective direction cosines and chord distances, both independent of the translation parameters and from each other. In a subsequent adjustment, the translations are calculated while the rotations and scale are constrained at their previously determined values with weights corresponding to their variances. For details of this procedure see [Kumar, 1972].

If the geodetic coordinates referred to any of the datums listed are to be shifted to the "best" geocenter, subtract from the Cartesian datum coordinates the values Δu, Δv, Δw listed and add 21 m, 5 m and -2 m (or other values from Table 5.4-6) respectively.

The variance-covariance matrix, the coefficients of correlation and the residuals after adjustment for those datum blocks where three or more stations are available are shown in Tables 5.5-2 to 5.5-8. The datum with the poorest fit is the European 50, followed by the South American 1969.

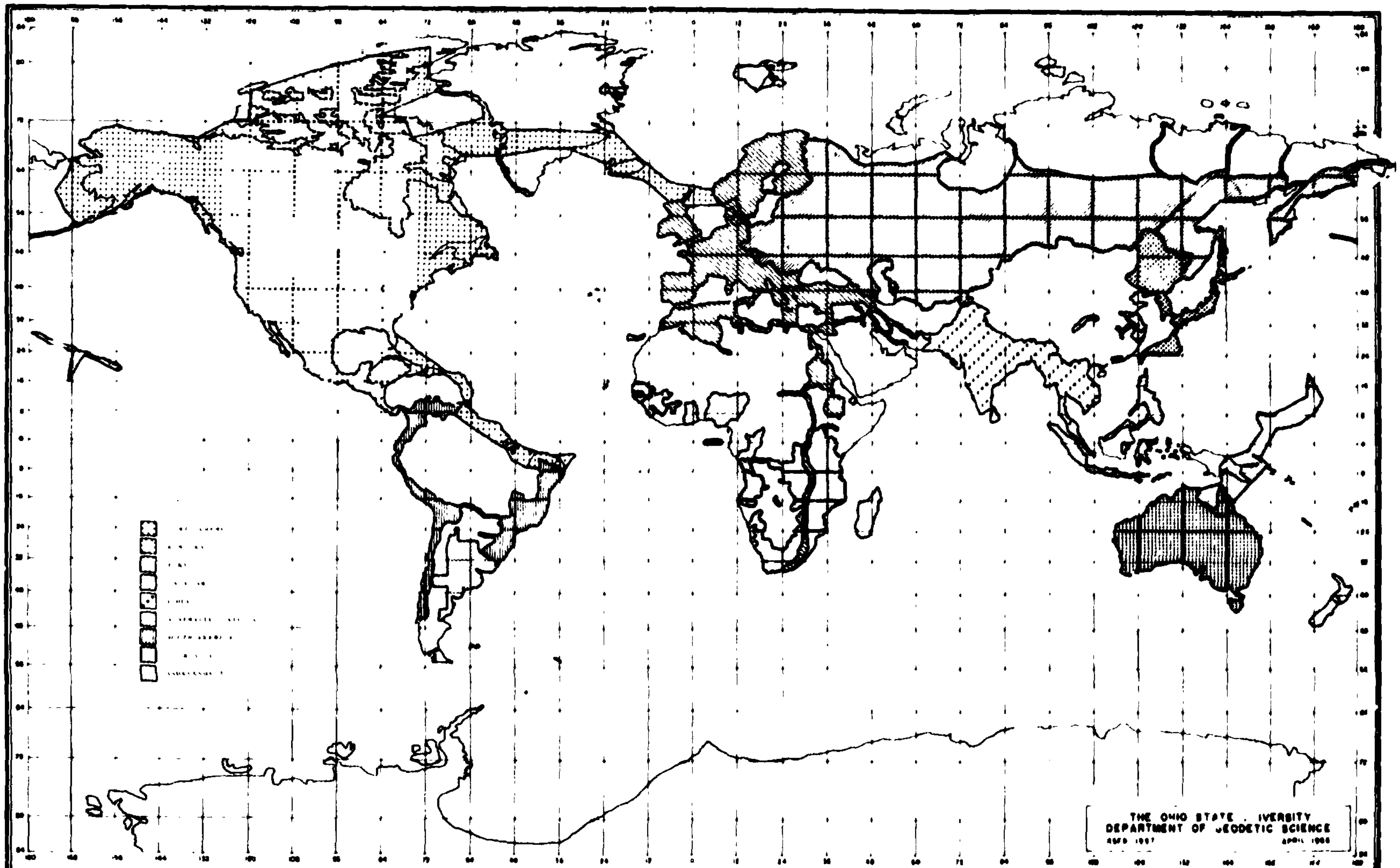

Fig. 5.5-1 Major geodetic datum blocks.

Table 5.5-1

Relationship Between Various Geodetic Datums and the WN System (Datum - WN14)

Datum No.	Datum Name[1]	No. of Stations	Δu (m)*	Δv (m)*	Δw (m)*	ω (″)**	ψ (″)**	ϵ (″)**	$\Delta (\times 10^6)$
1	Adindan (Ethiopia)	2	184 ±19	21 ±11	-200 ± 6				
2	American Samoa 1962	1	119 ± 8	-105 ± 8	-413 ±10				
3	Arc Cape (South Africa)	1	152 ± 7	126 ± 7	298 ±10				
5	Ascension Island 1958	1	227 ± 7	- 93 ± 7	- 58 ± 8				
6	Australian Geodetic	3	118.2± 5.0	41.1± 6.2	-121.0± 6.9	1.03±0.18	0.99±0.18	-0.25±0.22	-1.20±0.71
10	Camp Area Astro 1961/62(USGS)	1	111 ±10	148 ± 9	-238 ±10				
12	Christmas Island Astro 1967	1	-115 ± 9	-224 ±12	529 ± 8				
15	Easter Island Astro 1967	1	-182 ±10	-138 ±10	-128 ±11				
16	European-50 (W)[2]	11	133.3± 9.5	114.2±15.9	152.2± 9.2	-1.76±0.38	0.01±0.31	-0.38±0.44	-7.30±1.14
	European-50 (All stations)[3]	16	134.3± 9.1	152.7± 8.0	144.6± 8.8	-0.41±0.20	0.27±0.30	-0.51±0.22	-7.24±0.88
17	Graciosa Island (Azores)	1	123 ±17	-147 ± 9	37 ±17				
20	Heard Astro 1969	1	182 ±12	56 ±12	-114 ±14				
22	Indian[4]	1	-165 ±17	-711 ±10	-228 ±11				
23	Isla Socoro Astro	1	-134 ±12	-206 ± 7	-503 ± 9				
24	Johnston Island 1961	1	-161 ±13	51 ±25	211 ±13				
26	Luzon 1911 (Philippines)	1	151 ±10	51 ± 7	111 ± 8				
27	Midway Astro 1961	1	-377 ± 7	84 ± 7	-279 ± 9				

*If (Datum - Geocenter) is sought add to the tabulated values of Δu, Δv, Δw the respective quantities -21m, -5 m, 2 m (see Table 5.4-6).

**ω, ψ, ϵ when positive, represent counterclockwise rotations about the respective w, v, u axes, as viewed from the end of the positive axis.

Table 5.5-1 (cont'd)

Datum No.	Datum Name[1]	No. of Stations	Δu (m)*	Δv (m)*	Δw (m)*	ω (″)**	ψ (″)**	ε (″)	Δ (×10⁶)
28	New Zealand 1949	1	- 61 ± 8	41 ± 9	-192 ± 9				
29	North American 1927 (W)[5]	8	30.6± 7.3	-170.3± 4.5	-134.9± 6.8	0.21±0.20	0.59±0.21	-0.45±0.23	-7.91±0.45
	North American 1927 (E)[6]	13	56.4± 6.9	-144.6± 4.4	-196.4± 4.3	1.01±0.19	-0.01±0.16	0.54±0.14	2.15±0.62
	North American (All Stations)[7]	21	57.1± 2.2	-147.9± 2.6	-187.5± 2.9	0.86±0.06	0.23±0.06	0.33±0.11	0.80±0.27
36	Pitcairn Island Astro	1	-167 ±12	-168 ±11	- 60 ±11				
39	Provisional South Chile 1963	1	0 ± 8	-196 ± 8	- 93 ± 9				
41	South American 1969[9]	10	54.4± 5.5	30.0± 4.8	42.9± 4.9	-0.63±0.17	0.17±0.12	-0.12±0.13	6.67±0.59
42	Southeast Island (Mahe)	1	54 ± 8	186 ± 8	272 ± 9				
43	South Georgia Astro	1	820 ± 8	-101 ±11	291 ±11				
46	Tokyo	1	183 ±10	-506 ± 9	-686 ± 9				
47	Tristan Astro 1968	1	654 ±14	-420 ±11	622 ±13				
49	Wake Island Astronomic 1952	1	-260 ± 7	67 ±12	-140 ± 8				
50	Yof Astro 1967 (Dakar)	1	55 ± 6	-143 ± 7	- 95 ± 7				
51	Palmer Astro 1969	1	-218 ± 9	- 8 ±12	-226 ±12				

*If (Datum - Geocenter) is sought add to the tabulated values of Δu, Δv, Δw the respective quantities -21m, -5 m, 2 m (see Table 5.4-6).

**ω, ψ, ε when positive, represent counterclockwise rotations about the respective w, v, u axes, as viewed from the end of the positive axis.

Table 5.5-1 (cont'd)

[1] See Table 3.1-3 for datum description and other related information.

[2] Stations included are Tromso (6006), Catania (6016), Hohenpeissenberg (6065), Wippolder (8009), Zimmerwald (8010), Haute Provence (8015), Nice (8019), Meudon (8030), San Fernando (9004), Dionysos (9091) and Harestua (9426).

[3] Stations included are as in #2 and Mashhad (6015), Malvern (8011), Naini Tal (9006), Shiraz (9008) and Riga (9431).

[4] Based on p. 70, Bulletin Geodesique, 107, 1973.

[5] Stations included are Goldstone (1030), Colorado Springs (3400), Vandenberg AFB (4280), Wrightwood II (6134), Moses Lake (6003), Edinburg (7036), Denver (704. and Organ Pass (9001).

[6] Stations included are Blossom Point (1021), Fort Myers (1022), E. Grand Forks (1034), Rosman (1042), Bedford (3401), Semmes (3402), Hunter AFB (3648), Aberdeen (3657), Homestead (3861), Beltsville (6002), Greenbelt (7043), Jupiter (7072) and Sudbury (7075).

[7] Stations included are as in #4 and #5 above.

[8] Stations included are Brasilia (3414), Asunction (3431), Bogota (3477), Paramaribe (6008), Quito (6009), Villa Dolores (6019), Natal (6067), Arequipa (9007), Curacao (9009) and Comodoro Rivadavia (9031).

Table 5.5-2

Transformation : Australian Datum - WN14

SCALE FACTOR AND ROTATION PARAMETERS CONSTRAINED

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
118.16	41.14	-120.95	-1.20	1.03	0.99	-0.25

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 =$ 0.48

0.2500D+02	0.375D+01	0.187D+01	0.207D-05	-0.254D-05	-0.141D-05	0.574D-06
0.375D+01	0.391D+02	0.189D+02	-0.197D-05	-0.414D-05	0.162D-05	0.457D-05
0.187D+01	0.189D+02	0.474D+02	0.124D-05	-0.214D-05	0.442D-05	0.588D-05
0.207D-05	-0.197D-05	0.124D-05	0.507D-12	0.335D-14	-0.155D-13	-0.457D-14
-0.254D-05	-0.414D-05	-0.214D-05	0.335D-14	0.765D-12	-0.148D-12	-0.408D-12
-0.141D-05	0.162D-05	0.442D-05	-0.155D-13	-0.148D-12	0.748D-12	0.379D-12
0.574D-06	0.457D-05	0.588D-05	-0.457D-14	-0.408D-12	0.379D-12	0.114D-11

COEFFICIENTS OF CORRELATION

0.100D+01	0.120D+00	0.542D-01	0.582D+00	-0.580D+00	-0.326D+00	0.107D+00
0.120D+00	0.100D+01	0.438D+00	-0.443D+00	-0.757D+00	0.300D+00	0.683D+00
0.542D-01	0.438D+00	0.100D+01	0.252D+00	-0.356D+00	0.743D+00	0.798D+00
0.582D+00	-0.443D+00	0.252D+00	0.100D+01	0.539D-02	-0.252D-01	-0.600D-02
-0.580D+00	-0.757D+00	-0.356D+00	0.539D-02	0.100D+01	-0.196D+00	-0.436D+00
-0.326D+00	0.300D+00	0.743D+00	-0.252D-01	-0.196D+00	0.100D+01	0.410D+00
0.107D+00	0.683D+00	0.798D+00	-0.600D-02	-0.436D+00	0.410D+00	0.100D+01

Table 5.5-2 (cont'd)

RESIDUALS V

	V1(WN14)				V2(AUST.)			V1 - V2		
6023	0.9	-0.4	-3.0	6023	-0.8	0.4	1.9	1.7	-0.8	-4.9
6032	1.0	1.2	0.7	6032	-0.9	-1.1	-0.5	1.9	2.3	1.2
6060	-1.9	-0.8	1.9	6060	1.7	0.7	-1.4	-3.6	-1.5	3.3

Table 5.5-3

Transformation : European 50 Datum (W) - WN14

SCALE FACTOR AND ROTATION PARAMETERS CONSTRAINED

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
133.27	114.18	152.20	-7.30	-1.76	0.01	-0.38

VARIANCE - COVARIANCE MATRIX

σ_0^2 = 0.64

0.895D+02	-0.147D+02	-0.172D+02	-0.550D-05	-0.281D-05	0.105D-04	0.146D-[illegible]
-0.147D+02	0.253D+03	-0.125D+02	-0.839D-06	0.238D-04	-0.606D-06	-0.293D-04
-0.172D+02	-0.125D+02	0.851D+02	-0.610D-05	-0.851D-06	-0.938D-05	0.281D-05
-0.550D-05	-0.839D-06	-0.610D-05	0.132D-11	0.420D-14	0.984D-15	-0.299D-14
-0.281D-05	0.238D-04	-0.851D-06	0.420D-14	0.344D-11	-0.121D-12	-0.207D-11
0.105D-04	-0.606D-06	-0.938D-05	0.984D-15	-0.121D-12	0.226D-11	0.229D-13
0.146D-05	-0.293D-04	0.281D-05	-0.299D-14	-0.207D-11	0.229D-13	0.447D-11

COEFFICIENTS OF CORRELATION

0.100D+01	-0.979D-01	-0.197D+00	-0.506D+00	-0.160D+00	0.738D+00	0.730D-01
-0.979D-01	0.100D+01	-0.854D-01	-0.459D-01	0.806D+00	-0.253D-01	-0.871D+00
-0.197D+00	-0.854D-01	0.100D+01	-0.576D+00	-0.497D-01	-0.676D+00	0.144D+00
-0.506D+00	-0.459D-01	-0.576D+00	0.100D+01	0.197D-02	0.570D-03	-0.123D-02
-0.160D+00	0.806D+00	-0.497D-01	0.197D-02	0.100D+01	-0.434D-01	-0.527D+00
0.738D+00	-0.253D-01	-0.676D+00	0.570D-03	-0.434D-01	0.100D+01	0.719D-02
0.730D-01	-0.871D+00	0.144D+00	-0.123D-02	-0.527D+00	0.719D-02	0.100D+01

Table 5.5-3 (cont'd)

RESIDUALS V

	V1(WN14)				V2(EU-50W)			V1 - V2		
6006	0.0	-0.7	0.3	6006	-1.7	21.4	-10.2	1.9	-22.1	10.6
6016	0.2	-0.8	-0.0	6016	-19.4	40.9	1.9	19.6	-41.7	-1.9
6065	0.1	-0.4	-0.1	6065	-5.1	16.6	4.4	5.2	-17.0	-4.4
8009	-3.2	0.0	0.3	8009	11.4	-0.1	-1.9	-14.6	0.1	2.2
8010	-1.3	1.0	0.9	8010	10.1	-3.7	-7.5	-11.4	4.7	8.3
8015	-0.1	2.6	-0.1	8015	1.9	-10.5	1.3	-2.1	13.2	-1.3
8019	-0.0	3.0	-0.1	8019	0.5	-12.2	1.9	-0.5	15.1	-2.0
8030	-1.5	4.7	0.2	8030	9.0	-12.8	-1.7	-10.5	17.4	2.0
9004	0.0	3.8	0.0	9004	-0.4	-9.8	-0.7	0.5	13.6	0.7
9091	0.3	7.7	-0.5	9091	-4.7	-18.6	7.1	5.0	26.3	-7.6
9426	·0.4	3.9	-0.7	9426	-1.5	-11.3	5.5	1.9	15.1	-6.2

Table 5.5-4

Transformation: European 50 Datum - WN14

SCALE FACTOR AND ROTATION PARAMETERS CONSTRAINED

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
134.32	152.68	144.60	-7.24	-0.41	0.27	-0.51

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 =$ 1.06

0.836D+02	0.548D+01	-0.289D+02	-0.308D-05	-0.265D-05	0.102D-04	-0.275D-05
0.548D+01	0.641D+02	-0.651D+01	-0.794D-06	0.372D-05	0.128D-05	-0.534D-05
-0.289D+02	-0.651D+01	0.769D+02	-0.357D-05	0.150D-05	-0.911D-05	0.349D-05
-0.308D-05	-0.794D-06	-0.357D-05	0.776D-12	-0.131D-15	0.423D-15	-0.273D-15
-0.265D-05	0.372D-05	0.150D-05	-0.131D-15	0.988D-12	-0.373D-12	0.308D-13
0.102D-04	0.128D-05	-0.911D-05	0.423D-15	-0.373D-12	0.216D-11	-0.596D-12
-0.275D-05	-0.534D-05	0.349D-05	-0.273D-15	0.308D-13	-0.596D-12	0.119D-11

COEFFICIENTS OF CORRELATION

0.100D+01	0.748D-01	-0.360D+00	-0.383D+00	-0.291D+00	0.762D+00	-0.276D+00
0.748D-01	0.100D+01	-0.927D-01	-0.113D+00	0.467D+00	0.109D+00	-0.612D+00
-0.360D+00	-0.927D-01	0.100D+01	-0.462D+00	0.172D+00	-0.706D+00	0.365D+00
-0.383D+00	-0.113D+00	-0.462D+00	0.100D+01	-0.149D-03	0.326D-03	-0.284D-03
-0.291D+00	0.467D+00	0.172D+00	-0.149D-03	0.100D+01	-0.255D+00	0.284D-01
0.762D+00	0.109D+00	-0.706D+00	0.326D-03	-0.255D+00	0.100D+01	-0.372D+00
-0.276D+00	-0.612D+00	0.365D+00	-0.284D-03	0.284D-01	-0.372D+00	0.100D+01

Table 5.5-4 (cont'd)

RESIDUALS V

	V1(WN14)				V2(EU-50)			V1 - V2		
6006	0.1	-1.4	0.4	6006	-3.9	41.5	-13.7	4.0	-42.8	14.1
6015	0.1	-0.0	0.2	6015	-14.2	3.5	-15.7	14.3	-3.6	15.9
6016	0.2	-0.9	-0.0	6016	-14.0	45.1	1.4	14.2	-46.0	-1.4
6065	0.1	-0.6	-0.1	6065	-4.3	24.3	3.0	4.3	-24.9	-3.1
8009	-2.5	-2.6	0.7	8009	9.0	6.6	-3.6	-11.5	-9.3	4.3
8010	-1.2	-0.5	1.0	8010	9.5	1.9	-8.8	-10.7	-2.4	9.8
8011	-0.9	13.7	0.4	8011	3.0	-17.2	-2.2	-3.9	31.0	2.7
8015	-0.1	1.5	-0.0	8015	1.0	-6.0	0.0	-1.1	7.6	-0.0
8019	-0.0	1.9	-0.1	8019	0.4	-7.6	0.7	-0.4	9.5	-0.8
8030	-1.0	2.6	0.4	8030	6.0	-7.2	-3.4	-6.9	9.8	3.9
9004	0.3	3.2	0.1	9004	-6.8	-8.2	-2.3	7.1	11.4	2.5
9006	-0.8	0.1	-0.1	9006	5.0	-2.0	2.0	-5.8	2.1	-2.1
9008	-0.4	0.4	0.7	9008	6.0	-7.9	-13.2	-6.4	8.4	13.9
9091	-0.3	5.8	-0.5	9091	4.7	-14.0	6.8	-5.0	19.8	-7.3
9426	0.9	0.2	-0.4	9426	-3.1	-0.6	3.2	4.0	0.8	-3.6
9431	-0.2	19.3	-5.6	9431	0.4	-56.3	29.3	-0.6	75.6	-35.0

Table 5.5-5

Transformation : NAD 1927 (W) - WN14

SCALE FACTOR AND ROTATION PARAMETERS CONSTRAINED

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
30.60	-170.28	-134.88	-7.91	0.21	0.59	-0.45

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 =$ 0.29

0.531D+02	0.528D+01	0.276D+02	0.285D-06	0.596D-05	0.569D-05	-0.392D-05
0.528D+01	0.207D+02	0.164D+02	0.985D-06	-0.251D-06	0.137D-05	-0.372D-05
0.276D+02	0.164D+02	0.461D+02	-0.830D-06	0.253D-05	0.462D-05	-0.691D-05
0.285D-06	0.985D-06	-0.830D-06	0.207D-12	-0.639D-14	-0.580D-14	0.102D-13
0.596D-05	-0.251D-06	0.253D-05	-0.639D-14	0.930D-12	0.395D-12	-0.382D-12
0.569D-05	0.137D-05	0.462D-05	-0.580D-14	0.395D-12	0.105D-11	-0.579D-12
-0.392D-05	-0.372D-05	-0.691D-05	0.102D-13	-0.382D-12	-0.579D-12	0.123D-11

COEFFICIENTS OF CORRELATION

0.100D+01	0.159D+00	0.557D+00	0.861D-01	0.848D+00	0.761D+00	-0.485D+00
0.159D+00	0.100D+01	0.532D+00	0.475D+00	-0.573D-01	0.294D+00	-0.736D+00
0.557D+00	0.532D+00	0.100D+01	-0.269D+00	0.387D+00	0.664D+00	-0.918D+00
0.861D-01	0.475D+00	-0.269D+00	0.100D+01	-0.146D-01	-0.124D-01	0.201D-01
0.848D+00	-0.573D-01	0.387D+00	-0.146D-01	0.100D+01	0.399D+00	-0.356D+00
0.761D+00	0.294D+00	0.664D+00	-0.124D-01	0.399D+00	0.100D+01	-0.508D+00
-0.485D+00	-0.736D+00	-0.918D+00	0.201D-01	-0.356D+00	-0.508D+00	0.100D+01

Table 5.5-5 (cont'd)

RESIDUALS V

	V1(WN14)				V2(NAD-27W)			V1 - V2		
1030	-0.9	0.4	1.6	1030	4.5	-1.4	-6.7	-5.4	1.8	8.3
3400	2.2	0.5	3.0	3400	-6.7	-2.6	-6.9	8.8	3.1	9.9
4280	0.1	-0.2	-0.9	4280	-0.7	1.1	4.0	0.8	-1.3	-4.9
6003	0.2	-0.2	-0.2	6003	-4.0	5.4	1.5	4.2	-5.6	-1.7
6134	0.2	-0.2	-0.6	6134	-2.7	1.9	5.1	2.9	-2.1	-5.7
7036	-0.1	-0.2	-0.9	7036	0.1	0.9	3.5	-0.2	-1.1	-4.4
7045	-1.2	0.5	0.0	7045	2.5	-1.7	-0.1	-3.7	2.2	0.2
9001	-0.2	0.1	0.5	9001	2.6	-2.3	-5.3	-2.8	2.4	5.8

Table 5.5-6

Transformation : NAD 1927 (E) - WN14

SCALE FACTOR AND ROTATION PARAMETERS CONSTRAINED

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
56.37	-144.64	-196.45	2.15	1.01	-0.01	0.54

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 = 0.76$

0.475D+02	0.587D+01	0.136D+01	-0.288D-06	0.581D-05	0.427D-05	-0.757D-06
0.587D+01	0.191D+02	0.116D+01	0.193D-05	0.106D-05	0.545D-06	-0.176D-05
0.136D+01	0.116D+01	0.188D+02	-0.142D-05	0.177D-06	-0.163D-06	-0.226D-05
-0.288D-06	0.193D-05	-0.142D-05	0.379D-12	0.130D-14	-0.194D-14	0.207D-15
0.581D-05	0.106D-05	0.177D-06	0.130D-14	0.866D-12	0.392D-12	-0.101D-12
0.427D-05	0.545D-06	-0.163D-06	-0.194D-14	0.392D-12	0.618D-12	-0.676D-13
-0.757D-06	-0.176D-05	-0.226D-05	0.207D-15	-0.101D-12	-0.676D-13	0.462D-12

COEFFICIENTS OF CORRELATION

0.100D+01	0.195D+00	0.455D-01	-0.679D-01	0.905D+00	0.788D+00	-0.162D+00
0.195D+00	0.100D+01	0.610D-01	0.717D+00	0.260D+00	0.159D+00	-0.592D+00
0.455D-01	0.610D-01	0.100D+01	-0.530D+00	0.439D-01	-0.477D-01	-0.768D+00
-0.679D-01	0.717D+00	-0.530D+00	0.100D+01	0.227D-02	-0.400D-02	0.495D-03
0.905D+00	0.260D+00	0.439D-01	0.227D-02	0.100D+01	0.535D+00	-0.159D+00
0.788D+00	0.159D+00	-0.477D-01	-0.400D-02	0.535D+00	0.100D+01	-0.126D+00
-0.162D+00	-0.592D+00	-0.768D+00	0.495D-03	-0.159D+00	-0.126D+00	0.100D+01

Table 5.5-6 (cont'd)

RESIDUALS V

	V1(WN14)				V2(NAD-27E)			V1 - V2		
1021	0.6	0.2	1.3	1021	-2.5	-0.9	-3.8	3.1	1.1	5.1
1022	0.1	0.8	0.5	1022	-0.6	-4.8	-2.6	0.7	5.6	3.1
1034	-3.2	1.2	0.5	1034	5.8	-3.5	-1.8	-9.0	4.6	2.3
1042	2.4	0.3	0.9	1042	-7.2	-1.2	-2.7	9.6	1.5	3.6
3401	1.6	-1.0	-1.0	3401	-6.7	3.7	2.9	8.3	-4.6	-3.9
3402	0.5	-0.5	0.4	3402	-0.8	1.5	-1.0	1.3	-2.0	1.4
3648	-1.2	0.4	1.5	3648	2.8	-1.7	-2.7	-4.0	2.1	4.1
3657	2.0	0.6	-0.4	3657	-7.2	-2.3	1.0	9.3	2.9	-1.4
3861	-1.4	-0.3	-0.0	3861	4.4	1.5	0.1	-5.8	-1.8	-0.1
6002	-0.2	-0.6	-0.9	6002	1.1	5.9	6.6	-1.3	-6.4	-7.5
7043	-0.2	-0.6	-0.9	7043	1.2	5.9	6.5	-1.3	-5.5	-7.4
7072	0.4	0.4	0.5	7072	-4.3	-4.4	-5.2	4.7	4.7	5.7
7075	-3.4	-1.2	-0.3	7075	7.8	3.6	1.0	-11.2	-4.9	-1.3

Table 5.5-7

Transformation : NAD 1927 - WN14

SCALE FACTOR AND ROTATION PARAMETERS CONSTRAINED

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
57.13	-147.90	-187.52	0.80	0.86	0.23	0.33

VARIANCE - COVARIANCE MATRIX

$\sigma_0^2 =$ 0.76

0.498D+01	0.529D+00	0.824D+00	-0.194D-07	0.421D-06	0.304D-06	-0.158D-06
0.529D+00	0.653D+01	0.294D+01	0.368D-06	0.449D-07	0.108D-06	-0.876D-06
0.824D+00	0.294D+01	0.836D+01	-0.275D-06	0.493D-07	0.138D-06	-0.119D-05
-0.194D-07	0.368D-06	-0.275D-06	0.734D-13	-0.200D-15	0.191D-16	0.262D-15
0.421D-06	0.449D-07	0.493D-07	-0.200D-15	0.771D-13	0.959D-14	-0.100D-13
0.304D-06	0.108D-06	0.138D-06	0.191D-16	0.959D-14	0.695D-13	-0.293D-13
-0.158D-06	-0.876D-06	-0.119D-05	0.262D-15	-0.100D-13	-0.293D-13	0.242D-12

COEFFICIENTS OF CORRELATION

0.100D+01	0.927D-01	0.128D+00	-0.320D-01	0.679D+00	0.517D+00	-0.144D+00
0.927D-01	0.100D+01	0.398D+00	0.532D+00	0.633D-01	0.160D+00	-0.697D+00
0.128D+00	0.398D+00	0.100D+01	-0.351D+00	0.614D-01	0.181D+00	-0.839D+00
-0.320D-01	0.532D+00	-0.351D+00	0.100D+01	-0.266D-02	0.267D-03	0.197D-02
0.679D+00	0.633D-01	0.614D-01	-0.266D-02	0.100D+01	0.131D+00	-0.733D-01
0.517D+00	0.160D+00	0.181D+00	0.267D-03	0.131D+00	0.100D+01	-0.226D+00
-0.144D+00	-0.697D+00	-0.839D+00	0.197D-02	-0.733D-01	-0.226D+00	0.100D+01

Table 5.5-7 (cont'd)

RESIDUALS V

	V1(WN14)				V2(NAD-27)			V1 - V2		
1021	0.9	0.2	1.3	1021	-3.7	-1.0	-3.8	4.6	1.2	5.1
1022	0.0	0.6	0.5	1022	-0.2	-3.3	-2.3	0.2	3.9	2.8
1030	-0.5	-0.4	1.5	1030	2.4	1.3	-6.2	-2.9	-1.7	7.7
1034	-2.9	1.7	1.2	1034	5.4	-5.0	-3.9	-8.4	6.7	5.0
1042	2.5	0.3	1.1	1042	-7.5	-0.9	-3.0	10.1	1.1	4.1
3400	0.5	0.5	2.2	3400	-1.6	-2.9	-5.1	2.2	3.4	7.3
3401	2.1	-0.8	-1.1	3401	-8.8	3.0	3.1	11.0	-3.8	-4.2
3402	0.2	-0.7	0.7	3402	-0.4	2.2	-1.6	0.6	-2.9	2.3
3648	-1.1	0.2	1.5	3648	2.6	-1.0	-2.7	-3.7	1.3	4.2
3657	2.4	0.6	-0.4	3657	-8.6	-2.5	1.0	11.1	3.1	-1.4
3861	-1.5	-0.7	-0.2	3861	4.7	3.0	0.6	-6.2	-3.7	-0.8
4280	1.0	-1.1	-0.9	4280	-4.7	5.6	4.0	5.7	-6.7	-5.0
6002	0.0	-0.5	-0.9	6002	-0.3	5.7	6.5	0.4	-6.2	-7.5
6003	0.0	-0.6	-0.9	6003	-0.7	18.4	6.8	0.7	-19.0	-7.6
6134	0.5	-0.5	-0.6	6134	-5.8	4.9	5.2	6.4	-5.4	-5.8
7036	-2.1	2.2	0.7	7036	4.3	-9.6	-0.7	-6.4	11.8	0.8
7043	0.0	-0.6	-0.9	7043	-0.3	5.8	6.4	0.3	-6.3	-7.4
7045	-3.5	0.5	-0.6	7045	7.4	-1.6	2.0	-10.9	2.1	-2.6
7072	0.4	0.2	0.4	7072	-4.1	-2.9	-4.7	4.5	3.1	5.1
7075	-2.8	-0.9	-0.1	7075	6.4	2.5	0.2	-9.2	-3.4	-0.3
9001	-0.3	0.4	0.6	9001	4.9	-6.6	-6.2	-5.3	6.9	6.8

Table 5.5-8

Transformation : South American 1969 Datum - WN14

SCALE FACTOR AND ROTATION PARAMETERS CONSTRAINED

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS

(USING VARIANCES ONLY)

DU METERS	DV METERS	DW METERS	DELTA (X1.D+6)	OMEGA SECONDS	PSI SECONDS	EPSILON SECONDS
54.37	29.98	42.92	6.67	-0.63	0.17	-0.12

VARIANCE - COVARIANCE MATRIX

$\sigma_o^2 =$ 0.97

0.298D+02	0.477D+01	0.188D+01	-0.990D-06	0.348D-05	-0.906D-06	-0.473D-07
0.477D+01	0.228D+02	0.262D+00	0.182D-05	0.188D-05	-0.225D-06	0.421D-06
0.188D+01	0.262D+00	0.236D+02	0.327D-06	0.275D-06	-0.128D-05	-0.208D-05
-0.990D-06	0.182D-05	0.327D-06	0.352D-12	0.128D-14	0.159D-14	0.252D-14
0.348D-05	0.188D-05	0.275D-06	0.128D-14	0.657D-12	-0.103D-12	0.463D-14
-0.906D-06	-0.225D-06	-0.128D-05	0.159D-14	-0.103D-12	0.240D-12	0.585D-13
-0.473D-07	0.421D-06	-0.208D-05	0.252D-14	0.463D-14	0.585D-13	0.[illegible]73D-12

COEFFICIENTS OF CORRELATION

0.100D+01	0.183D+00	0.708D-01	-0.306D+00	0.787D+00	-0.285D+00	-0.142D-01
0.183D+00	0.100D+01	0.113D-01	0.641D+00	0.487D+00	-0.807D-01	0.144D+00
0.708D-01	0.113D-01	0.100D+01	0.114D+00	0.698D-01	-0.450D+00	-0.702D+00
-0.306D+00	0.641D+00	0.114D+00	0.100D+01	0.266D-02	0.458D-02	0.696D-02
0.787D+00	0.487D+00	0.698D-01	0.266D-02	0.100D+01	-0.219D+00	0.934D-02
-0.285D+00	-0.807D-01	-0.450D+00	0.458D-02	-0.219D+00	0.100D+01	0.164D+00
-0.142D-01	0.144D+00	-0.702D+00	0.696D-02	0.934D-02	0.164D+00	0.100D+01

Table 5.5-8 (cont'd)

RESIDUALS V

	V1(WN14)				V2(SA-1969)			V1 - V2		
3414	3.9	-1.1	6.0	3414	-1.7	0.7	-2.8	5.6	-1.8	8.8
3431	-1.3	2.5	0.0	3431	1.4	-3.8	-0.0	-2.7	6.3	0.1
3477	16.8	2.2	14.1	3477	-10.3	-3.2	-9.9	27.1	5.5	24.1
6008	0.1	0.3	1.9	6008	-1.0	-5.1	-14.4	1.0	5.4	16.3
6009	-1.9	-1.0	-1.8	6009	9.5	5.7	6.7	-11.3	-6.7	-8.5
6019	-0.2	-0.2	-0.6	6019	2.3	2.0	3.6	-2.5	-2.2	-4.4
6067	-0.2	-0.5	-0.9	6067	2.9	7.0	8.2	-3.1	-7.5	-9.1
9007	1.0	0.4	-1.1	9007	-10.6	-2.8	3.7	11.6	3.1	-4.8
9009	-0.4	0.0	-1.9	9009	4.8	-0.4	10.6	-5.3	0.4	-12.5
9031	-5.7	1.6	2.4	9031	5.3	-1.3	-1.3	-11.0	2.9	3.7

6. SUMMARY AND CONCLUSIONS

The OSU WN14 solution is a geometric adjustment for the coordinates of 158 tracking stations.

The coordinate system in which the coordinates are presented is oriented towards the Greenwich Mean Astronomical Meridian (u axis) and the Conventional International Origin (w axis), as both defined by the Bureau International de l'Heure. The v axis forms a right-handed system with u and w, and with the former defines the average geodetic equator. The coordinates of the origin with respect to the geocenter are suggested to be $u^o_{WN14} = -21$ m, $v^o_{WN14} = -5$ m, $w^o_{WN14} = 2$ m.

The scale in the solution is defined through SECOR observations and weighted height constraints. Chord distances derived from C-Band radar observations and from electronic distance measurements (geodimeter and tellurometer) are also included as weighted constraints, but they seem to have very little or no effect. The main reason that the SECOR observations are successfully utilized (perhaps for the first time) is that the ill-conditioning arising in quadrilateration when the four stations lie near a plane (which is always the case with SECOR) is eliminated by "pinning down" the stations to the geoid through the height constraints and the directions defined by the optical observations from the collocated stations.

The scale in the solution is such that when the coordinates are transformed to a geocentric rotational ellipsoid of a = 6 378 142 m and 1/f = 298.25, they produce geoid undulations consistent with dynamically determined ones with $k^2M = 3.9860092 \times 10^{14} m^3 sec^{-2}$ and $\gamma_e = 978.0326$ cm sec^{-2}.

The consistency of the solution is represented by the average standard deviation in a Cartesian coordinate of ±3.9 m, and in height of ±2.9 m. The correlations between the coordinates of a given station and those between different stations are low, except at those nearby stations where the relative positions are maintained at the surveyed values with weighted constraints.

Comparisons with the EDM chords show an average agreement of 1:575,000, with 1:2,700,000 at best and 1:330,000 at worst. The average agreement with the C-Band chords is 1:1,000,000, varying between 1:2,100,000 and 1:525,000. The scale agreement with the dynamic solutions on the average is 1:3,600,000, with 1:1,000,000 at worst and 1:5,900,000 at best.

Comparisons with coordinates from dynamic satellite solutions show significant inconsistencies in the orientation of the coordinate systems which need to be resolved. The residuals after transformation are all within the noise level.

Table 6.1 is a summary of the Cartesian coordinates from solutions WN12 and WN14. As mentioned earlier the former differs from the latter only in that in it the heights are not constrained. The scale in WN12 is such that when the coordinates are transformed to a geocentric rotational ellipsoid of a = 6 378 154 m and 1/f = 298.25, they produce geoid undulations consistent with dynamically determined ones with $k^2M = 3.9860089 \times 10^{14}\ m^3\ sec^{-2}$ and $\gamma_e = 978.0285\ cm\ sec^{-2}$. For various comparisons between solutions WN12 and WN14 see Tables 5.3-1, 5.3-2 and 5.3-4.

Comparisons with geoid undulations from satellite and surface gravimetric solutions in case of the WN14 solution show an rms residual of ±6.1, with an average of only -0.3 m. Similar comparison with the WN12 solution, where the heights are not constrained, shows that the rms of the residuals is ±16.1 m, and the average -0.2 m.

Comparisons with survey coordinates result in satisfactory transformation parameters for the NAD-1927, the Australian and the South American 1969 datums, and marginal ones for the European 1950 datum.

In order to fulfill the "three station per datum" general requirement for the other major datum blocks, additional observations are needed from Europe, the Soviet Union, India, Japan, the Philippines, South Africa, Madagascar, New Zealand and North Africa, in order of preference.

Table 6-1

Summary of Cartesian Coordinates (Solutions WN12 and WN14)

STATION		SOLUTION WN-12						SOLUTION WN-14					
NO	NAME	U	V	W	σ_u	σ_v	σ_w	U	V	W	σ_u	σ_v	σ_w
1021	BLOSSOM POINT	1118021.8	-4876331.7	3942970.9	3.1	4.0	4.2	1118023.1	-4876323.4	3942963.9	2.8	2.6	2.8
1022	FORT MYERS	807850.8	-5652004.0	2833509.0	2.6	3.3	3.3	807851.9	-5651989.6	2833500.2	2.2	1.9	2.3
1030	GOLDSTONE	-2357249.2	-4646346.4	3668312.5	6.1	4.4	4.7	-2357242.9	-4646338.5	3668306.8	5.6	3.3	3.2
1032	ST. JOHN'S	2602704.3	-3419179.7	4697621.1	49.1	89.5	29.9	2602688.6	-3419228.9	4697637.3	39.3	46.7	13.8
1033	FAIRBANKS	-2299292.3	-1445690.5	5751823.3	7.5	10.0	10.5	-2299282.6	-1445693.7	5751811.6	6.9	9.7	5.7
1034	E. GRAND FORKS	-521708.3	-4242074.9	4718726.5	3.5	4.0	4.4	-521704.5	-4242064.3	4718716.8	3.1	3.0	2.7
1042	ROSMAN	647495.9	-5177948.0	3656714.4	3.1	3.6	4.0	647497.5	-5177935.6	3656705.9	2.8	2.4	2.8
3106	ANTIGUA	2881840.5	-5372180.7	1868548.5	4.1	4.6	4.9	2881838.3	-5372164.6	1868538.6	3.7	3.3	4.3
3334	STONEVILLE	-84969.1	-5327986.3	3493434.3	15.6	14.0	10.8	-84963.8	-5327974.9	3493428.3	13.6	6.8	9.0
3400	COLORADO SPRINGS	-1275239.4	-4798062.9	3994279.5	16.3	12.4	8.6	-1275207.2	-4798029.3	3994208.3	9.1	5.1	5.7
3401	BEDFORD	1513134.8	-4463580.1	4283061.2	3.5	5.3	4.6	1513136.1	-4463576.8	4283055.8	3.2	3.4	3.0
3402	SEMMES	167256.1	-5481980.4	3245042.6	4.2	4.3	4.6	167259.7	-5481971.0	3245037.0	3.9	2.8	3.5
3404	SWAN ISLAND	642485.7	-6053942.4	1895690.5	5.0	5.3	5.5	642491.4	-6053940.3	1895688.6	4.7	3.7	4.9
3405	GRAND TURK	1919482.1	-5621096.5	2315780.1	3.6	5.6	4.9	1919482.9	-5621088.1	2315775.3	3.3	3.5	4.0
3406	CURACAO	2251802.9	-5816929.0	1327197.4	2.8	3.5	3.8	2251800.2	-5816912.9	1327191.1	2.4	2.1	3.4
3407	TRINIDAD	2979892.9	-5513532.6	1181126.8	5.2	5.1	5.9	2979891.1	-5513530.9	1181129.3	4.7	3.4	5.3
3413	NATAL	5186366.4	-3654725.1	-653022.7	3.4	2.9	3.2	5186348.4	-3654722.4	-653018.9	2.1	2.2	2.7
3414	BRASILIA	4114987.8	-4554148.5	-1732166.1	9.9	8.4	7.9	4114977.8	-4554142.5	-1732154.0	7.7	6.1	7.2
3431	ASUNCION	3093056.1	-4870100.4	-2710845.8	8.5	9.3	12.5	3093045.4	-4870081.7	-2710823.0	7.6	6.5	10.8
3476	PARAMARIBO	3623293.6	-5214213.7	601514.0	3.4	3.3	3.6	3623277.3	-5214210.7	601515.3	2.2	2.0	3.0
3477	BOGOTA	1744649.6	-6114305.6	532205.2	10.4	13.7	9.8	1744650.2	-6114286.7	532208.6	10.2	6.6	9.6
3478	MANAUS	3185765.4	-5514574.5	-347713.2	19.3	35.4	35.8	3185777.0	-5514585.9	-347703.2	18.7	14.5	35.1
3499	QUITO	1280834.0	-6250966.2	-10805.5	3.8	5.9	4.5	1280834.2	-6250955.9	-10800.6	3.6	3.4	4.1
3648	HUNTER AFB	832562.6	-5349553.4	3360596.4	4.1	5.0	5.4	832566.2	-5349540.7	3360585.3	3.6	2.5	3.6
3657	ABERDEEN	1186786.1	-4785205.1	4032892.3	3.4	5.0	4.5	1186787.1	-4785193.1	4032882.3	3.1	3.0	3.0
3661	HOMESTEAD	961766.7	-5679170.6	2729893.8	3.3	3.8	3.7	961767.9	-5679156.6	2729883.5	3.0	2.3	2.6
3902	CHEYENNE	-1234689.4	-4651235.9	4174763.4	28.6	32.1	11.3	-1234700.7	-4651242.8	4174758.6	8.6	6.3	6.3
3903	HERNDON	1068960.0	-4842973.2	3991763.9	17.3	15.5	11.4	1068989.7	-4843005.4	3991776.6	12.1	8.5	8.9
4050	PRETORIA	5051614.8	2726608.6	-2774181.0	4.4	3.8	5.5	5051608.1	2726603.3	-2774166.8	3.2	3.2	4.4
4061	ANTIGUA	2881594.5	-5372540.2	1868034.3	4.2	4.7	5.0	2881592.3	-5372523.9	1868024.4	3.8	3.5	4.3
4081	GRAND TURK	1920409.9	-5619426.1	2319133.4	3.7	5.7	5.0	1920410.9	-5619417.8	2319128.5	3.3	3.6	4.0
4082	MERRITT ISLAND	910567.9	-5539130.2	3017974.8	2.9	3.8	3.7	910567.2	-5539113.2	3017965.3	2.6	2.4	2.8
4280	VANDENBERG AFB	-2671883.7	-4521217.3	3607495.0	4.3	4.4	4.8	-2671873.8	-4521210.5	3607490.4	3.8	3.3	3.6
4740	BERMUDA	2308888.6	-4874314.8	3393092.0	3.8	5.4	5.1	2308887.3	-4874298.2	3393082.1	3.3	3.1	3.8
5001	HERNDON	1088874.4	-4842954.9	3991857.8	4.9	10.2	7.9	1088849.4	-4842948.7	3991840.2	3.6	3.0	3.7
5201	MOSES LAKE	-2127810.4	-3785912.3	4656011.9	2.7	2.8	3.7	-2127802.2	-3785911.5	4656012.1	2.3	2.2	2.4
5410	MIDWAY ISLANDS	-5618764.5	-258231.5	2997243.8	2.9	3.2	4.1	-5618754.1	-258237.5	2997250.2	2.3	2.8	3.6
5648	FORT STEWART	794687.3	-5360063.7	3353093.5	4.2	5.0	5.5	794691.0	-5360051.1	3353082.4	3.6	2.5	3.6
5712	PARAMARIBO	3623307.1	-5214190.5	601672.3	3.4	3.3	3.6	3623289.8	-5214188.0	601673.2	2.1	2.0	2.9
5713	TERCEIRA	4433654.4	-2268159.2	3971673.1	2.7	2.8	3.8	4433637.8	-2268153.2	3971656.8	2.0	2.2	2.5

Table 6-1 (cont'd)

STATION		SOLUTION WN-12						SOLUTION WN-14					
NO	NAME	U	V	W	σ_u	σ_v	σ_w	U	V	W	σ_u	σ_v	σ_w
5715	DAKAR	5884479.9	-1853580.1	1612763.8	2.3	2.5	3.1	5884468.8	-1853580.1	1612760.1	1.6	2.0	2.3
5717	FORT LAMY	6023416.1	1617949.5	1331651.2	2.7	2.8	3.3	6023410.7	1617946.5	1331655.8	2.0	2.0	2.7
5720	ADDIS ABABA	4900750.1	3968255.1	966348.3	2.7	2.9	3.4	4900749.1	3968253.0	966354.7	2.0	2.1	2.9
5721	MASHHAD	2604406.6	4444124.9	3750345.7	2.6	2.8	3.5	2604404.8	4444122.3	3750344.3	2.1	2.1	2.7
5722	DIEGO GARCIA	1905122.3	6032294.5	-810776.4	4.2	5.5	4.8	1905127.0	6032287.5	-810716.2	3.5	4.1	4.3
5723	CHIANG MAI	-941713.7	5967448.6	2039317.5	3.1	3.3	4.1	-941709.4	5967445.0	2039322.9	2.5	2.3	3.5
5726	ZAMBOANGA	-3361953.2	5365845.5	763623.6	3.0	3.3	3.8	-3361946.8	5365837.0	763627.8	2.3	2.2	3.2
5730	WAKE ISLAND	-5858583.8	1394474.9	2093844.7	2.8	3.1	3.8	-5858574.6	1394467.2	2093847.4	2.1	2.5	3.1
5732	PAGO PAGO	-6099984.0	-997345.6	-1568577.0	5.7	4.4	4.9	-6099970.5	-997355.3	-1568570.9	3.6	3.5	4.1
5733	CHRISTMAS ISLAND	-5885350.8	-2448375.3	221663.1	4.4	3.5	4.6	-5885333.9	-2448380.4	221670.7	2.7	2.9	3.9
5734	SHEMYA	-3851808.1	396416.1	5051343.3	3.2	3.7	4.9	-3851799.0	396409.3	5051342.0	2.7	3.3	3.9
5735	NATAL	5186360.5	-3654226.0	-653022.6	3.3	2.8	3.1	5186350.6	-3654223.7	-653018.9	2.0	2.1	2.5
5736	ASCENSION ISLAND	6118355.5	-1571763.1	-878558.4	3.3	2.9	3.3	6118340.3	-1571761.9	-878553.6	2.3	2.2	2.7
5739	TERCEIRA	4433646.0	-2268192.2	3971663.3	2.7	2.8	3.8	4433629.3	-2268186.2	3971647.0	2.0	2.2	2.5
5744	CATANIA	4896444.1	1316129.4	3856628.4	2.4	2.8	3.2	4896437.7	1316125.0	3856626.2	1.8	2.2	2.3
5907	WORTHINGTON	-449391.6	-4600910.6	4380315.4	5.8	13.8	13.5	-449417.5	-4600905.5	4380288.1	4.2	3.2	4.5
5911	BERMUDA	2308010.4	-4873778.3	3394476.1	3.6	4.9	5.2	2307991.2	-4873773.2	3394463.4	2.6	2.3	3.0
5912	PANAMA	1142664.4	-6196104.1	988340.8	4.8	9.1	7.0	1142644.5	-6196109.1	988336.6	3.1	3.4	4.1
5914	PUERTO RICO	2349423.9	-5576023.2	2010340.5	13.5	21.1	9.7	2349456.9	-5576027.1	2010342.6	10.5	7.0	6.4
5915	AUSTIN	-744066.7	-5465234.3	3192485.8	5.6	15.3	12.8	-744091.1	-5465238.7	3192467.4	3.8	3.8	4.7
5923	CYPRUS	4363335.9	2862256.6	3655380.7	2.5	2.7	3.3	4363332.2	2862254.9	3655380.7	1.9	2.1	2.4
5924	ROTA	5093565.8	-565319.1	3784273.1	2.4	3.1	3.8	5093556.2	-565372.3	3784268.3	1.9	2.6	2.9
5925	ROBERTS FIELD	6237376.8	-1140741.8	687740.0	3.0	3.1	3.6	6237366.3	-1140241.5	687740.2	2.3	2.6	3.0
5930	SINGAPORE	-1542556.4	6186964.6	151627.8	3.3	3.9	4.0	-1542549.4	6186956.7	151833.8	2.6	2.7	3.4
5931	HONG KONG	-2423919.1	5388254.6	2394863.9	3.1	3.5	4.3	-2423914.9	5388250.3	2394869.2	2.5	2.5	3.6
5933	DARWIN	-4071578.3	4714267.0	-1366533.3	4.3	4.4	4.3	-4071568.4	4714253.3	-1366528.3	3.2	3.2	3.7
5934	MANUS	-5367671.7	3437881.4	-225419.4	3.6	3.5	3.8	-5367663.1	3437869.9	-225416.0	2.5	2.5	3.3
5935	GUAM	-5059832.6	3591194.2	1472759.4	2.9	3.0	3.4	-5059825.7	3591186.0	1472762.5	2.1	2.2	2.8
5937	PALAU	-4433470.5	4512939.3	809955.3	3.1	3.2	3.7	-4433463.6	4512930.3	809958.7	2.2	2.2	3.2
5938	GUADALCANAL	-5915106.0	2146873.2	-1037912.8	4.4	3.9	4.0	-5915096.5	2146860.8	-1037909.5	3.0	3.0	3.5
5941	MAUI	-5467771.9	-2381242.7	2254024.0	3.5	3.2	4.4	-5467757.3	-2381246.7	2254033.8	2.5	2.8	3.8
6001	THULE	546566.4	-1389493.6	6180242.4	2.7	2.7	4.4	546568.7	-1389993.7	6180236.7	2.6	2.4	3.4
6002	BELTSVILLE	1130762.7	-4830837.6	3994709.9	2.2	2.7	3.1	1130764.9	-4830831.9	3994704.0	2.0	1.7	1.9
6003	MOSES LAKE	-2127839.9	-3785864.2	4656037.4	2.5	2.7	3.5	-2127832.1	-3785863.0	4656037.2	2.1	2.0	2.3
6004	SHEMYA	-3851806.8	396416.1	5051341.7	3.2	3.7	5.0	-3851797.5	396409.4	5051340.5	2.7	3.3	3.9
6006	TROMSO	2102930.3	721674.1	5958181.7	2.7	3.3	4.4	2102927.4	721668.5	5958180.8	2.4	2.9	2.9
6007	TERCEIRA	4433653.3	-2268156.9	3971671.0	2.7	2.7	3.8	4433637.3	-2268151.4	3971655.0	2.0	2.2	2.5
6008	PARAMARIBO	3623257.3	-5214236.7	601534.8	3.4	3.3	3.6	3623241.0	-5214233.7	601536.1	2.1	2.0	2.9
6009	QUITO	1280834.0	-6250966.2	-10805.5	3.8	5.9	4.5	1280834.2	-6250955.9	-10800.6	3.6	3.4	4.1
6011	MAUI	-5466039.2	-2404429.3	2242224.6	4.4	3.4	3.9	-5466018.6	-2404431.5	2242224.4	3.0	2.9	3.3

Table 6-1 (cont'd)

STATION		SOLUTION WN-12						SOLUTION WN-14					
NO	NAME	U	V	W	σ_u	σ_v	σ_w	U	V	W	σ_u	σ_v	σ_w
6012	WAKE ISLAND I	-5858578.8	1394516.4	2093817.4	2.9	3.2	3.8	-5858569.3	1394508.7	2093820.3	2.1	2.6	3.2
6013	KANOYA	-3565901.4	4120723.2	3303426.9	4.0	5.2	5.9	-3565892.8	4120713.6	3303428.3	3.3	4.4	4.9
6015	MASHHAD	2604355.4	4444169.2	3750321.7	2.6	2.9	3.5	2604353.3	4444166.0	3750320.5	2.1	2.2	2.6
6016	CATANIA	4896394.6	1316176.2	3856670.7	2.4	2.8	3.2	4896388.3	1316172.1	3856668.2	1.8	2.2	2.2
6019	VILLA DOLORES	2280630.7	-4914547.7	-3355417.9	2.7	3.6	5.2	2280627.1	-4914543.2	-3355402.8	2.4	2.7	3.7
6020	EASTER ISLAND	-1888621.5	-5354898.4	-2895762.3	6.0	6.1	6.9	-1888614.3	-5354894.4	-2895749.0	5.4	4.5	5.5
6022	TUTUILA	-6099975.9	-997357.7	-1568593.6	4.8	3.9	5.2	-6099961.7	-997362.2	-1568585.5	3.4	3.6	4.7
6023	THURSDAY ISLAND	-4955391.2	3842255.7	-1163855.5	4.5	3.9	4.7	-4955386.8	3842247.8	-1163847.4	3.2	3.0	4.0
6031	INVERCARGILL	-4313830.4	891340.6	-4597277.7	4.4	4.2	5.3	-4313825.3	891333.9	-4597265.8	3.4	3.9	3.8
6032	CAVERSHAM	-2375426.0	4875557.6	-3345424.5	3.7	4.3	5.0	-2375420.6	4875546.7	-3345411.1	3.3	3.2	3.9
6038	SOCORRO ISLAND	-2160989.6	-5642717.9	2035368.0	2.9	3.8	4.4	-2160980.9	-5642710.5	2035367.8	2.5	2.8	3.8
6039	PITCAIRN ISLAND	-3724775.0	-4421234.4	-2686094.4	7.9	7.2	7.3	-3724765.9	-4421237.6	-2686084.7	6.2	5.4	5.5
6040	COCOS ISLAND	-741986.1	6190803.6	-1338557.1	4.7	4.8	4.7	-741981.7	6190792.9	-1338546.3	4.5	3.7	4.2
6042	ADDIS ABABA	4900752.0	3968255.1	966318.9	2.7	2.9	3.4	4900750.7	3968252.7	966325.3	2.0	2.1	2.9
6043	CERRO SOMBRERO	1371376.5	-3614750.6	-5055947.1	3.5	4.2	7.0	1371375.9	-3614750.3	-5055927.8	3.3	3.8	4.8
6044	HEARD ISLAND	1098898.5	3684617.0	-5071900.1	6.9	6.7	11.1	1098897.9	3684606.6	-5071873.1	6.8	6.2	7.8
6045	MAURITIUS	3223434.7	5045343.6	-2191818.0	3.6	4.0	4.6	3223432.0	5045336.3	-2191805.7	3.2	3.1	3.9
6047	ZAMBOANGA	-3361983.5	5365820.6	763620.5	3.1	3.4	3.9	-3361976.9	5365811.9	763624.7	2.4	2.3	3.2
6050	PALMER STATION	1192679.3	-2451013.2	-5747052.4	5.0	6.3	9.8	1192678.8	-2451015.6	-5747034.2	4.9	6.1	6.1
6051	MAWSON STATION	1111337.1	2169270.2	-5874355.2	5.0	4.2	7.3	1111336.1	2169262.7	-5874334.1	4.9	3.7	4.4
6052	WILKES STATION	-902611.4	2409530.0	-5816569.9	4.6	4.4	7.4	-902608.8	2409522.1	-5816551.8	4.4	4.0	5.4
6053	MCMURDO STATION	-1310854.8	311262.9	-6213294.3	4.8	4.8	7.4	-1310852.3	311257.5	-6213276.5	4.6	4.5	4.3
6055	ASCENSION ISLAND	6118349.3	-1571749.2	-878601.3	3.3	2.9	3.4	6118334.2	-1571748.3	-878596.5	2.3	2.3	2.8
6059	CHRISTMAS ISLAND	-5885350.2	-2448374.4	221663.6	4.3	3.4	4.5	-5885333.5	-2448379.0	221671.1	2.7	2.9	3.8
6060	CULGOORA	-4751655.0	2792065.7	-3200174.2	4.5	4.0	4.7	-4751650.0	2792058.1	-3200164.0	3.3	3.3	3.7
6061	SOUTH GEORGIA IS.	2999921.2	-2219366.3	-5155267.1	3.9	5.9	7.8	2999915.6	-2219369.3	-5155246.0	3.7	5.7	5.3
6063	DAKAR	5884479.3	-1853496.4	1612858.7	2.4	2.6	3.2	5884467.4	-1853495.8	1612855.1	1.7	2.1	2.5
6064	FORT LAMY	6023394.4	1617934.2	1331731.7	3.3	3.1	3.7	6023386.7	1617931.9	1331733.2	2.7	2.6	3.2
6065	HOHENPEISSENBERG	4213570.2	820833.7	4702786.5	2.6	3.0	3.6	4213564.6	820830.0	4702784.4	2.0	2.4	2.3
6066	WAKE ISLAND II	-5858580.7	1394474.0	2093843.0	2.9	3.2	3.8	-5858571.2	1394466.4	2093846.0	2.1	2.6	3.2
6067	NATAL	5186415.0	-3652935.9	-654280.7	3.3	2.8	3.1	5186397.1	-3653933.3	-654276.9	2.1	2.2	2.6
6068	JOHANNESBURG	5084837.1	2670346.5	-2768109.3	4.2	3.5	5.3	5084830.4	2670341.2	-2768095.2	3.0	2.9	4.2
6069	TRISTAN DA CUNHA	4978430.9	-1086871.1	-3823187.7	8.3	6.6	10.4	4978421.7	-1086874.0	-3823167.8	6.5	6.4	8.1
6072	CHIANG MAI	-941707.8	5967462.5	2039307.4	5.9	5.1	4.9	-941702.1	5967455.1	2039311.6	5.[illegible]	4.0	4.3
6073	DIEGO GARCIA	1905134.3	6032292.0	-810742.3	3.7	4.8	4.7	1905134.1	6032282.4	-810732.7	3.4	3.7	4.2
6075	MAHE	3602824.5	5238248.2	-515957.7	4.2	4.6	4.5	3602820.6	5238240.7	-515948.3	3.8	3.6	4.0
6078	PORT VILA	-5952307.7	1231910.5	-1925983.7	19.9	9.4	16.6	-5952303.4	1231904.9	-1925972.5	9.7	8.0	12.4
6111	WRIGHTWOOD I	-2448862.8	-4667992.3	3582759.4	3.0	3.2	3.8	-2448853.3	-4667985.8	3582754.9	2.6	2.1	2.4
6123	POINT BARROW	-1881807.4	-812435.3	6019599.3	4.9	4.6	7.1	-1881799.4	-812439.0	6019590.7	4.6	4.4	4.5
6134	WRIGHTWOOD II	-2448916.5	-4668082.4	3582454.1	3.0	3.2	3.8	-2448907.0	-4668075.9	3582449.6	2.6	2.1	2.4

Table 6-1 (cont'd)

STATION		SOLUTION WN-12						SOLUTION WN-14					
NO	NAME	U	V	W	σ_u	σ_v	σ_w	U	V	W	σ_u	σ_v	σ_w
7036	EDINBURG	-828491.0	-5657486.5	2816825.5	3.8	3.9	4.0	-828487.0	-5657471.3	2816816.0	3.5	2.4	2.9
7037	COLUMBIA	-191294.8	-4967308.3	3983264.5	3.2	3.5	3.9	-191291.0	-4967293.9	3983252.6	2.9	2.2	2.4
7039	BERMUDA	2308214.8	-4873614.8	3394568.4	3.7	5.3	5.0	2308213.4	-4873598.3	3394558.5	3.3	3.1	3.6
7040	SAN JUAN	2465050.9	-5534945.5	1985522.2	4.0	4.4	4.7	2465049.5	-5534930.0	1985513.1	3.7	3.2	4.0
7043	GREENBELT	1130706.5	-4831337.2	3994141.4	2.2	2.7	3.1	1130708.6	-4831331.3	3994135.5	2.0	1.7	1.9
7045	DENVER	-1240475.1	-4760256.0	4048997.8	4.6	4.2	4.7	-1240470.2	-4760242.1	4048985.3	4.2	2.8	2.9
7072	JUPITER	976261.3	-5601416.4	2880251.4	2.5	3.3	3.3	976261.3	-5601399.9	2880241.9	2.2	1.8	2.3
7075	SUDBURY	692618.7	-4347090.4	4600487.7	4.0	5.7	5.4	692620.7	-4347076.5	4600475.4	3.7	3.8	3.4
7076	KINGSTON	1384159.2	-5905680.0	1966554.4	4.3	5.8	5.9	1384158.7	-5905662.0	1966545.7	4.1	4.4	5.3
8009	WIPPOLDER	3923429.9	299866.1	5003013.3	13.3	13.1	15.2	3923397.4	299869.4	5002975.5	8.5	10.1	6.9
8010	ZIMMERWALD	4331312.7	567499.7	4633118.9	7.9	10.9	11.5	4331307.0	567490.8	4633106.3	5.7	8.3	5.4
8011	MALVERN	3920186.9	-134806.7	5017776.2	12.8	16.5	15.5	3920153.5	-134804.5	5012734.8	8.9	14.3	6.9
8015	HAUTE PROVENCE	4578328.1	457945.6	4403204.8	6.4	10.7	10.2	4578322.1	457936.5	4403195.3	4.2	8.0	4.4
8019	NICE	4579469.1	586582.7	4386428.4	6.3	10.6	10.1	4579463.2	586573.5	4386419.2	4.1	7.9	4.3
8030	MEUDON	4205629.1	163695.4	4776550.9	9.0	12.3	11.8	4205626.9	163683.4	4776540.6	6.5	9.7	5.8
9001	ORGAN PASS	-1535755.1	-5167026.6	3401047.1	4.6	3.9	3.8	-1535750.7	-5167014.4	3401039.4	4.2	2.8	2.7
9002	OLIFANTSFONTEIN	5056115.1	2716514.0	-2775782.9	4.2	3.6	5.3	5056108.4	2716508.7	-2775768.8	3.0	3.0	4.2
9004	SAN FERNANDO	5105589.8	-555269.7	3769685.6	6.3	12.9	8.5	5105581.5	-555271.5	3769676.0	3.4	10.0	4.0
9005	TOKYO	-3946751.4	3366303.2	3698890.3	11.2	10.3	9.8	-3946730.5	3366286.1	3698822.9	9.2	9.0	7.5
9006	NAINI TAL	1018153.3	5471119.3	3109622.2	14.2	10.9	9.6	1018164.5	5471108.7	3109625.6	12.4	5.5	6.0
9007	AREQUIPA	1942762.4	-5804101.6	-1796905.8	2.8	4.0	5.3	1942760.9	-5804088.2	-1796900.9	2.5	2.9	4.4
9008	SHIRAZ	3376872.6	4403980.0	3136250.1	8.1	10.3	9.5	3376875.2	4403976.2	3136257.3	6.8	6.1	6.1
9009	CURACAO	2251813.5	-5816933.6	1327169.7	2.8	3.5	3.8	2251810.7	-5816917.6	1327163.4	2.4	2.1	3.4
9010	JUPITER	976276.2	-5601418.8	2880244.0	2.5	3.3	3.3	976276.2	-5601402.2	2880234.5	2.1	1.8	2.3
9011	VILLA DOLORES	2280578.9	-4914584.8	-3355398.8	2.7	3.6	5.3	2280575.3	-4914580.2	-3355383.7	2.4	2.7	3.7
9012	MAUI	-5466088.5	-2404310.5	2242188.7	4.5	3.4	3.9	-5466067.8	-2404312.7	2242186.4	3.0	2.9	3.3
9021	MOUNT HOPKINS	-1936799.1	-5077719.4	3331926.1	7.3	6.8	6.4	-1936789.3	-5077714.7	3331922.7	7.1	5.3	5.3
9028	ADDIS ABABA	4903727.7	3965208.6	963853.2	2.8	2.9	3.4	4903726.6	3965206.3	963859.6	2.1	2.1	2.9
9029	NATAL	5186459.3	-3653874.6	-654317.9	3.4	2.9	3.2	5186441.4	-3653871.9	-654314.1	2.1	2.2	2.7
9031	COMODORO R'DAVIA	1693795.5	-4112354.3	-4556644.1	8.4	9.4	14.3	1693797.3	-4112353.1	-4556622.0	8.3	8.8	11.2
9051	ATHENS	4606866.7	2029708.0	3903567.4	6.0	12.6	8.9	4606861.5	2029692.2	3903562.2	4.2	10.3	4.4
9091	DIONYSOS	4595164.1	2039433.4	3912675.8	6.0	12.6	8.9	4595158.9	2039417.6	3912670.6	4.2	10.3	4.4
9424	COLD LAKE	-1264834.5	-3466912.6	5185449.2	5.2	6.5	7.7	-1264831.9	-3466915.4	5185450.9	4.7	5.5	4.3
9425	EDWARDS AFB	-2450022.2	-4624438.2	3635041.1	3.1	3.2	3.8	-2450012.7	-4624431.6	3635036.6	2.6	2.2	2.4
9426	HARESTUA	3121262.6	592607.0	5512720.9	9.6	11.4	15.5	3121261.3	592605.7	5512723.0	8.6	9.4	5.8
9427	JOHNSTON ISLAND	-6007458.1	-1111834.2	1825730.0	10.9	20.6	8.8	-6007428.7	-1111852.5	1825733.9	8.9	19.8	8.6
9431	RIGA	3183891.2	1421439.3	5322819.8	13.1	11.7	14.7	3183897.6	1421426.7	5322814.7	12.3	9.4	7.0
9432	UZHGOROD	3907423.8	1602394.2	4763932.7	10.2	12.6	13.7	3907419.2	1602378.6	4763922.1	7.9	10.4	5.9

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APPENDIX

Solution WN12 (Heights not Constrained)

Information pertinent to the WN12 solution may be found in sections 5.3 and 6.

Tables corresponding to those in the Appendix, but for the solution WN14 (heights constrained), are 5.2-2, 3 and 4, on pp. 124 - 157.

Coordinates and statistical information for solution WN16 (no EDM and C-Band scalars) are not given. For various comparisons with solutions WN12 and WN14 see section 5.3.

Table A - 1

Cartesian and Geodetic Coordinates
(Solution WN12, Heights not Constrained)

Sta. No	u		σ_u	v	σ_v	w	σ_w
	φ		σ_φ	λ	σ_λ	H	σ_H
			a_a	A_a	r_a		
			a_b	A_b	r_b		
			a_c	A_c	r_c		

u, v, w · Cartesian coordinates in meters (Orientation: u ≡ the Greenwich meridian as defined by the B.I.H.; v − λ = 90° (E); w ≡ Conventional International Origin).

φ, λ Geodetic latitude and longitude in angular units (degrees, minutes and seconds of arc) computed from the Cartesian coordinates and referred to a rotational ellipsoid of a = 6378155.00 m and b = 6356769.70 m.

H Geodetic (ellipsoidal) height in meters referred to the same ellipsoid.

$\sigma_u, \sigma_v, \sigma_w$ Standard deviations of the Cartesian coordinates in meters.

$\sigma_\varphi, \sigma_\lambda$ Standard deviations of the geodetic coordinates in seconds of arc.

σ_H Standard deviations of the geodetic height in meters.

a_a, A_a, r_a Altitude (elevation angle), azimuth and magnitude of the major semi axis of the error ellipsoid, respectively. Angles in degrees, magnitude in meters. Altitude is positive above the horizon. Azimuth is positive east reckoned from the north (see section 4.74).

a_b, A_b, r_b Same as above for the mean axis of the error ellipsoid.

a_c, A_c, r_c Same as above for the minor axis of the error ellipsoid.

Table A - 1 (cont'd)

1021	1118021.79	3.08	-4876331.74	4.02	3942970.91	4.22
	38 25 49.58	0.12	282 54 47.93	0.13	-37.25	4.61
		77.22	-22.57	4.66		
		-10.14	15.44	3.50		
		7.71	104.06	3.07		
1022	807850.80	2.59	-5652004.03	3.28	2833508.99	3.33
	26 32 52.99	0.09	278 8 3.45	0.09	-16.00	3.78
		70.26	-9.18	3.91		
		16.55	136.74	2.65		
		-10.45	49.89	2.51		
1030	-2357249.25	6.06	-4646346.37	4.43	3668312.46	4.69
	35 19 47.41	0.11	243 5 59.18	0.24	900.93	5.28
		1.58	79.40	6.25		
		74.84	-16.44	5.40		
		-15.07	-10.18	3.19		
1032	2602704.27	49.06	-3419179.74	89.45	4697621.12	29.90
	47 44 28.96	0.82	307 16 43.15	4.37	29.05	48.75
		-23.15	76.07	101.26		
		65.45	55.50	30.88		
		7.71	162.75	9.71		
1033	-2299292.27	7.52	-1445690.55	10.01	5751823.26	10.48
	64 52 17.47	0.24	212 9 35.34	0.75	183.52	10.69
		80.84	50.11	10.75		
		4.78	-71.12	10.09		
		-7.80	18.22	7.02		
1034	-521708.32	3.46	-4242074.91	4.03	4718726.53	4.40
	48 1 20.58	0.12	262 59 19.43	0.17	232.09	4.63
		71.40	-33.55	4.68		
		-18.28	-44.67	4.17		
		-3.35	46.44	2.87		

Table A - 1 (cont'd)

1042	647495.88	3.05	-5177948.03	3.62	3656714.45	4.01
	35 12 7.07	0.10	277 7 39.96	0.12	878.21	4.35
		71.87	-10.47	4.46		
		15.66	138.43	3.21		
		-8.90	50.95	2.88		
3106	2881840.45	4.10	-5372180.72	4.58	1868548.48	4.92
	17 8 55.01	0.15	298 12 38.84	0.14	-41.24	5.07
		52.81	-22.80	5.57		
		31.89	122.29	4.14		
		-17.08	43.31	3.73		
3334	-84969.13	15.63	-5327986.33	14.01	3493434.31	10.82
	33 25 30.96	0.35	269 5 10.83	0.60	10.32	14.08
		-37.59	73.02	18.39		
		48.08	42.04	10.81		
		-15.82	-29.57	10.14		
3400	-1275239.36	16.26	-4798062.94	12.40	3994229.54	8.60
	39 0 21.44	0.28	255 6 57.27	0.57	2205.45	15.18
		-47.07	68.16	19.54		
		-30.15	-60.48	7.69		
		27.39	12.00	7.14		
3401	1513134.75	3.46	-4463580.09	5.32	4283061.16	4.61
	42 27 17.76	0.13	288 43 35.19	0.16	40.11	5.53
		-72.55	52.38	5.64		
		16.28	30.70	4.32		
		6.11	122.49	3.31		
3402	167256.13	4.16	-5481980.43	4.27	3245042.65	4.57
	30 46 49.96	0.12	271 44 51.22	0.16	38.80	4.97
		66.76	32.69	5.17		
		-11.89	93.32	4.10		
		-19.66	-0.99	3.59		

Table A - 1 (cont'd)

3404	642485.65	4.96	-6053942.43	5.26	1895690.46	5.51
	17 24 19.20	0.17	276 3 28.60	0.17	0.62	5.66
		48.04	37.71	6.21		
		-41.96	38.61	4.89		
		0.45	128.21	4.48		
3405	1919482.06	3.63	-5621096.52	5.59	2315780.14	4.91
	21 25 48.61	0.14	288 51 14.11	0.13	-58.16	6.10
		-73.37	149.73	6.26		
		-11.34	17.54	4.07		
		12.00	105.10	3.57		
3406	2251802.88	2.78	-5816928.95	3.51	1327197.36	3.81
	12 5 25.95	0.12	291 9 43.26	0.09	-20.23	3.71
		43.17	-21.90	4.15		
		-46.82	-19.56	3.28		
		0.72	69.68	2.56		
3407	2979892.91	5.15	-5513532.61	5.09	1181126.82	5.87
	10 44 34.80	0.18	298 23 23.43	0.17	188.52	5.48
		27.87	-35.78	6.88		
		56.08	106.09	5.18		
		-17.73	44.49	3.56		
3413	5186366.38	3.39	-3654225.08	2.89	-653022.67	3.18
	- 5 54 57.61	0.10	324 49 55.67	0.09	16.35	3.44
		70.52	131.38	3.50		
		13.54	-1.54	3.15		
		-13.73	85.08	2.80		
3414	4114987.81	9.91	-4554148.48	8.43	-1732166.11	7.89
	-15 51 37.66	0.25	312 5 59.97	0.28	1030.76	10.13
		67.20	62.72	10.29		
		-22.18	48.62	9.33		
		5.01	-39.33	6.20		

Table A - 1 (cont'd)

3431	3093056.06	8.49	-4870100.38	9.32	-2710845.83	12.48
	-25 18 57.79	0.39	302 25 12.34	0.27	174.32	10.55
		-26.28	12.12	12.63		
		-63.57	-174.59	9.98		
		2.67	100.80	7.45		
3476	3623293.59	3.44	-5214213.74	3.33	601514.00	3.63
	5 26 52.65	0.12	304 47 41.88	0.09	-25.26	3.93
		78.73	89.58	3.97		
		3.30	-17.25	3.70		
		-10.76	72.12	2.57		
3477	1744649.59	10.40	-6114305.58	13.73	532205.16	9.84
	4 49 0.09	0.32	285 55 31.84	0.36	2572.65	13.13
		-37.05	55.20	14.41		
		51.75	38.44	12.50		
		-8.19	-41.04	5.45		
3478	3185785.39	19.25	-5514574.52	35.38	-347713.16	35.78
	- 3 8 46.06	1.17	300 0 54.53	0.88	48.51	29.79
		15.24	-38.23	43.59		
		-62.34	20.46	30.90		
		22.50	58.25	6.91		
3499	1280834.05	3.77	-6250966.19	5.86	-10805.45	4.55
	- 0 5 51.65	0.15	281 34 47.01	0.12	2693.82	5.84
		-69.63	161.18	6.03		
		-17.81	11.27	4.35		
		9.56	98.17	3.75		
3648	832567.57	4.14	-5349553.36	4.98	3360596.37	5.44
	32 0 6.38	0.15	278 50 45.96	0.16	-20.08	5.81
		67.94	-16.88	6.02		
		-21.77	-7.13	4.27		
		3.39	81.52	4.13		

Table A - 1 (cont'd)

3657	1186786.07	3.40	-4785205.14	5.01	4032892.27	4.55
	39 28 19.03	0.12	283 55 44.27	0.15	-29.45	5.48
		-80.38	77.67	5.53		
		5.99	25.95	3.95		
		7.49	116.74	3.34		
3861	961766.69	3.26	-5679170.55	3.77	2729893.83	3.72
	25 30 26.19	0.09	279 36 42.61	0.12	-26.74	4.45
		-69.92	160.24	4.62		
		12.52	107.66	3.29		
		-15.44	21.17	2.54		
3902	-1234689.39	28.61	-4651235.90	32.12	4174763.36	11.28
	41 7 57.61	0.64	255 8 0.48	0.87	1855.30	34.27
		-52.22	45.81	43.01		
		2.52	132.55	8.81		
		37.66	40.60	7.09		
3903	1088979.96	12.26	-4842973.23	15.52	3991763.89	1[illegible].36
	38 59 34.47	0.37	282 40 21.45	0.51	76.40	15.48
		-69.40	23.21	16.10		
		-2.49	119.86	12.65		
		20.43	30.79	10.05		
4050	5051614.78	4.39	2726608.63	3.75	-2774180.99	5.45
	-25 56 38.17	0.16	28 21 28.62	0.13	1589.72	5.12
		-50.27	2.32	5.67		
		38.74	-12.80	4.20		
		7.47	83.24	3.63		
4061	2881594.50	4.15	-5372540.16	4.73	1868034.31	5.02
	17 8 37.11	0.15	298 12 25.75	0.14	-1.25	5.20
		54.68	-20.73	5.67		
		30.50	125.51	4.16		
		-16.07	45.28	3.90		

Table A - 1 (cont'd)

4081	1920409.94	3.66	-5619426.13	5.71	2319133.37	4.96
	21 27 45.31	0.14	288 52 3.36	0.13	-24.19	6.21
		-74.68	150.88	6.35		
		-8.96	25.72	4.20		
		12.32	113.75	3.54		
4082	910567.93	2.93	-5539130.15	3.77	3017974.77	3.69
	28 25 28.71	0.10	279 20 6.94	0.11	-16.18	4.23
		-75.78	173.63	4.30		
		-14.01	-16.45	3.11		
		-2.39	74.15	2.89		
4280	-2671883.71	4.25	-4521217.33	4.36	3607495.03	4.82
	34 39 56.70	0.13	239 25 6.15	0.16	96.95	5.07
		69.57	11.21	5.20		
		-8.63	77.17	4.20		
		-18.37	-15.72	3.95		
4740	2308888.60	3.77	-4874314.80	5.42	3393092.00	5.13
	32 20 52.79	0.14	295 20 46.32	0.14	-22.10	6.09
		-76.56	123.13	6.19		
		-9.43	-10.91	4.39		
		9.48	77.50	3.50		
5001	1088874.44	4.86	-4842954.94	10.24	3991857.81	7.87
	38 59 37.67	0.22	282 40 17.34	0.22	103.64	10.77
		-75.43	42.59	11.01		
		13.02	15.41	6.81		
		6.43	106.90	4.79		
5201	-2127810.44	2.70	-3785912.34	2.85	4656011.95	3.66
	47 11 5.03	0.09	240 39 45.16	0.12	344.39	3.90
		77.05	10.73	3.95		
		-12.15	31.25	2.72		
		-4.40	-59.70	2.41		

Table A - 1 (cont'd)

5410	-5618764.51	2.88	-258231.46	3.21	2997243.77	4.14
	28 12 42.97	0.13	182 37 53.01	0.12	27.63	3.05
		20.77	5.40	4.16		
		24.78	-94.68	3.31		
		-56.70	-49.32	2.72		
5648	794687.29	4.18	-5360063.67	5.01	3353093.54	5.47
	31 55 18.92	0.15	278 25 59.82	0.16	-3.04	5.84
		67.97	-16.20	6.05		
		-21.82	-8.02	4.30		
		2.84	80.84	4.17		
5712	3623307.10	3.41	-5214190.54	3.32	601672.76	3.62
	5 26 57.81	0.12	304 47 42.67	0.09	-21.52	3.93
		79.26	81.07	3.98		
		1.27	-15.66	3.68		
		-10.66	74.10	2.53		
5713	4433654.42	2.74	-2268159.21	2.80	3971673.06	3.81
	38 45 36.57	0.10	332 54 24.20	0.12	115.58	3.70
		60.33	-13.35	4.01		
		9.62	93.97	2.77		
		-7.77	-170.91	2.49		
5715	5884479.91	2.26	-1853580.11	2.53	1612763.77	3.08
	14 44 39.26	0.10	342 30 57.05	0.09	42.22	2.39
		26.14	-12.90	3.14		
		13.14	83.68	2.57		
		60.28	-162.19	2.14		
5717	6023416.10	2.65	1617949.45	2.79	1331651.17	3.30
	12 7 52.03	0.11	15 2 7.14	0.09	288.98	2.72
		1.36	-21.60	3.41		
		62.25	70.99	2.77		
		27.71	-112.32	2.53		

Table A - 1 (cont'd)

5720	4900750.11	2.74	3968255.14	2.89	966348.26	3.39
	8 46 13.11	0.11	38 59 52.53	0.09	1854.51	2.88
		-6.83	-15.82	3.48		
		76.61	43.96	2.88		
		11.46	-104.43	2.64		
5721	2604406.62	2.57	4444124.91	2.82	3750345.66	3.53
	36 14 26.70	0.11	59 37 41.75	0.10	955.63	2.97
		27.12	-15.07	3.59		
		62.69	157.74	2.79		
		2.93	-106.57	2.51		
5722	1905122.27	4.22	6032294.51	5.47	-810726.36	4.81
	- 7 21 6.47	0.15	72 28 22.13	0.14	-85.15	5.67
		63.18	175.46	6.00		
		15.89	51.19	4.45		
		21.01	-45.09	3.88		
5723	-941713.74	3.11	5967448.58	3.33	2039317.47	4.06
	18 46 10.94	0.13	98 58 4.09	0.11	254.75	3.54
		30.12	15.96	4.15		
		59.45	-174.63	3.31		
		4.64	-76.73	3.02		
5726	-3361953.23	3.05	5365845.53	3.31	763623.65	3.78
	6 55 20.46	0.12	122 4 8.65	0.10	95.45	3.31
		30.73	-1.24	3.90		
		31.61	-112.70	3.24		
		-42.95	-57.65	2.97		
5730	-5858583.78	2.85	1394474.89	3.14	2093844.73	3.76
	19 17 29.26	0.12	166 36 41.20	0.10	34.22	3.16
		25.72	10.83	3.80		
		41.58	-104.48	3.26		
		-37.54	-57.45	2.65		

Table A - 1 (cont'd)

5732	-6099983.96	5.71	-997345.64	4.36	-1568577.00	4.92
	-14 19 53.94	0.15	189 17 8.46	0.15	51.55	5.76
		-59.46	53.10	6.03		
		28.51	30.13	5.05		
		-10.03	-54.35	3.73		
5733	-5885350.80	4.42	-2448375.27	3.52	221663.06	4.57
	2 0 18.13	0.15	202 35 16.39	0.12	39.20	4.35
		4.69	24.97	4.82		
		-74.15	98.16	4.42		
		-15.10	-63.76	3.18		
5734	-3851808.13	3.19	396416.13	3.69	5051343.27	4.94
	52 42 48.10	0.12	174 7 26.34	0.19	58.61	4.63
		57.52	16.91	5.00		
		25.26	-120.93	3.97		
		-19.03	-40.29	2.72		
5735	5186368.50	3.29	-3654225.97	2.78	-653022.62	3.07
	- 5 54 57.60	0.10	324 49 55.68	0.09	18.58	3.37
		69.19	134.20	3.43		
		16.81	-8.45	3.05		
		-11.91	77.89	2.65		
5736	6118355.50	3.29	-1571763.06	2.89	-878558.41	3.31
	- 7 58 13.71	0.11	345 35 33.55	0.10	72.03	3.27
		-24.67	-10.61	3.32		
		61.35	22.20	3.29		
		-13.66	85.80	2.89		
5739	4433645.98	2.74	-2268192.23	2.81	3971663.26	3.82
	38 45 36.17	0.10	332 54 22.82	0.12	115.31	3.70
		60.35	-13.33	4.01		
		9.30	93.38	2.77		
		27.88	-171.65	2.49		

Table A - 1 (cont'd)

5744	4896444.11	2.41	1316129.40	2.80	3856628.42	3.24
	37 26 37.22	0.10	15 2 42.34	0.11	25.53	2.90
		33.53	-21.04	3.29		
		43.95	108.66	2.89		
		27.50	-131.22	2.24		
5907	-449391.62	5.78	-4600910.61	13.80	4380315.36	13.48
	43 38 57.61	0.30	264 25 16.89	0.25	465.51	17.02
		-89.22	-69.67	17.02		
		0.08	14.57	9.46		
		-0.77	104.57	5.12		
5911	2308010.43	3.59	-4873778.30	4.88	3394476.12	5.23
	32 21 45.70	0.13	295 20 24.75	0.12	-8.49	6.15
		76.57	10.91	6.26		
		-13.43	11.91	3.94		
		0.23	101.85	3.06		
5912	1142664.35	4.77	-6196104.08	9.09	988340.83	7.00
	8 58 26.97	0.22	280 26 56.02	0.15	-5.68	9.33
		-76.71	155.28	9.45		
		-13.15	-16.14	6.75		
		1.91	73.41	4.41		
5914	2349423.88	15.50	-5576023.18	21.11	2010340.54	9.72
	18 29 39.46	0.37	292 50 52.20	0.49	-25.62	19.66
		-65.04	51.42	21.15		
		11.21	116.23	13.96		
		21.99	21.64	8.94		
5915	-744066.67	5.59	-5465234.26	15.26	3192485.84	12.81
	30 13 46.54	0.33	262 14 49.59	0.20	173.55	17.26
		-85.40	-159.30	17.30		
		-4.36	1.85	10.02		
		-1.48	91.96	5.34		

Table A - 1 (cont'd)

5923	4363335.92	2.47	2862258.83	2.74	3655380.74	3.28
	35 11 30.27	0.10	33 15 50.59	0.10	174.41	2.87
		24.87	-19.60	3.36		
		61.90	130.62	2.78		
		12.25	-115.38	2.31		
5924	5093565.84	2.43	-565319.12	3.06	3784273.08	3.75
	36 37 36.84	0.10	353 40 0.62	0.13	29.53	3.09
		41.64	-8.48	3.77		
		9.04	89.65	3.11		
		46.94	-170.55	2.37		
5925	6237376.79	2.96	-1140241.76	3.08	687740.04	3.58
	6 13 54.13	0.12	349 38 24.98	0.10	26.13	2.97
		-4.08	-15.82	3.65		
		-41.33	77.78	3.10		
		48.38	69.58	2.84		
5930	-1542556.38	3.34	6186964.65	3.90	151827.82	3.98
	1 22 23.53	0.13	103 59 59.15	0.11	28.03	3.82
		36.38	0.54	4.14		
		41.16	-129.56	3.84		
		-27.62	-66.78	3.21		
5931	-2423919.09	3.06	5388254.76	3.54	2394863.85	4.31
	22 11 55.47	0.13	114 13 14.56	0.10	144.12	4.02
		47.68	2.79	4.50		
		41.43	-162.93	3.37		
		-7.15	-79.28	2.97		
5933	-4071578.29	4.25	4714266.96	4.39	-1366533.27	4.29
	-12 27 15.16	0.14	130 48 58.46	0.14	94.10	4.47
		68.49	-14.65	4.50		
		-17.53	22.04	4.31		
		-12.06	-71.83	4.11		

Table A - 1 (cont'd)

5934	-5367671.67	3.60	3437881.37	3.49	-225417.36	3.83
	- 2 7 20.43	0.13	147 21 40.64	0.11	95.84	3.65
		28.86	15.45	4.00		
		55.67	-128.38	3.56		
		-16.95	-64.88	3.35		
5935	-5059832.63	2.89	3591194.19	3.02	1472759.43	3.45
	13 26 21.91	0.11	144 38 5.78	0.10	106.56	3.10
		18.09	17.68	3.51		
		64.73	-116.10	3.09		
		-17.04	-66.58	2.74		
5937	-4433470.52	3.05	4512939.33	3.17	809955.32	3.74
	7 20 40.19	0.12	134 29 27.85	0.10	146.59	3.20
		22.81	8.93	3.81		
		43.13	-104.28	3.16		
		-38.19	-61.74	2.97		
5938	-5915106.01	4.43	2146873.19	3.89	-1037912.81	4.04
	- 9 25 40.97	0.13	160 3 6.33	0.13	94.51	4.46
		-72.09	-168.20	4.50		
		-17.22	28.30	4.11		
		-4.79	-63.19	3.73		
5941	-5467771.89	3.46	-2381242.67	3.23	2254023.97	4.35
	20 49 54.29	0.14	203 32 0.14	0.11	66.65	3.47
		11.47	16.44	4.46		
		-77.71	-5.01	3.42		
		4.38	-74.45	3.11		
6001	546566.45	2.68	-1389993.59	2.74	6180242.37	4.38
	76 30 4.78	0.08	291 27 55.80	0.40	216.93	4.38
		81.99	27.11	4.41		
		-6.36	64.75	3.04		
		4.85	154.21	2.29		

Table A - 1 (cont'd)

6002	1130762.75	2.23	-4830837.60	2.70	3994709.87	3.11
	39 1 39.39	0.08	283 10 26.91	0.09	0.92	3.37
		71.81	-25.01	3.47		
		17.77	142.30	2.25		
		-3.74	53.50	2.20		
6003	-2127839.88	2.53	-3785864.18	2.69	4656037.40	3.54
	47 11 6.25	0.08	240 39 42.82	0.11	344.33	3.77
		76.55	13.31	3.83		
		-12.67	33.21	2.55		
		-4.43	-57.79	2.23		
6004	-3851806.76	3.20	396416.10	3.67	5051341.73	4.95
	52 42 48.10	0.12	174 7 26.34	0.19	56.55	4.64
		57.30	15.66	5.01		
		25.54	-122.46	3.99		
		-18.99	-41.92	2.70		
6006	2102930.27	2.67	721674.08	3.34	5958181.65	4.37
	69 39 45.05	0.10	18 56 27.47	0.28	113.69	4.41
		80.94	-18.03	4.43		
		7.87	132.03	3.51		
		4.47	-137.35	2.33		
6007	4433653.31	2.74	-2268156.86	2.73	3971570.98	3.79
	38 45 36.56	0.09	332 54 24.27	0.11	112.66	3.66
		59.76	-12.11	3.97		
		13.23	101.67	2.74		
		26.66	-161.56	2.46		
6008	3623257.28	3.39	-5214236.72	3.30	601534.83	3.60
	5 26 53.33	0.12	304 47 40.48	0.09	-25.12	3.91
		79.11	84.72	3.95		
		2.23	-16.98	3.67		
		-10.65	72.60	2.51		

Table A - 1 (cont'd)

6009	1280834.05	3.77	-6250966.19	5.86	-10805.46	4.55
	- 0 5 51.65	0.15	281 34 47.01	0.12	2693.82	5.84
		-69.63	161.18	6.03		
		-17.81	11.27	4.35		
		9.56	98.16	3.75		
6011	-5466039.24	4.43	-2404429.31	3.36	2242224.57	3.90
	20 42 26.77	0.12	203 44 38.33	0.13	3091.27	4.46
		-75.66	159.30	4.55		
		-5.21	48.38	4.32		
		-13.32	-42.86	2.60		
6012	-5858578.80	2.94	1394516.35	3.21	2093817.38	3.77
	19 17 28.37	0.12	166 36 39.78	0.11	29.67	3.26
		26.45	12.27	3.82		
		43.23	-105.62	3.35		
		-35.21	-57.18	2.71		
6013	-3565901.45	3.98	4120723.17	5.16	3303426.94	5.88
	31 23 42.34	0.17	130 52 17.55	0.17	104.05	5.28
		28.71	28.74	6.21		
		56.88	-118.32	5.08		
		-15.11	-52.76	3.55		
6015	2604355.41	2.55	4444169.18	2.86	3750321.68	3.50
	36 14 25.84	0.11	59 37 44.41	0.10	951.38	2.98
		26.67	-14.83	3.56		
		61.67	143.86	2.82		
		8.87	-109.32	2.51		
6016	4896394.57	2.39	1316176.24	2.79	3856670.75	3.23
	37 26 39.02	0.09	15 2 44.70	0.11	22.94	2.91
		36.01	-21.06	3.28		
		42.58	110.84	2.88		
		26.32	-132.13	2.20		

Table A - 1 (cont'd)

6019	2280630.74	2.74	-4914547.69	3.56	-3355417.89	5.24
	-31 56 35.25	0.15	294 53 38.37	0.10	619.03	4.54
		-45.45	-0.34	5.33		
		-44.36	173.08	3.57		
		3.29	86.31	2.57		
6020	-1888621.47	5.97	-5354898.38	6.07	-2895762.32	6.92
	-27 10 36.23	0.18	250 34 21.87	0.19	228.82	7.94
		-68.61	33.53	8.35		
		4.66	-44.45	5.58		
		20.82	47.32	4.41		
6022	-6099975.88	4.81	-997357.69	3.90	-1568593.64	5.20
	-14 19 54.52	0.16	189 17 8.90	0.13	49.83	4.91
		-28.98	28.84	5.59		
		-59.85	-168.68	4.71		
		-7.60	-65.40	3.45		
6023	-4955391.18	4.54	3842255.66	3.94	-1163855.47	4.66
	-10 35 3.18	0.15	142 12 40.02	0.13	129.96	4.70
		-45.47	11.72	4.85		
		-42.36	-146.24	4.62		
		11.21	-66.66	3.62		
6031	-4313850.43	4.44	891340.59	4.23	-4597277.74	5.32
	-46 24 57.98	0.14	168 19 32.20	0.20	12.92	5.42
		-70.77	5.36	5.56		
		-11.60	-120.67	4.54		
		-15.13	146.15	3.79		
6032	-2375425.99	3.73	4875557.63	4.28	-3345424.51	4.96
	-31 50 25.42	0.14	115 58 33.09	0.14	11.30	4.99
		-61.34	12.50	5.27		
		25.93	-14.69	3.93		
		-11.37	-99.08	3.69		

Table A - 1 (cont'd)

6038	-2160989.61	2.92	-5642717.93	3.78	2035368.01	4.35
	18 43 58.17	0.13	249 2 40.84	0.10	-5.95	4.11
		44.61	-2.02	4.50		
		-45.14	-9.63	3.70		
		-3.81	84.21	2.81		
6039	-3724775.03	7.86	-4421234.44	7.20	-2686094.35	7.26
	-25 4 6.62	0.18	229 53 12.24	0.22	323.72	9.98
		-76.99	34.17	10.17		
		-4.56	-75.99	6.11		
		12.16	13.02	5.05		
6040	-741986.07	4.71	6190803.59	4.83	-1338557.08	4.72
	-12 11 44.20	0.15	96 50 4.08	0.16	-35.90	5.07
		59.26	-178.79	5.38		
		3.99	-82.04	4.74		
		30.42	10.31	4.04		
6042	4900751.97	2.74	3968255.09	2.90	966318.93	3.38
	8 46 12.16	0.11	38 59 52.49	0.09	1851.44	2.89
		-8.03	-16.29	3.48		
		76.77	36.82	2.88		
		10.44	-104.80	2.64		
6043	1371376.55	3.47	-3614750.64	4.23	-5055947.15	7.01
	-52 46 52.90	0.19	290 46 33.30	0.17	87.59	5.88
		-44.81	2.29	7.06		
		-44.93	-170.06	4.43		
		-3.84	96.11	3.10		
6044	1098898.48	6.87	3684616.99	6.67	-5071900.10	11.10
	-53 1 9.97	0.27	73 23 36.02	0.38	51.79	9.66
		-52.91	1.91	11.10		
		-14.89	-108.68	7.33		
		33.06	-28.65	6.16		

Table A - 1 (cont'd)

6045	3223434.73	3.57	5045343.56	4.03	-2191818.01	4.60
	-20 13 53.64	0.14	57 25 32.79	0.12	125.84	4.43
		-49.89	-10.98	4.87		
		36.37	18.08	3.76		
		14.60	-82.97	3.51		
6047	-3361983.48	3.07	5365820.63	3.36	763620.46	3.83
	6 55 20.38	0.12	122 4 9.91	0.10	90.07	3.37
		29.95	-1.28	3.94		
		38.12	-118.16	3.28		
		-37.44	-65.09	3.02		
6050	1192679.27	5.00	-2451013.23	6.33	-5747052.45	9.81
	-64 46 26.35	0.27	295 56 52.30	0.34	23.64	8.30
		-43.39	2.35	10.27		
		-46.53	178.05	6.03		
		2.15	90.32	4.41		
6051	1111337.13	4.96	2169270.22	4.18	-5874355.23	7.25
	-67 36 5.26	0.15	62 52 24.67	0.40	44.13	7.08
		-71.06	-22.06	7.31		
		15.76	-56.73	4.96		
		10.23	36.20	4.08		
6052	-902611.43	4.59	2409529.97	4.40	-5816569.86	7.42
	-66 16 45.07	0.15	110 32 9.53	0.35	14.51	7.45
		-78.59	13.76	7.55		
		-9.78	-134.94	4.70		
		5.81	-45.95	4.05		
6053	-1310854.82	4.80	311262.87	4.79	-6213294.28	7.36
	-77 50 41.09	0.16	166 38 32.92	0.73	-33.23	7.27
		-77.95	-9.54	7.36		
		-11.19	148.49	4.88		
		-4.39	-120.64	4.70		

Table A - 1 (cont'd)

6055	6118349.28	3.29	-1571749.24	2.93	-878601.29	3.37
	- 7 58 15.13	0.11	345 35 33.94	0.10	68.61	3.25
		-14.58	-9.71	3.37		
		63.98	48.07	3.29		
		-21.05	86.03	2.92		
6059	-5885350.23	4.34	-2448374.39	3.44	221663.61	4.53
	2 0 18.15	0.15	202 35 16.37	0.11	38.35	4.28
		7.86	23.09	4.75		
		-72.68	86.83	4.35		
		-15.34	-64.73	3.12		
6060	-4751654.99	4.47	2792065.66	3.95	-3200174.19	4.72
	-30 18 34.26	0.14	149 33 41.64	0.15	245.25	4.90
		-65.75	11.70	5.03		
		-21.87	-141.30	4.31		
		9.96	-55.35	3.74		
6061	2999921.23	3.95	-2219366.28	5.85	-5155267.05	7.80
	-54 17 1.43	0.18	323 30 20.38	0.32	11.74	6.88
		-51.84	-22.58	7.91		
		-23.74	101.45	5.87		
		27.95	24.94	3.69		
6063	5884479.35	2.40	-1853496.36	2.58	1612858.73	3.16
	14 44 42.46	0.10	342 30 59.72	0.09	41.54	2.52
		27.42	-9.39	3.21		
		14.77	88.46	2.64		
		58.24	-156.33	2.26		
6064	6023394.41	3.30	1617934.17	3.05	1331731.69	3.68
	12 7 54.76	0.12	15 2 6.84	0.10	281.55	3.41
		11.90	-10.94	3.70		
		73.32	123.77	3.42		
		-11.51	76.60	2.90		

Table A - 1 (cont'd)

6065	4213570.18	2.63	820833.75	2.95	4702786.47	3.64
	47 48 4.39	0.09	11 1 24.84	0.14	965.28	3.51
		59.85	-15.20	3.71		
		23.02	121.81	3.08		
		18.38	-140.08	2.37		
6066	-5858580.74	2.94	1394474.01	3.21	2093843.05	3.77
	19 17 29.24	0.12	166 36 41.21	0.11	30.67	3.26
		26.45	12.28	3.82		
		43.24	-105.62	3.35		
		-35.20	-57.18	2.71		
6067	5186415.01	3.34	-3653935.93	2.84	-654280.70	3.13
	- 5 55 36.77	0.10	324 50 4.26	0.09	20.03	3.40
		70.69	131.71	3.45		
		13.50	-1.53	3.10		
		-13.55	85.15	2.74		
6068	5084837.07	4 [illegible]	2670346.52	3.52	-2768109.30	5.29
	-25 52 59.82	0.15	27 42 23.76	0.12	1529.74	4.95
		-50.35	1.75	5.52		
		38.76	-12.64	4.00		
		7.11	83.10	3.39		
6069	4978430.89	8.32	-1086871.05	6.65	-3823187.75	10.43
	-37 3 54.13	0.28	347 41 4.73	0.28	37.46	10.01
		-57.69	-21.20	10.91		
		24.01	24.02	7.76		
		-20.28	104.55	6.53		
6072	-941707.81	5.91	5967462.54	5.05	2039307.39	4.85
	18 46 10.49	0.15	98 58 3.81	0.20	263.69	5.44
		-2.63	-71.48	6.00		
		71.82	10.50	5.56		
		-17.98	19.38	4.13		

Table A - 1 (cont'd)

6073	1905134.35	3.72	6032292.03	4.81	-810742.32	4.66
	- 7 21 6.98	0.15	72 28 21.73	0.12	-81.84	4.85
		53.68	157.16	5.17		
		33.51	2.91	4.27		
		12.39	-95.45	3.70		
6075	3602824.49	4.24	5238248.23	4.55	-515957.74	4.51
	- 4 40 14.99	0.14	55 28 48.44	0.13	527.88	4.97
		55.89	166.98	5.31		
		30.21	-43.73	4.25		
		-14.33	-125.18	3.58		
6078	-5952307.73	19.88	1231910.54	9.37	-1925983.72	16.62
	-17 41 31.75	0.69	168 18 25.03	0.26	88.03	15.67
		-34.41	174.81	25.35		
		-38.94	-61.58	8.09		
		32.30	-120.85	7.15		
6111	-2448862.77	3.03	-4667992.31	3.19	3582759.41	3.79
	34 22 54.24	0.09	242 19 5.41	0.12	2262.44	4.11
		69.88	6.82	4.27		
		-6.03	80.05	2.95		
		-19.12	-12.05	2.59		
6123	-1881807.42	4.86	-812435.30	4.57	6019599.26	7.13
	71 18 47.61	0.14	203 21 4.94	0.52	14.09	6.99
		74.56	-29.91	7.17		
		0.60	62.25	5.41		
		-15.43	-27.59	3.83		
6134	-2448916.50	3.03	-4668082.35	3.19	3582454.09	3.79
	34 22 44.15	0.09	242 19 5.18	0.12	2176.44	4.11
		69.88	6.77	4.27		
		-6.01	80.08	2.95		
		-19.13	-12.01	2.60		

Table A - 1 (cont'd)

7036	-828491.01	3.84	-5657486.49	3.89	2816825.47	4.02
	26 22 46.35	0.11	261 40 7.45	0.14	52.58	4.56
		66.30	24.56	4.76		
		-14.36	78.88	3.86		
		-18.44	-16.01	2.93		
7037	-191294.76	3.22	-4967308.32	3.47	3983264.47	3.90
	38 53 35.51	0.10	267 47 40.51	0.13	251.66	4.23
		72.86	-17.06	4.32		
		12.76	120.18	3.42		
		-11.25	32.76	2.69		
7039	2308214.77	3.73	-4873614.77	5.32	3394568.37	5.00
	32 21 49.28	0.14	295 20 34.49	0.14	-10.07	5.98
		-76.40	122.37	6.08		
		-9.41	-10.87	4.24		
		9.73	77.50	3.50		
7040	2465050.88	3.99	-5534945.53	4.42	198[illegible]522.20	4.66
	18 15 28.51	0.14	294 0 22.84	0.14	8.22	4.79
		42.85	-39.80	5.52		
		-47.23	-52.58	4.11		
		-6.40	44.39	3.13		
7043	1130706.51	2.24	-4831337.15	2.72	3994141.37	3.11
	39 1 15.40	0.08	283 10 19.90	0.09	10.89	3.38
		72.22	-25.56	3.48		
		17.26	140.06	2.26		
		-4.15	51.35	2.22		
7045	-1240475.11	4.60	-4760256.04	4.16	4048997.78	4.66
	39 38 47.64	0.11	255 23 38.85	0.20	1787.06	5.13
		69.98	-40.89	5.25		
		14.50	94.34.	4.64		
		-13.50	7.90	3.33		

Table A - 1 (cont'd)

7072	976261.26	2.49	-5601416.41	3.30	2880251.42	3.26
	27 1 14.16	0.09	279 53 12.03	0.09	-11.73	3.78
		-71.79	161.40	3.89		
		-17.57	-34.30	2.60		
		-4.6[illegible]	57.17	2.41		
7075	692618.68	3.97	-4347090.42	5.71	4600487.67	5.36
	46 27 20.78	0.16	279 3 10.09	0.19	249.08	6.10
		-77.90	44.92	6.16		
		9.63	7.29	4.83		
		7.25	98.53	3.96		
7076	1384159.21	4.32	-5905679.99	5.82	1966554.36	5.85
	18 4 34.72	0.18	283 11 26.71	0.15	430.40	6.20
		55.60	-28.38	6.62		
		-34.18	-21.04	5.20		
		3.42	66.63	3.99		
8009	3923429.85	13.29	299866.13	13.09	5003013.26	15.16
	52 0 6.44	0.40	4 22 14.14	0.69	93.64	15.81
		52.25	-67.68	17.90		
		27.30	160.52	12.64		
		23.93	57.28	9.89		
8010	4331312.67	7.93	567499.75	10.93	4632118.94	11.50
	46 52 37.05	0.30	7 27 52.27	0.52	933.31	10.35
		35.59	-52.40	12.86		
		38.86	72.82	9.41		
		31.15	-168.03	7.79		
8011	3920188.87	12.84	-134806.73	16.48	5012776.21	15.48
	52 8 36.18	0.38	358 1 49.80	0.87	193.35	16.26
		-35.04	114.83	19.16		
		54.72	122.47	14.64		
		3.60	27.36	9.71		

Table A - 1 (cont'd)

[illegible]	4578328.11	6.41	457945.63	10.70	4403204.79	10.16
	43 55 57.92	0.24	5 42 43.17	0.48	690.57	9.36
		-31.30	119.89	12.35		
		48.64	73.56	8.51		
		24.10	-165.90	5.81		
8019	4579469.08	6.34	586582.69	10.62	4386428.42	10.09
	43 43 33.36	0.24	7 17 57.30	0.48	405.86	9.23
		-30.41	120.55	12.26		
		49.25	73.48	8.46		
		24.34	-164.85	5.73		
8030	4205629.05	9.02	163695.35	12.25	4776550.95	11.77
	48 48 22.39	0.31	2 13 44.38	0.60	192.34	11.31
		-35.55	115.39	14.20		
		49.32	81.61	9.62		
		17.15	-167.35	8.71		
9001	-1535755.11	4.58	-5167026.59	3.92	3401047.07	3.81
	32 25 24.37	0.09	253 26 48.77	0.18	1638.66	4.56
		-27.81	104.77	4.79		
		-59.01	-103.80	4.59		
		-12.58	8.01	2.63		
9002	5056115.09	4.23	2716513.96	3.57	-2775782.87	5.33
	-25 57 36.68	0.15	28 14 52.57	0.12	1549.91	4.98
		-50.29	2.25	5.55		
		38.75	-12.67	4.04		
		7.37	83.29	3.44		
9004	5105589.78	6.27	-555269.67	12.88	3769680.57	8.52
	36 27 46.84	0.18	353 47 35.04	0.51	60.75	9.36
		-28.45	99.97	13.86		
		53.62	57.33	7.98		
		20.69	178.16	4.68		

Table A - 1 (cont'd)

9005	-3946751.36	11.20	3366303.20	10.32	3698830.26	9.81
	35 40 21.70	0.28	139 32 17.30	0.45	120.23	11.19
		-36.67	-87.00	11.71		
		52.37	-71.98	10.95		
		-7.29	8.47	8.44		
9006	1018153.29	14.17	5471119.27	10.89	3109622.24	9.58
	29 21 34.48	0.22	79 27 29.08	0.53	1867.29	12.62
		-21.12	-98.45	14.73		
		66.43	-70.72	12.44		
		-9.99	-4.54	6.30		
9007	1942762.37	2.82	-5804101.64	3.99	-1796905.76	5.32
	-16 27 56.14	0.17	288 30 23.56	0.09	2483.27	4.24
		-22.97	-5.98	5.36		
		-66.29	158.90	4.01		
		5.54	81.66	2.71		
9008	3376872.59	8.14	4403980.05	10.33	3136250.06	9.48
	29 38 13.64	0.24	52 31 11.36	0.33	1551.01	11.48
		70.11	53.59	11.90		
		11.35	-70.11	8.62		
		16.11	-163.43	6.85		
9009	2251813.45	2.77	-5816933.57	3.51	1327169.71	3.80
	12 5 25.02	0.12	291 9 43.53	0.09	-18.08	3.72
		43.37	-20.96	4.15		
		-46.62	-19.32	3.28		
		0.82	69.81	2.54		
9010	976276.21	2.48	-5601418.80	3.30	2880243.99	3.25
	27 1 13.87	0.09	279 53 12.55	0.09	-10.73	3.78
		-71.88	161.71	3.89		
		-17.49	-33.87	2.59		
		-4.57	57.57	2.40		

Table A - 1 (cont'd)

9011	2280578.88	2.74	-4914584.83	3.58	-3355398.84	5.27
	-31 56 34.52	0.15	294 53 35.99	0.10	619.02	4.55
		-45.10	-0.65	5.34		
		-44.69	172.38	3.58		
		3.49	85.84	2.58		
9012	-5466088.52	4.46	-2404310.50	3.39	2242188.67	3.91
	20 42 25.71	0.12	203 44 33.88	0.13	3076.02	4.49
		-76.20	152.71	4.57		
		-3.49	48.32	4.35		
		-13.33	-42.51	2.62		
9021	-1936799.06	7.34	-5077719.38	6.79	3331926.12	6.42
	31 41 2.90	0.20	249 7 17.77	0.30	2358.35	6.43
		-0.39	114.12	8.35		
		72.49	25.34	6.52		
		-17.50	24.00	5.38		
9028	4903727.67	2.76	3965208.62	2.91	963853.17	3.40
	8 44 50.89	0.11	38 57 33.80	0.09	1868.26	2.91
		-7.87	-16.14	3.49		
		76.58	38.45	2.90		
		10.80	-104.63	2.65		
9029	5186459.35	3.38	-3653874.57	2.90	-654317.92	3.18
	- 5 55 39.97	0.10	324 50 6.72	0.09	24.78	3.44
		71.00	132.27	3.49		
		13.32	-1.17	3.15		
		-13.30	85.62	2.79		
9031	1693795.54	8.42	-4112354.26	9.43	-4556644.13	14.26
	-45 53 12.21	0.46	292 23 8.78	0.33	194.17	10.66
		-23.69	10.03	15.00		
		-66.03	-160.74	9.61		
		-3.42	101.53	6.76		

Table A - 1 (cont'd)

9051	4606866.74	5.99	2029707.98	12.63	3903567.43	8.89
	37 58 37.17	0.24	23 46 38.94	0.49	204.43	8.60
		5.58	111.32	12.83		
		64.19	9.67	9.14		
		25.12	-156.06	5.13		
9091	4595164.11	5.96	2039433.37	12.62	3912675.81	8.87
	38 4 45.11	0.24	23 55 57.67	0.49	483.07	8.60
		5.65	111.43	12.81		
		64.31	9.57	9.13		
		24.98	-155.92	5.10		
9424	-1264834.45	5.18	-3466912.61	6.52	5185449.25	7.70
	54 44 33.06	0.22	249 57 23.41	0.28	667.49	7.64
		69.02	-13.79	7.79		
		-20.73	-4.57	6.59		
		3.08	84.27	4.95		
9425	-2450022.22	3.11	-4624438.17	3.25	3635041.10	3.85
	34 57 50.36	0.10	242 5 7.46	0.12	763.81	4.17
		70.21	6.95	4.32		
		-6.42	78.72	3.03		
		-18.63	-13.46	2.67		
9426	3121262.56	9.62	592607.01	11.37	5512720.86	15.45
	60 12 39.75	0.42	10 45 1.07	0.70	587.40	13.27
		40.99	-26.57	16.30		
		41.50	113.69	10.84		
		21.18	-136.25	8.80		
9427	-6007458.13	10.94	-1111834.16	20.62	1825729.98	8.84
	16 44 38.03	0.31	190 29 7.47	0.74	48.78	7.37
		7.73	-110.69	23.58		
		-66.40	177.42	7.06		
		-22.15	-23.86	4.13		

Table A - 1 (cont'd)

9431	3183891.18	13.08	1421439.29	11.65	5322819.83	14.71
	56 56 55.84	0.46	24 3 29.66	0.79	12.01	11.98
		22.86	32.30	16.33		
		35.95	-75.50	12.78		
		45.26	147.47	9.65		
9432	·3907423.80	10.22	1602394.18	12.62	4763932.72	13.68
	48 38 2.32	0.35	22 17 52.90	0.64	217.43	12.80
		59.08	·1.87	13.80		
		0.47	88.92	13.09		
		30.92	179.20	9.44		

Table A - 2

Station to Station Correlation Coefficients $\rho_{ij} > 0.75$ (Solution WN12)

STA.NO.3106 WITH STA.NO.4061

0.961	-0.079	0.021
-0.085	0.969	-0.353
0.026	-0.351	0.973

STA.NO.3406 WITH STA.NO.9009

0.978	-0.126	-0.143
-0.127	0.986	-0.272
-0.143	-0.272	0.988

STA.NO.3413 WITH STA.NO.5735

0.942	-0.151	-0.076
-0.153	0.919	-0.005
-0.086	-0.015	0.934

STA.NO.3413 WITH STA.NO.6055

0.767	-0.066	0.019
0.055	0.716	-0.001
-0.040	-0.069	0.750

STA.NO.3413 WITH STA.NO.9029

0.970	-0.142	-0.068
-0.143	0.959	0.004
-0.067	0.004	0.966

STA.NO.3476 WITH STA.NO.5735

0.774	-0.194	-0.023
-0.135	0.542	-0.107
-0.217	-0.002	0.697

STA.NO.3476 WITH STA.NO.6008

0.985	-0.380	-0.093
-0.381	0.985	-0.131
-0.092	-0.130	0.987

STA.NO.3648 WITH STA.NO.5648

0.990	-0.001	-0.018
-0.001	0.993	-0.320
-0.018	-0.320	0.994

STA.NO.4050 WITH STA.NO.9002

0.964	0.147	-0.209
0.145	0.950	-0.125
-0.212	-0.128	0.977

STA.NO.4082 WITH STA.NO.9010

0.793	-0.085	0.009
-0.060	0.865	-0.359
-0.008	-0.358	0.863

STA.NO.4280 WITH STA.NO.6134

0.702	0.065	-0.126
0.068	0.718	-0.304
-0.139	-0.328	0.778

STA.NO.4740 WITH STA.NO.7039

0.953	-0.215	0.012
-0.211	0.977	-0.361
0.011	-0.360	0.974

STA.NO.5001 WITH STA.NO.5911

0.803	-0.140	0.216
-0.356	0.931	-0.486
0.265	-0.292	0.897

STA.NO.3405 WITH STA.NO.4081

0.950	-0.112	0.144
-0.121	0.979	-0.378
0.158	-0.378	0.972

STA.NO.3413 WITH STA.NO.5712

0.772	-0.121	-0.196
-0.174	0.524	0.018
-0.012	-0.088	0.677

STA.NO.3413 WITH STA.NO.5736

0.791	-0.089	0.029
0.054	0.754	-0.006
-0.042	-0.068	0.769

STA.NO.3413 WITH STA.NO.6067

0.985	-0.145	-0.069
-0.144	0.979	0.003
-0.069	0.003	0.983

STA.NO.3476 WITH STA.NO.5712

0.943	-0.377	-0.092
-0.369	0.940	-0.127
-0.080	-0.123	0.949

STA.NO.3476 WITH STA.NO.5912

0.757	-0.289	-0.120
-0.440	0.616	-0.076
0.013	-0.188	0.723

STA.NO.3499 WITH STA.NO.6009

1.000	-0.065	0.066
-0.065	1.000	-0.201
0.066	-0.201	1.000

STA.NO.4050 WITH STA.NO.6069

0.953	0.149	-0.211
0.146	0.935	-0.126
-0.214	-0.132	0.970

STA.NO.4082 WITH STA.NO.7072

0.773	-0.083	0.009
-0.058	0.852	-0.357
-0.009	-0.357	0.850

STA.NO.4280 WITH STA.NO.6111

0.702	0.065	-0.126
0.068	0.719	-0.304
-0.138	-0.328	0.778

STA.NO.4280 WITH STA.NO.9425

0.726	0.065	-0.123
0.066	0.741	-0.300
-0.134	-0.321	0.795

STA.NO.5001 WITH STA.NO.5907

0.877	0.094	0.090
0.136	0.963	-0.545
0.145	-0.395	0.939

STA.NO.5001 WITH STA.NO.5912

0.652	0.049	0.187
-0.066	0.752	-0.597
-0.213	0.054	0.794

Table A - 2 (cont'd)

STA.NO.5001 WITH STA.NO.5914		
-0.517	0.065	-0.012
-0.075	-0.802	0.242
0.159	0.185	-0.589

STA.NO.5201 WITH STA.NO.6003		
0.929	0.201	-0.129
0.189	0.935	-0.357
-0.126	-0.367	0.961

STA.NO.5410 WITH STA.NO.5941		
0.790	-0.220	0.103
-0.032	0.796	-0.140
0.149	-0.119	0.849

STA.NO.5410 WITH STA.NO.6066		
0.788	-0.008	-0.031
-0.186	0.779	-0.109
0.023	-0.164	0.821

STA.NO.5712 WITH STA.NO.5912		
0.803	-0.303	-0.114
-0.450	0.655	-0.073
0.017	-0.194	0.764

STA.NO.5712 WITH STA.NO.6067		
0.784	-0.178	-0.013
-0.123	0.535	-0.089
-0.199	0.019	0.689

STA.NO.5713 WITH STA.NO.5739		
0.997	-0.008	0.250
-0.009	0.997	-0.226
0.250	-0.225	0.998

STA.NO.5713 WITH STA.NO.6007		
0.937	-0.007	0.243
0.004	0.938	-0.227
0.243	-0.224	0.966

STA.NO.5715 WITH STA.NO.5736		
0.622	0.136	0.201
0.056	0.830	-0.105
0.201	-0.110	0.731

STA.NO.5715 WITH STA.NO.6055		
0.616	0.135	0.190
0.061	0.810	-0.105
0.193	-0.103	0.709

STA.NO.5717 WITH STA.NO.5720		
0.751	-0.095	0.029
0.185	0.844	-0.087
0.108	-0.190	0.829

STA.NO.5717 WITH STA.NO.5923		
0.626	-0.015	-0.056
0.171	0.802	-0.162
0.030	-0.200	0.704

STA.NO.5717 WITH STA.NO.6016		
0.567	0.080	-0.044
0.093	0.773	-0.177
-0.001	-0.164	0.686

STA.NO.5001 WITH STA.NO.5915		
0.846	0.127	0.091
0.062	0.918	-0.612
0.015	-0.236	0.914

STA.NO.5410 WITH STA.NO.5730		
0.835	0.004	-0.030
-0.195	0.812	-0.105
0.031	-0.166	0.847

STA.NO.5410 WITH STA.NO.6012		
0.788	-0.008	-0.031
-0.186	0.779	-0.109
0.023	-0.164	0.821

STA.NO.5712 WITH STA.NO.5725		
0.818	-0.200	-0.008
-0.126	0.577	-0.101
-0.223	0.004	0.731

STA.NO.5712 WITH STA.NO.6008		
0.957	-0.395	-0.079
-0.384	0.955	-0.124
-0.090	-0.128	0.962

STA.NO.5712 WITH STA.NO.9029		
0.772	-0.175	-0.012
-0.122	0.524	-0.087
-0.196	0.019	0.677

STA.NO.5713 WITH STA.NO.5924		
0.842	0.127	0.080
0.188	0.604	-0.090
0.138	-0.019	0.635

STA.NO.5715 WITH STA.NO.5717		
0.613	-0.006	0.047
0.193	0.776	-0.087
0.132	-0.163	0.728

STA.NO.5715 WITH STA.NO.5925		
0.776	0.047	0.125
0.097	0.808	-0.091
0.103	-0.136	0.840

STA.NO.5715 WITH STA.NO.6063		
0.915	0.108	0.117
0.109	0.938	-0.121
0.125	-0.116	0.951

STA.NO.5717 WITH STA.NO.5744		
0.610	0.073	-0.065
0.085	0.811	-0.187
-0.008	-0.160	0.716

STA.NO.5717 WITH STA.NO.5925		
0.655	0.156	0.100
-0.069	0.740	-0.168
0.030	-0.091	0.767

STA.NO.5717 WITH STA.NO.6042		
0.726	-0.086	0.027
0.183	0.821	-0.091
0.101	-0.188	0.811

Table A - 2 (cont'd)

STA.NO.5717 WITH STA.NO.9028

0.724	-0.087	0.027
0.184	0.870	-0.090
0.102	-0.187	0.810

STA.NO.5720 WITH STA.NO.9028

0.962	0.086	0.009
0.086	0.966	-0.154
0.010	-0.155	0.975

STA.NO.5721 WITH STA.NO.5923

0.895	0.222	0.093
-0.056	0.867	-0.200
0.064	-0.159	0.815

STA.NO.5723 WITH STA.NO.5726

0.854	-0.136	-0.112
0.207	0.820	0.080
-0.045	0.083	0.831

STA.NO.5723 WITH STA.NO.5931

0.924	-0.217	-0.141
0.089	0.911	0.082
-0.120	0.141	0.917

STA.NO.5723 WITH STA.NO.6047

0.812	-0.134	-0.109
0.192	0.785	0.076
-0.046	0.077	0.804

STA.NO.5726 WITH STA.NO.5931

0.874	0.061	-0.058
-0.034	0.817	0.062
-0.086	0.112	0.860

STA.NO.5726 WITH STA.NO.5934

0.844	-0.127	-0.175
0.220	0.832	0.031
-0.055	0.104	0.839

STA.NO.5726 WITH STA.NO.5937

0.974	-0.075	-0.155
0.088	0.925	0.070
-0.091	0.081	0.919

STA.NO.5730 WITH STA.NO.5935

0.840	-0.001	-0.037
-0.204	0.922	-0.105
-0.084	-0.124	0.829

STA.NO.5730 WITH STA.NO.6012

0.942	-0.160	-0.109
-0.161	0.952	-0.080
-0.119	-0.073	0.965

STA.NO.5732 WITH STA.NO.5733

0.783	-0.160	0.142
0.057	0.834	-0.371
-0.067	-0.239	0.841

STA.NO.5732 WITH STA.NO.5938

0.839	0.023	-0.047
-0.293	0.859	-0.117
0.136	-0.321	0.781

STA.NO.5720 WITH STA.NO.6042

0.962	0.086	0.009
0.085	0.966	-0.154
0.010	-0.156	0.975

STA.NO.5721 WITH STA.NO.5744

0.784	0.240	0.059
-0.101	0.781	-0.191
0.038	-0.162	0.700

STA.NO.5721 WITH STA.NO.6015

0.929	0.040	0.099
0.021	0.941	-0.130
0.092	-0.113	0.961

STA.NO.5723 WITH STA.NO.5930

0.862	0.054	-0.122
0.083	0.813	0.129
-0.095	0.007	0.858

STA.NO.5723 WITH STA.NO.5937

0.786	-0.127	-0.086
0.284	0.669	0.011
-0.027	0.056	0.708

STA.NO.5726 WITH STA.NO.5930

0.928	0.206	-0.068
-0.119	0.857	0.146
-0.180	0.097	0.872

STA.NO.5726 WITH STA.NO.5933

0.834	-0.019	-0.147
0.120	0.811	0.124
-0.090	0.137	0.855

STA.NO.5726 WITH STA.NO.5935

0.905	-0.117	-0.172
0.141	0.834	-0.007
-0.065	-0.009	0.862

STA.NO.5726 WITH STA.NO.6047

0.947	0.002	-0.112
0.003	0.955	0.130
-0.109	0.126	0.966

STA.NO.5730 WITH STA.NO.5937

0.692	0.089	0.004
-0.158	0.775	-0.114
-0.109	-0.141	0.636

STA.NO.5730 WITH STA.NO.6066

0.941	-0.160	-0.109
-0.161	0.952	-0.080
-0.119	-0.073	0.965

STA.NO.5732 WITH STA.NO.5934

0.673	0.078	-0.109
-0.300	0.752	-0.004
0.065	-0.267	0.604

STA.NO.5732 WITH STA.NO.6059

0.759	-0.146	0.131
0.057	0.799	-0.366
-0.067	-0.239	0.821

Table A - 2 (cont'd)

STA.NO.5733 WITH STA.NO.5941

0.836	-0.055	0.134
0.044	0.815	-0.297
-0.095	-0.169	0.902

STA.NO.5733 WITH STA.NO.6059

0.974	0.039	0.028
0.031	0.959	-0.304
0.030	-0.303	0.976

STA.NO.5734 WITH STA.NO.6004

0.952	-0.305	-0.146
-0.311	0.963	-0.116
-0.137	-0.110	0.979

STA.NO.5735 WITH STA.NO.6008

0.785	-0.137	-0.219
-0.197	0.551	-0.001
-0.021	-0.107	0.707

STA.NO.5735 WITH STA.NO.6067

0.956	-0.157	-0.087
-0.153	0.939	-0.015
-0.077	-0.005	0.951

STA.NO.5736 WITH STA.NO.6055

0.955	0.014	-0.008
0.005	0.944	-0.027
-0.002	-0.035	0.957

STA.NO.5736 WITH STA.NO.6067

0.803	0.055	-0.042
-0.091	0.770	-0.069
0.030	-0.005	0.782

STA.NO.5739 WITH STA.NO.5924

0.843	0.127	0.080
0.189	0.604	-0.089
0.138	-0.019	0.635

STA.NO.5744 WITH STA.NO.5923

0.944	0.083	0.052
0.246	0.954	-0.137
0.077	-0.153	0.888

STA.NO.5744 WITH STA.NO.6015

0.765	-0.075	0.037
0.229	0.756	-0.159
0.052	-0.176	0.699

STA.NO.5744 WITH STA.NO.6065

0.743	0.183	0.036
0.155	0.814	-0.129
0.044	-0.145	0.777

STA.NO.5907 WITH STA.NO.5912

0.608	0.258	0.143
0.026	0.778	-0.563
-0.213	-0.052	0.784

STA.NO.5911 WITH STA.NO.5912

0.649	-0.288	0.389
-0.229	0.712	-0.503
-0.131	-0.107	0.886

STA.NO.5733 WITH STA.NO.6011

0.670	-0.040	-0.108
-0.112	0.780	-0.348
0.016	-0.250	0.317

STA.NO.5733 WITH STA.NO.9012

0.664	-0.042	-0.107
-0.113	0.768	-0.348
0.016	-0.248	0.313

STA.NO.5735 WITH STA.NO.5736

0.835	-0.096	0.025
0.071	0.810	-0.019
-0.049	-0.076	0.807

STA.NO.5735 WITH STA.NO.6055

0.808	-0.071	0.014
0.071	0.768	-0.015
-0.047	-0.077	0.784

STA.NO.5735 WITH STA.NO.9029

0.942	-0.155	-0.085
-0.152	0.919	-0.014
-0.075	-0.004	0.934

STA.NO.5736 WITH STA.NO.6063

0.605	0.031	0.190
0.115	0.791	-0.109
0.166	-0.089	0.707

STA.NO.5736 WITH STA.NO.9029

0.791	0.053	-0.041
-0.090	0.754	-0.067
0.030	-0.004	0.769

STA.NO.5739 WITH STA.NO.6007

0.934	-0.007	0.243
0.004	0.935	-0.226
0.243	-0.223	0.964

STA.NO.5744 WITH STA.NO.5924

0.883	0.218	0.053
0.093	0.824	-0.084
0.013	-0.076	0.760

STA.NO.5744 WITH STA.NO.6016

0.923	0.195	0.089
0.194	0.941	-0.104
0.095	-0.114	0.955

STA.NO.5907 WITH STA.NO.5911

0.663	-0.035	0.217
-0.295	0.855	-0.440
0.285	-0.412	0.840

STA.NO.5907 WITH STA.NO.5915

0.932	0.353	0.028
0.221	0.969	-0.619
-0.060	-0.380	0.974

STA.NO.5911 WITH STA.NO.5915

0.674	-0.277	0.317
-0.134	0.805	-0.473
0.104	-0.330	0.853

Table A - 2 (cont'd)

STA.NO.5912 WITH STA.NO.5915

0.794	0.027	-0.240
0.115	0.885	-0.145
0.046	-0.491	0.872

STA.NO.5923 WITH STA.NO.5924

0.729	0.229	0.016
0.030	0.776	-0.109
-0.034	-0.111	0.629

STA.NO.5923 WITH STA.NO.6016

0.877	0.243	0.084
0.104	0.903	-0.147
0.063	-0.141	0.855

STA.NO.5924 WITH STA.NO.6007

0.807	0.169	0.132
0.134	0.608	-0.022
0.076	-0.100	0.628

STA.NO.5925 WITH STA.NO.6063

0.715	0.087	0.101
0.046	0.757	-0.130
0.120	-0.084	0.800

STA.NO.5930 WITH STA.NO.5933

0.795	-0.152	-0.191
0.276	0.770	0.092
-0.006	0.127	0.790

STA.NO.5930 WITH STA.NO.5937

0.865	-0.129	-0.218
0.289	0.718	0.049
-0.043	0.097	0.770

STA.NO.5931 WITH STA.NO.5935

0.834	-0.165	-0.051
0.140	0.696	-0.032
-0.045	-0.016	0.710

STA.NO.5931 WITH STA.NO.6047

0.832	-0.039	-0.084
0.053	0.784	0.106
-0.057	0.058	0.830

STA.NO.5933 WITH STA.NO.5935

0.740	-0.027	-0.235
0.120	0.663	0.037
-0.093	0.001	0.769

STA.NO.5933 WITH STA.NO.5936

0.816	-0.250	-0.156
0.178	0.843	-0.064
-0.031	0.057	0.774

STA.NO.5934 WITH STA.NO.5935

0.876	-0.003	-0.168
-0.044	0.881	-0.006
-0.128	-0.054	0.920

STA.NO.5934 WITH STA.NO.5936

0.939	-0.164	-0.127
0.020	0.950	-0.061
-0.100	0.012	0.914

STA.NO.5912 WITH STA.NO.6008

0.768	-0.446	0.015
-0.294	0.625	-0.190
-0.120	-0.076	0.733

STA.NO.5923 WITH STA.NO.6015

0.857	-0.038	0.065
0.202	0.831	-0.157
0.081	-0.185	0.801

STA.NO.5923 WITH STA.NO.6065

0.709	0.225	0.033
0.106	0.791	-0.145
0.031	-0.159	0.706

STA.NO.5924 WITH STA.NO.6016

0.818	0.108	0.023
0.212	0.782	-0.075
0.064	-0.089	0.734

STA.NO.5930 WITH STA.NO.5931

0.782	-0.033	-0.095
0.180	0.636	0.001
-0.062	0.109	0.764

STA.NO.5930 WITH STA.NO.5935

0.759	-0.097	-0.232
0.336	0.568	-0.013
-0.018	0.008	0.687

STA.NO.5930 WITH STA.NO.6047

0.878	-0.119	-0.174
0.190	0.815	0.094
-0.065	0.135	0.843

STA.NO.5931 WITH STA.NO.5937

0.835	-0.089	-0.052
0.130	0.715	0.023
-0.042	0.030	0.745

STA.NO.5933 WITH STA.NO.5934

0.901	-0.163	-0.180
0.099	0.887	-0.008
-0.077	0.050	0.879

STA.NO.5933 WITH STA.NO.5937

0.844	-0.001	-0.180
0.041	0.796	0.095
-0.126	0.077	0.826

STA.NO.5933 WITH STA.NO.6047

0.785	0.106	-0.087
-0.025	0.772	0.134
-0.137	0.127	0.825

STA.NO.5934 WITH STA.NO.5937

0.904	0.076	-0.129
-0.104	0.914	0.063
-0.164	-0.001	0.809

STA.NO.5934 WITH STA.NO.6047

0.797	0.199	-0.053
-0.126	0.797	0.101
-0.161	0.030	0.809

Table A - 2 (cont'd)

STA.NO.5935 WITH STA.NO.5937

0.950	0.016	-0.095
-0.100	0.929	-0.039
-0.157	-0.031	0.911

STA.NO.5935 WITH STA.NO.6012

0.789	-0.200	-0.083
-0.016	0.879	-0.131
-0.055	-0.101	0.796

STA.NO.5935 WITH STA.NO.6066

0.789	-0.200	-0.083
-0.016	0.879	-0.131
-0.055	-0.101	0.795

STA.NO.5937 WITH STA.NO.6047

0.923	0.075	-0.069
-0.078	0.886	0.079
-0.144	0.066	0.887

STA.NO.6002 WITH STA.NO.7043

0.966	-0.014	-0.009
-0.014	0.977	-0.396
-0.008	-0.397	0.983

STA.NO.6003 WITH STA.NO.6134

0.728	0.180	-0.110
0.170	0.567	-0.199
-0.149	-0.163	0.758

STA.NO.6011 WITH STA.NO.6059

0.687	-0.112	0.009
-0.043	0.813	-0.248
-0.111	-0.360	0.319

STA.NO.6012 WITH STA.NO.6066

0.999	-0.163	-0.117
-0.163	1.000	-0.079
-0.117	-0.079	1.000

STA.NO.6019 WITH STA.NO.9007

0.784	-0.210	-0.100
-0.235	0.578	0.273
-0.013	0.290	0.661

STA.NO.6022 WITH STA.NO.6059

0.766	0.065	0.025
0.007	0.565	-0.075
0.077	-0.032	0.590

STA.NO.6023 WITH STA.NO.6032

0.539	-0.223	0.041
-0.044	0.775	-0.199
-0.006	-0.101	0.639

STA.NO.6031 WITH STA.NO.6060

0.909	0.001	0.110
0.187	0.653	-0.231
0.203	-0.225	0.780

STA.NO.6038 WITH STA.NO.6111

0.859	0.140	-0.116
0.231	0.594	-0.430
0.009	-0.344	0.478

STA.NO.5935 WITH STA.NO.5938

0.724	-0.096	-0.125
0.064	0.774	-0.073
-0.162	0.033	0.818

STA.NO.5935 WITH STA.NO.6047

0.862	0.124	-0.063
-0.117	0.802	-0.008
-0.159	-0.006	0.833

STA.NO.5937 WITH STA.NO.5938

0.745	-0.147	-0.150
0.157	0.810	-0.038
-0.108	0.098	0.768

STA.NO.5941 WITH STA.NO.6059

0.820	0.049	-0.093
-0.056	0.785	-0.172
0.130	-0.295	0.882

STA.NO.6003 WITH STA.NO.6111

0.728	0.180	-0.110
0.170	0.567	-0.199
-0.149	-0.163	0.758

STA.NO.6008 WITH STA.NO.6067

0.753	-0.176	-0.025
-0.134	0.512	-0.096
-0.195	0.013	0.667

STA.NO.6011 WITH STA.NO.9012

0.991	-0.078	-0.117
-0.077	0.985	-0.443
-0.116	-0.442	0.989

STA.NO.6016 WITH STA.NO.6065

0.777	0.177	0.035
0.148	0.856	-0.144
0.052	-0.143	0.813

STA.NO.6019 WITH STA.NO.9011

0.977	-0.236	-0.118
-0.236	0.987	0.166
-0.120	0.164	0.994

STA.NO.6023 WITH STA.NO.6031

0.834	0.193	0.181
-0.053	0.556	-0.272
-0.018	-0.284	0.606

STA.NO.6023 WITH STA.NO.6060

0.904	-0.042	0.082
-0.115	0.864	-0.214
-0.017	-0.247	0.791

STA.NO.6032 WITH STA.NO.6060

0.568	-0.045	-0.007
-0.216	0.701	-0.191
0.043	-0.148	0.766

STA.NO.6038 WITH STA.NO.6134

0.859	0.140	-0.116
0.231	0.594	-0.430
0.009	-0.344	0.478

Table A - 2 (cont'd)

STA.NO.6038 WITH STA.NO.9425		
0.830	0.138	-0.114
0.224	0.577	-0.422
0.008	-0.234	0.468
STA.NO.6050 WITH STA.NO.6061		
0.156	-0.367	0.042
0.165	0.851	-0.073
-0.233	-0.261	0.598
STA.NO.6055 WITH STA.NO.6067		
0.779	0.056	-0.041
-0.068	0.732	-0.070
0.019	-0.001	0.764
STA.NO.6059 WITH STA.NO.9012		
0.681	-0.045	-0.111
-0.113	0.801	-0.360
0.009	-0.247	0.315
STA.NO.6068 WITH STA.NO.9002		
0.989	0.154	-0.219
0.154	0.984	-0.135
-0.218	-0.133	0.993
STA.NO.6111 WITH STA.NO.9425		
0.967	0.092	-0.173
0.089	0.970	-0.412
-0.173	-0.408	0.978
STA.NO.7072 WITH STA.NO.9010		
0.973	-0.059	-0.022
-0.060	0.985	-0.408
-0.022	-0.408	0.984
STA.NO.8009 WITH STA.NO.8011		
0.459	0.144	0.029
0.079	0.574	-0.359
0.078	-0.401	0.811
STA.NO.8009 WITH STA.NO.8019		
0.467	0.044	0.030
-0.044	0.823	-0.344
0.186	-0.281	0.752
STA.NO.8010 WITH STA.NO.8019		
0.783	-0.031	0.169
-0.070	0.963	-0.357
0.252	-0.334	0.927
STA.NO.8010 WITH STA.NO.9004		
0.586	0.144	0.315
-0.101	0.807	-0.401
0.543	-0.588	0.817
STA.NO.8010 WITH STA.NO.9091		
0.686	-0.180	0.246
-0.017	0.680	-0.379
0.260	0.088	0.835
STA.NO.8010 WITH STA.NO.9432		
0.588	-0.124	0.065
0.044	0.721	-0.276
-0.058	-0.029	0.773
STA.NO.6042 WITH STA.NO.9029		
0.981	0.087	0.008
0.088	0.983	-0.157
0.008	-0.156	0.987
STA.NO.6055 WITH STA.NO.6063		
0.603	0.035	0.183
0.113	0.782	-0.102
0.156	-0.089	0.687
STA.NO.6055 WITH STA.NO.9029		
0.767	0.054	-0.040
-0.068	0.716	-0.068
0.020	0.000	0.750
STA.NO.6067 WITH STA.NO.9029		
0.985	-0.145	-0.069
-0.146	0.979	0.004
-0.068	0.005	0.983
STA.NO.6111 WITH STA.NO.6134		
0.999	0.092	-0.178
0.092	0.999	-0.417
-0.178	-0.417	1.000
STA.NO.6134 WITH STA.NO.9425		
0.966	0.092	-0.174
0.089	0.969	-0.411
-0.173	-0.408	0.978
STA.NO.8009 WITH STA.NO.8010		
0.514	0.024	-0.025
-0.016	0.838	-0.286
0.046	-0.277	0.730
STA.NO.8009 WITH STA.NO.8015		
0.464	0.048	0.030
-0.042	0.824	-0.343
0.183	-0.290	0.751
STA.NO.8010 WITH STA.NO.8015		
0.777	-0.026	0.167
-0.068	0.960	-0.356
0.248	-0.340	0.925
STA.NO.8010 WITH STA.NO.8030		
0.562	-0.015	0.147
-0.046	0.832	-0.314
0.138	-0.318	0.790
STA.NO.8010 WITH STA.NO.9051		
0.685	-0.180	0.245
-0.017	0.679	-0.378
0.259	0.088	0.834
STA.NO.8010 WITH STA.NO.9431		
0.546	-0.121	0.003
0.092	0.799	-0.299
-0.200	-0.078	0.839
STA.NO.9015 WITH STA.NO.8019		
0.978	-0.036	0.321
-0.065	0.992	-0.377
0.323	-0.371	0.991

Table A - 2 (cont'd)

STA.NO.8015 WITH STA.NO.8030

0.702	-0.054	0.277
-0.043	0.864	-0.333
0.190	-0.351	0.852

STA.NO.8015 WITH STA.NO.9051

0.833	-0.119	0.364
-0.015	0.682	-0.392
0.309	0.025	0.907

STA.NO.8015 WITH STA.NO.9431

0.489	-0.093	0.149
0.102	0.805	-0.324
-0.148	-0.133	0.839

STA.NO.8019 WITH STA.NO.8030

0.691	-0.054	0.281
-0.045	0.859	-0.326
0.191	-0.349	0.848

STA.NO.8019 WITH STA.NO.9051

0.841	-0.121	0.369
-0.016	0.696	-0.391
0.311	0.023	0.912

STA.NO.8019 WITH STA.NO.9431

0.493	-0.095	0.152
0.091	0.815	-0.313
-0.148	-0.134	0.842

STA.NO.8030 WITH STA.NO.9004

0.549	0.071	0.299
-0.107	0.749	-0.366
0.488	-0.500	0.774

STA.NO.8030 WITH STA.NO.9091

0.593	-0.116	0.241
-0.008	0.570	-0.352
0.269	0.008	0.780

STA.NO.9004 WITH STA.NO.9091

0.784	0.150	0.517
0.044	0.285	-0.474
0.415	-0.208	0.951

STA.NO.9006 WITH STA.NO.9008

0.450	0.187	-0.143
0.046	0.819	0.457
0.098	0.448	0.749

STA.NO.9051 WITH STA.NO.9091

0.995	-0.107	0.423
-0.107	0.999	-0.157
0.424	-0.157	0.998

STA.NO.9051 WITH STA.NO.9432

0.592	-0.074	0.225
-0.278	0.859	0.098
0.140	-0.207	0.718

STA.NO.9091 WITH STA.NO.9432

0.594	-0.074	0.226
-0.278	0.860	0.098
0.140	-0.207	0.719

STA.NO.8015 WITH STA.NO.9004

0.801	0.047	0.434
-0.111	0.839	-0.415
0.570	-0.582	0.900

STA.NO.8015 WITH STA.NO.9091

0.835	-0.119	0.365
-0.014	0.683	-0.393
0.309	0.025	0.908

STA.NO.8015 WITH STA.NO.9432

0.563	-0.093	0.183
0.053	0.723	-0.306
-0.005	-0.0[illegible]	0.783

STA.NO.8019 WITH STA.NO.9004

0.813	[illegible]	0.441
-0.107	0.836	-0.415
0.573	[illegible]	0.906

STA.NO.8019 WITH STA.NO.9091

0.843	-0.121	0.369
-0.016	0.696	-0.392
0.312	0.023	0.9[illegible]4

STA.NO.8019 WITH STA.NO.9432

0.568	-0.095	0.186
0.046	0.734	-0.299
-0.004	-0.085	0.786

STA.NO.8030 WITH STA.NO.9051

0.592	-0.116	0.241
-0.009	0.570	-0.352
0.268	0.009	0.778

STA.NO.9004 WITH STA.NO.9051

0.781	0.150	0.516
0.043	0.285	-0.473
0.414	-0.208	0.949

STA.NO.9004 WITH STA.NO.9426

0.357	-0.153	0.440
0.395	0.852	-0.532
0.002	-0.336	0.705

STA.NO.9007 WITH STA.NO.9011

0.802	-0.235	-0.012
-0.211	0.584	0.290
-0.101	0.273	0.665

STA.NO.9051 WITH STA.NO.9431

0.482	-0.070	0.181
-0.390	0.877	0.216
0.021	-0.247	0.724

STA.NO.9091 WITH STA.NO.9431

0.484	-0.070	0.182
-0.3[illegible]	0.878	0.216
0.021	-0.248	0.726

STA.NO.9431 WITH STA.NO.9432

0.710	-0.337	-0.159
-0.231	0.889	-0.055
-0.160	0.081	0.823

Table A - 3

Station Correlation Coefficients $\rho_{ij} > 0.75$ (Solution WN12)

STA.NO.1032

1.000	0.905	-0.182
0.905	1.000	-0.514
-0.182	-0.514	1.000

STA.NO.3902

1.000	0.922	-0.742
0.922	1.000	-0.699
-0.742	-0.699	1.000

STA.NO.9427

1.000	-0.807	0.487
-0.807	1.000	-0.777
0.487	-0.777	1.000

STA.NO.3478

1.000	0.239	-0.913
0.239	1.000	-0.324
-0.913	-0.324	1.000

STA.NO.6078

1.000	-0.532	-0.813
-0.532	1.000	0.569
-0.813	0.569	1.000