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SATELLITE TRIANGULATION IN EUROPE FROM WEST AND ISAGEX DATA

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PREFACE AND ACKNOWLEDGMENTS

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TABLE OF CONTENTS

1. INTRODUCTION

In 1974 the Department of Geodetic Science at The Ohio State University (OSU) obtained observational data that was acquired during the West European Satellite Triangulation (WEST) program and the International Satellite Geodesy Experiment (ISAGEX) campaign.

The purpose of obtaining this observational data was twofold. Primarily it was intended to perform a geometric solution to improve the present values of coordinates of the European stations in the OSU WN14 solutions [Mueller, et al., 1973]. The secondary aim was to add some new stations and to assess the quality of the WN14 solution with the help of the additional data available.

This report contains the details of the above investigation as follows: In Section 2 the status of the data as received, the preprocessing required and the preliminary tests carried out for the initial screening of the data is discussed. Sections 3 and 4 describe the details of the adjustment computations carried out. The results of the adjustments are discussed in Section 5, which gives some concluding remarks on the entire investigation.

2. DATA

2.1 WEST Data

The unified optical program, otherwise known as WEST, was begun in 1966. The program was conducted by a subcommittee of the International Association of Geodesy (IAG). The program was formally terminated in 1972, as per resolution 1 of the Sixth Meeting of the Subcommission in 1972 [IAG, 1972]. Reduced data of approximately 3,500 simultaneous plates formed a major part of the data. However, more data may be expected because the plate reduction is still in progress.

WEST data was received by OSU in two forms. The first form consisted of cards in two sets. One set contained the direction cosines, referred to the Greenwich Hour Angle/Declination coordinate system, for a single fictitious image per plate, for all simultaneous events. The other set contained information about the standard errors associated with the single image observational data derived from the polynomial fitting. The second form contained the direction cosines of seven fictitious images per plate for all simultaneous events. The information about the standard errors of this observational data was not available separately. This report, therefore, contains only the results for single image data.

The Ohio State University Geometric and Orbital (Adjustment) Program (OSUGOP) for Satellite Observations [Reilly, et al., 1972] cannot accept optical data in the Greenwich Hour Angle/Declination system. A modified version of OSUGOP which had been previously used [Reilly, et al., 1972] to reduce the BC-4 seven image data, was further modified to accept single image observations. A separate program was made to merge the observational data of the single images on the first set of cards and the standard errors on the second set, thus forming an input set for the modified program.

2.2 ISAGEX Data

The Centre National d'Etudes Spatiales (CNES) provided OSU with data acquired during the ISAGEX satellite observation program. The data consisted of 5,186 laser ranges and 3,562 optical observations which were purported to be simultaneous.

The laser data was examined for simultaneity by computing the observation times at the satellite in International Atomic Time for all data. With a criterion of 0.2 ms discrepancy for simultaneity, no simultaneous observations could be detected. Laser data, therefore, was excluded from the present investigation.

Examination of the optical data was more complicated. The first test performed was to discover the amount of data which was simultaneous by using the above mentioned criterion. A wider definition of simultaneity was used to accommodate any possible variations in observation times which might arise from preprocessing. Approximately only ten percent of the data satisfied the test, indicating that further examination was warranted.

The requirement for preprocessing was reconsidered. The ISAGEX Data Handling Booklet [Brachet, 1973] contained some of the needed information. Further information was obtained [CNES, 1973, 1972 and 1970] which indicated that preprocessing by OSU was possible, but not practical due to limited resources. Subsequently, Wolf Research and Development Corporation offered to undertake the preprocessing of the data using their GEODYN program. Observations made on satellites GEOS I and II, DIADEME-C and -D were preprocessed initially because their orbital elements were available at Wolf Research and Development Corporation for the observational period. Orbital elements for MIDAS and PAGEOS were later provided by the Smithsonian Astrophysical Observatory (SAO). However, there were difficulties in obtaining the correct input data for preprocessing and it was decided not to use the observational data pertaining to either MIDAS or PAGEOS satellites.

The preprocessed optical data was tested for simultaneity with a criterion of 0.2 ms for discrepancy. A total of 353 observations proved to be simultaneous, involving 13 different stations. The acceptable ISAGEX preprocessed data could be input directly to the OSUGOP program for forming the normal equations and the subsequent adjustments.

3. WEST DATA PROCESSING

3.1 Transformation of Variances

The variances of the observations were given in the form of standard deviations along and across the satellite trail. In a few cases no statistics were provided, and in order not to lose these valuable observations, the standard deviations as given in [Ehrnsperger, 1974, Table 4] were substituted. The modified subroutines which were to be used to compute the normal equations required as input, the standard deviation of the Greenwich Hour Angle multiplied with the cosine of the declination ($\sigma_{GHA} \cdot \cos\delta$), the standard deviation of the declination (σ_δ) and the covariance term. The observational data also contained information about the length of the satellite trail and the declination for the beginning and the end of the satellite trail, which lead to the following transformations (Figures 1 and 2) to obtain $\sigma_{GHA} \cdot \cos\delta$ and σ_δ for the observations.

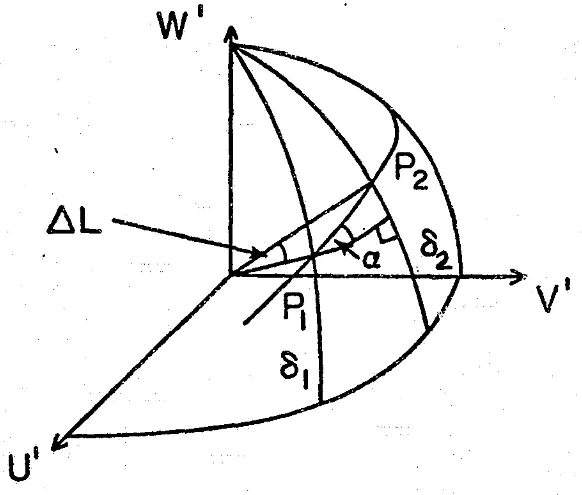

Fig. 1

Transformation of Variances

The following notation is used:

U,′ V,′ W′ : Topocentric Cartesian coordinate system parallel to the conventional geocentric U, V, W coordinate system.

ΔL : Length of the satellite trail.

δ_1, δ_2 : Declinations of the satellite at the beginning and end of the trail.

α : Rotation angle.

P_1, P_2: Satellite trail.

The actual rotation is approximated by a rotation around point P_1 at the beginning of the satellite trail, taken as a straight line.

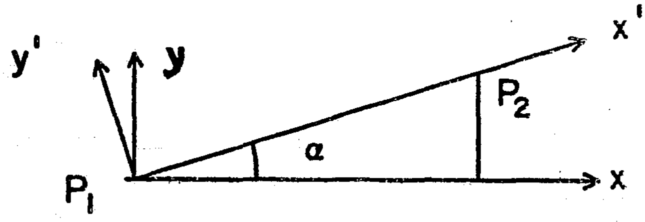

Fig. 2

Rotation to GHA System

If x′, y′ represent the directions along and across the trail and x, y represent the required directions parallel to the U′V′ plane, and along the tangent to the meridian of P_1, respectively, the following relation is obtained:

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \cos(-\alpha) & \sin(-\alpha) \\ -\sin(-\alpha) & \cos(-\alpha) \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix} \tag{3-1}$$

where α is computed from the spherical relation

$$\sin\alpha = \frac{\sin(\delta_2 - \delta_1)}{\sin\Delta L} . \tag{3-2}$$

Using the given variance-covariance matrix

$$\Sigma_{x', y'} = \begin{pmatrix} \sigma_\ell^2 & 0 \\ 0 & \sigma_c^2 \end{pmatrix} \tag{3-3}$$

where σ_ℓ^2 is the variance along the trail and σ_c^2 is the variance across the trail, and by using the relation (3-1) and the law of propagation of errors, the transformed variance-covariance matrix is obtained as given below:

$$\Sigma_{x,y} = \begin{pmatrix} \sigma_x^2 & \sigma_{x,y} \\ \sigma_{x,y} & \sigma_y^2 \end{pmatrix} = \left(\begin{array}{c|c} \cos^2(\alpha)\sigma_\ell^2 + \sin^2(\alpha)\sigma_c^2 & -\sin(\alpha)\cos(\alpha)(\sigma_c^2 - \sigma_\ell^2) \\ \hline -\sin(\alpha)\cos(\alpha)(\sigma_c^2 - \sigma_\ell^2) & \sin^2(\alpha)\sigma_\ell^2 + \cos^2(\alpha)\sigma_c^2 \end{array} \right) \tag{3-4}$$

It should be noted that σ_x stands for $\sigma_{GHA} \cdot \cos\delta$ and that σ_y denotes σ_δ.

3.2 Observation Station Information

3.21 Station Numbering System

The whole data set contains observations from 30 different tracking stations. They are listed in Table 1 and their relative locations can be seen from Figure 3. Since the numbering system for the WEST stations and the WN14 stations are independent, there were some cases where different stations had the same station numbers. In order to avoid confusion, the WEST stations were completely renumbered. The station number consists of four digits, the first two digits arbitrarily chosen as 87. In those cases where the tracking station was listed in [NASA, 1973], the NASA station number was maintained.

3.22 Stations Common with WN14 System

In order to compare and combine the WN14 and WEST systems, the common stations were identified, including those which could be established as common through relative constraints. These are marked in Table 1 with a superscript 2.

3.23 Relative Station Constraints

For the adjustment computations it is important to maintain the exact relationship between nearby stations by introducing relative station constraints. In most cases the information for these constraints was extracted from the Circular Letters [WEST, 1966-1972]. In some cases the relative location of observation stations could be established from Cartesian coordinates given in [Ehrnsperger, 1974]. Details of these constraints are given in Table 2.

Table 1

Tracking Stations

Station Number		NAME	Starting Coordinates in ED-50[1]							Height Constraints	
OSU	Original		Latitude °	′	″	Longitude °	′	″	Ell. Ht (M)	Ell. Ht. (M)	σ (M)
		WEST			STATIONS						
6006[2]	14002	TROMSO	69	39	44.375	18	56	31.020	119.00	113.19	4.0
6016[2]		CATANIA	37	26	42.345	15	02	47.696	-7.00	16.33	4.0
6065[2]		PEISEN	47	48	07.009	11	01	28.574	943.00	960.09	2.5
8004	6004	BRNSG	52	35	05.286	10	30	22.436	77.17	81.31	3.0
8009[2]	9001	DELFTH	52	00	09.240	4	22	21.230	20.70	41.11	4.0
8010[2]	12001	ZIMLD	46	52	40.318	7	27	58.239	900.34	920.58	2.5
8011[2]	13002	MALVRN	52	08	39.066	358	01	59.567	108.60	134.97	4.0
8015[2]		HAUTE PR	43	56	01.140	5	42	49.280	651.00	676.87	4.0
8016	5002	STRBG	48	35	01.884	7	46	11.135	151.90	165.93	3.0
8019[2]	5004	NICEFR	43	43	36.496	7	18	03.309	369.42	394.73	4.0
8030[2]	5001	MUDONI	48	48	25.354	2	13	51.339	155.46	183.23	2.5
8031	13001	EDNBG	55	44	04.054	356	46	21.114	285.10	301.37	3.0
8032	6110	HOPBG	47	48	08.287	11	01	26.245	939.30		
	6010	HOPBG									
8033	6005	FRNFT	50	13	14.257	8	43	51.822	177.70	188.07	3.0
8034	9002	DELFY	52	02	43.850	4	21	40.950	2.00		
8701	1001	GRAZA	47	04	03.821	15	29	40.117	484.60[3]	492.39	3.0
8702	2001	BRXOR	50	47	53.600	4	21	37.750	100.70	115.29	3.0
8703	3001	COPHN	55	44	22.064	12	30	04.101	52.89	52.39	3.0
8705	5003	BRDUX	44	50	06.500	359	28	24.600	77.00[4]	108.82	3.0
8706	5005	GOULT	43	51	12.069	5	13	34.032	200.30		
8710	6012	WSNDF	52	35	05.328	10	30	22.523	76.41		
8711	8004	CATAN	37	26	42.717	15	02	47.326	-7.80		
8712	8005	OPICI	45	40	59.268	13	46	40.675	383.28	395.12	3.0
8713	8006	ORIAA	40	30	01.079	17	38	32.862	179.90	196.50	3.0
8714	8007	SRDIN	39	13	20.960	9	07	04.500	116.97	146.53	3.0
8715	8008	TANIA	37	41	39.050	14	58	31.605	1718.12		
8716	10002	MADRD	40	27	07.699	356	16	31.979	642.38	688.56	3.0
8717	10003	MADRI	40	27	07.687	356	16	31.865	642.38		
8718	6006	KLSRH	49	00	43.050	8	24	43.760	132.50[5]	145.09	3.0
8719	8009	CATNA	37	41	39.050	14	58	31.605	1718.12		
8720	11002	LOVOA	59	20	17.576	17	49	48.173	49.40	41.48	3.0
8722	15001	REKVK	63	57	44.980	337	24	40.020	-26.17[6]	0.40	3.0
		ISAGEX			STATIONS						
8609[7]	8009	ST. MICH	43	55	59.186	5	42	48.383	650.20		
8721[8]	1147	ONDREJOV	49	55	19.4	14	48	03.90	508.61	512.98	3.0
8723[8]	1181	POTSDAM	52	22	51.4	13	03	58.80	109.00	111.81	3.0
9004[2]	9004	SAN FERN	36	27	51.367	353	47	42.091	-12.00	50.44	6.0

[1] Based on [Ehrnsperger, 1974] except where specified by superscript 7 and 8.

[2] Stations used for tying to the WN14 system.

[3] Recomputed in European Datum (ED).

[4] Astro Datum.

[5] ED values interpolated.

[6] Determined by WEST and reintroduced as starting coordinates.

[7] Based on [NASA, 1973].

[8] For details on source see Section 4.

Tracking Station Locations

△ WEST Station
● ISAGEX Station
▲ West and ISAGEX Station

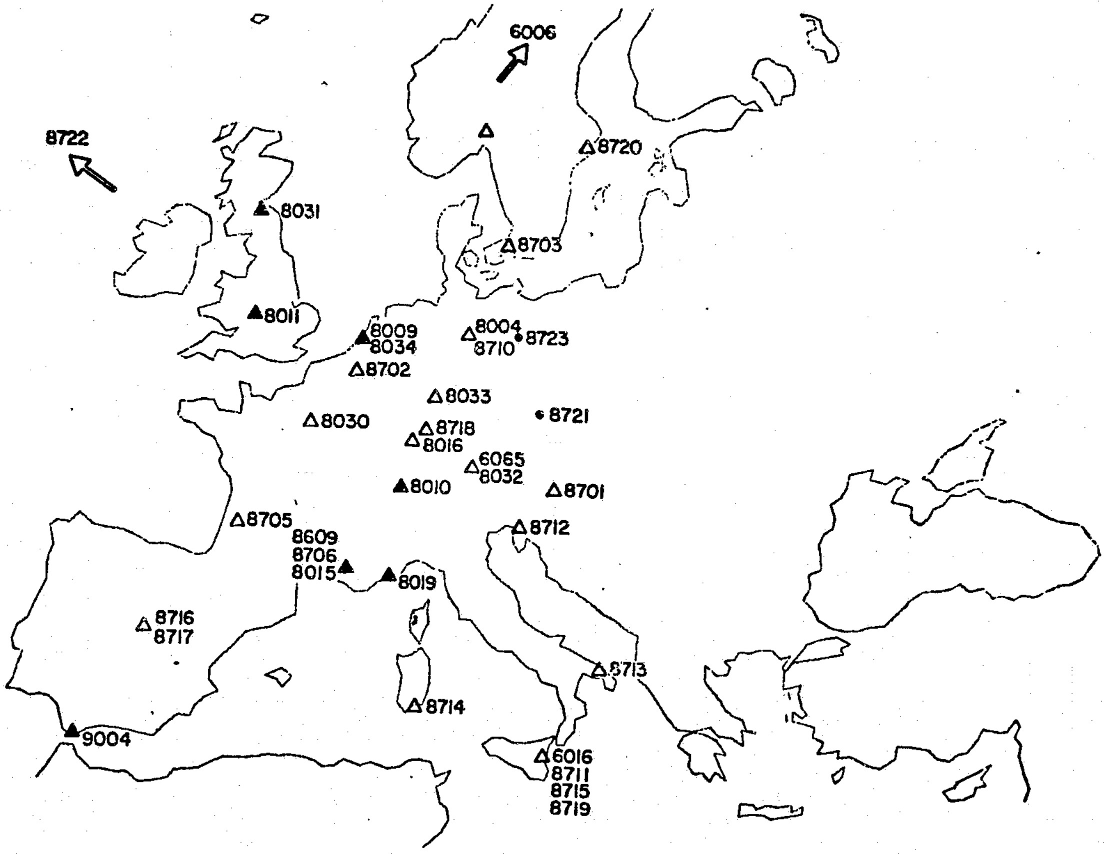

Fig. 3

3.3 Adjustment Computations

The observational data was given in the form of direction cosines in the Average Terrestrial Coordinate System. After conversion to the Greenwich Hour Angle/ Declination system, the observations were used in conjunction with the transformed variances to form a set of normal equations by the modified OSUGOP subroutines as given in Appendix IV.. A total of 396 events proved to be satisfactory. An event is defined as two or more ground stations simultaneously observing one satellite position. Table 4 gives the number of such observations on each line. All observations turned out to be of good quality as verified by means of the "test distance" while computing the normals [Reilly, et al., 1972].

3.31 Preliminary Adjustment

Although the variances are transformed to the Greenwich Hour Angle/ Declination system, they still represent only the errors from the smoothing procedure [Ehrnsperger, 1974]. This procedure yields an overly optimistic estimate for the variances. Thus preliminary adjustments were carried out using only minimum constraints to find the proper scaling factor for the variances. The variance of unit weight was found to be 36.

3.32 Solution WEST 34

This adjustment contains only observational data acquired during the WEST campaign. The version WEST 33 was submitted to the XVI General Assembly of the IUGG held in Grenoble, France on August 18 through September 6, 1975. While working on the combination solution for the WEST and ISAGEX data it was decided to add to the previous WEST 33 solution, the additional relative constraints between station 8015 (HAUTE PROVENCE) and station 8706 (GOULT). Also, some station numbers were modified, giving priority to the NASA station numbering system. But above all, it is recognized that the baseline between 6006 (TROMSO) and 6016 (CATANIA) is not sufficient to transfer scale to the whole network. The WEST satellite network is considered as consisting of two blocks: the central European block with a large number of observations and the northern block, connected to the central block by relatively few observations—namely, between 6006 (TROMSO) and some stations of the central block. An overall scale factor of 10 ppm was computed between the ED50 coordinates and the adjusted values. Comparing individual chords in the two systems it became clear that all chords originating from 6006 (TROMSO) yield a significantly smaller scale factor. Also, the scale factor in the central area is partly inherent in the weighted positional constraints of the WN14 stations. It thus became necessary to include more chord constraints, especially in the central area. These were taken from [Ehrnsperger, 1974].

The present adjustment, WEST 34, contains the following types of constraints appropriately weighted:

a) A priori constraints on coordinates of observation stations which are common with the WN14 solution (Table 1). These coordinates were constrained at the values obtained in the WN14 solution and weighted as per their variances.

b) Relative position constraints (Table 2).

c) Height constraints for stations common to the WN14 solution as per [Mueller, et al., 1973, Table 3.3-3]. Ellipsoidal height constraints were also applied for the other stations after transforming the European Datum height information available [Ehrnsperger, 1974] to the WN14-system. This was accomplished by means of iterations. For the first direct transformation from the ED50 to the WN14 system, the mean values of the shifts given in [Anderle, 1974] were taken and corrected for the offset of the origin of the WN14 system from the geocenter [Mueller, et al., 1973]. The height constraints for the final iteration are shown in Table 1.

d) The scale was introduced through three base lines (Table 3).

The values of the station coordinates as a result of this adjustment are given in Table 5.

Table 2

Relative Station Constraints (WEST)

Station from	to	X (m)	Y (m)	Z (m)	Source **
8711	8719	13329.91	10072.67	-22958.92	3
8711	8715	-4.04	-8.24	7.88	2, 3
8004	8710	1.78	-1.33	-0.16	2, 3
8716	8717	-0.06	2.70	0.28	2, 3
8009	8034	3709.06	1053.54	-2925.82	3, 4
8711	6016	-1.61	-0.43	2.17	2
6065	8032	20.79	53.37	-25.09	4
8015	8706	-9569.56	38443.07	6742.48	3, 4
		ISAGEX			
8609	8015	43.06	-15.80	-43.99	4

Table 3

Base Lines (WEST)

Station from	to	Chord Distance (m)	σ (m)	Source **
6006	6016	3 545 871.454	3.5	1
8011	8032	1 046 479.89	0.65	3
8032	8701	346 945.38	0.27	3
6006	8032	2 457 733.52*	1.20	3
8032	8711	1 194 842.47*	1.20	3

* Base line not used in this adjustment.

** Sources used in these tables:

[1] [Mueller, et al., 1973]

[2] [WEST, 1966-72]

[3] [Ehrnsperger, 1974]

[4] [NASA, 1973]

Table 4

Distribution of WEST Observations per Line

		6006 TRMSO	8004 BRNSG	8009 DELFTH	8010 ZIMLD	8011 MALVRN	8016 STRBG	8019 NICEFR	8030 MUDONI	8031 EDNBG	8032 HOPBG	8033 FRNFT	8034 DELFY	8701 GRAZA	8702 BRXOR	8703 COPHN	8705 BRDUX	8706 GOULT	8710 WSNDF	8711 CATAN	8712 OPICI	8713 ORIAA	8714 SRDIN	8715 TANIA	8716 MADRD	8717 MADRI	8718 KLSRH	8719 CATNA	8720 LOVOA	8722 REKVK
TRMSO	6006																													
BRNSG	8004																													
DELFTH	8009		2																											
ZIMLD	8010			6																										
MALVRN	8011	6		8	8																									
STRBG	8016		3	14	22	32																								
NICEFR	8019				7	1																								
MUDONI	8030			3	1	2	5	4																						
EDNBG	8031	2		1	1	11		3																						
HOPBG	8032	20		3	2	8	1			2																				
FRNFT	8033		3	4	6	4	14				3																			
DELFY	8034				1		2			1																				
GRAZA	8701	1	1	4	8	11	21	2	1	3	1	4	1																	
BRXOR	8702			5	3	6	7	3	1	2		1																		
COPHN	8703			1		3	5		2	1				2	2															
BRDUX	8705				3	2					1	3		3																
GOULT	8706			10	7	11	23					8		1	7															
WSNDF	8710					1	1				1			4		1	2													
CATAN	8711				1		3		2	1	1				1															
OPICI	8712				6	5		2	2		1			2						1										
ORIAA	8713				2	2	2	1	1		1						1			3	6									
SRDIN	8714				2	4	1							1							8	1								
TANIA	8715				10			11	2					5					1		8	2	5							
MADRD	8716			3	3	13	5	2	6	3			1	3	1	4	1							1						
MADRI	8717				1	1		1														1		1						
KLSRH	8718			1	3	6	12	1	1		1		1	3		1					1	1		2	6					
CATNA	8719																				2		1		1					
LOVOA	8720				1	3	2		1					2	1	4		1	1						3	1				
REKVK	8722	4				1					4																			

Table 5

Cartesian and Geodetic Coordinates (Solution WEST 34)

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: $u \equiv$ the Greenwich meridian as defined by the B.I.H.; $v \equiv \lambda = 90^\circ$ (E); $w \equiv$ 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 (Continued)

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6006	2102928.96	2.24	721666.42	2.67	5958181.83	2.41
	69 39 45.16	0.07	18 56 26.83	0.25	112.55	2.41
		0.18	99.14	2.68		
		82.94	7.70	2.42		
		7.06	-170.83	2.22		
6016	4896388.49	1.74	1316170.99	2.27	3856668.07	2.16
	37 26 39.09	0.07	15 2 44.56	0.09	15.57	1.90
		-1.68	109.42	2.28		
		37.83	20.73	2.15		
		52.12	-162.75	1.74		
6065	4213563.93	1.89	820824.78	2.18	4702785.56	2.09
	47 48 4.56	0.07	11 1 24.47	0.11	959.34	1.75
		15.09	19.52	2.24		
		-1.55	109.10	2.18		
		74.83	-166.63	1.71		
8004	3818505.85	4.97	708050.10	5.13	5042639.98	4.74
	52 35 3.00	0.20	10 30 17.33	0.28	82.64	2.99
		-6.64	-156.28	6.29		
		-0.62	113.65	5.04		
		83.33	-161.70	2.92		
8009	3923399.47	4.21	299882.98	5.19	5002971.24	4.05
	52 0 6.35	0.16	4 22 15.15	0.27	42.67	3.16
		0.83	127.83	5.41		
		-6.47	-142.27	4.68		
		83.47	-134.93	3.13		
8010	4331299.33	3.47	567503.55	4.92	4633113.20	3.60
	46 52 37.22	0.14	7 27 52.53	0.23	920.42	2.31
		-0.95	113.37	4.99		
		3.15	23.43	4.36		
		86.71	-173.34	2.30		

Table 5 (Continued)

8011	3920172.38	3.05	-134743.98	2.64	5012722.24	3.42
	52 8 35.59	0.12	358 1 53.07	0.14	139.31	2.86
		16.58	25.61	3.91		
		71.18	176.53	2.75		
		-8.64	113.01	2.25		
8015	4578317.79	3.36	457962.24	4.26	4403192.99	3.64
	43 55 57.83	0.13	5 42 43.95	0.19	676.18	2.74
		2.80	124.98	4.33		
		7.60	34.61	4.08		
		81.89	-124.97	2.71		
8016	4188648.12	3.21	571418.21	4.09	4760143.73	3.77
	48 34 58.73	0.14	7 46 6.15	0.20	165.33	2.42
		11.42	-5.69	4.39		
		3.90	85.10	4.09		
		77.92	-166.33	2.29		
8019	4579462.47	3.64	586587.06	6.90	4386418.66	3.83
	43 43 33.26	0.14	7 17 57.54	0.31	394.78	3.11
		2.98	98.63	6.92		
		3.39	8.45	4.27		
		85.48	-130.20	3.09		
8030	4205629.67	4.68	163702.54	7.94	4776538.93	4.14
	48 48 22.12	0.19	2 13 44.73	0.39	183.89	2.47
		-0.73	86.18	7.96		
		0.96	176.16	5.71		
		88.79	33.46	2.46		
8031	3593858.98	9.44	-202756.98	6.44	5248060.45	6.98
	55 44 0.92	0.36	356 46 15.35	0.38	299.95	3.05
		-1.03	161.27	11.68		
		4.16	71.34	5.82		
		85.71	-122.59	3.02		
8032	4213543.14	1.90	820771.38	2.19	4702810.63	2.10
	47 48 5.84	0.07	11 1 22.14	0.11	957.33	1.76
		15.18	19.10	2.25		
		-1.47	108.70	2.19		
		74.74	-166.71	1.72		

Table 5 (Continued)

8033	4041864.41	4.89	620630.38	6.00	4878629.41	4.56
	50 13 11.39	0.20	8 43 46.61	0.30	189.71	2.90
		1.08	142.60	6.39		
		4.06	52.52	5.61		
		85.80	-112.47	2.88		
8034	3919690.42	4.21	298829.43	5.19	5005897.06	4.05
	52 2 40.96	0.16	4 21 34.86	0.27	23.92	3.16
		0.80	127.83	5.42		
		-6.51	-142.26	4.69		
		83.44	-135.23	3.14		
8701	4194425.71	3.87	1162696.85	2.22	4647199.64	4.20
	47 4 0.67	0.16	15 29 36.24	0.11	487.29	2.89
		8.19	12.71	4.97		
		81.68	-157.11	2.83		
		1.45	102.92	2.20		
8702	4027918.87	4.78	307001.98	7.69	4919436.33	5.33
	50 47 50.83	0.21	4 21 30.86	0.39	115.71	3.01
		-3.18	123.88	8.26		
		10.10	34.45	5.83		
		79.40	-163.37	2.84		
8703	3513633.88	7.03	778936.23	6.25	5248194.03	4.95
	55 44 20.31	0.25	12 29 59.01	0.39	53.06	3.08
		0.93	-144.80	8.38		
		-1.81	125.23	5.77		
		87.97	98.05	3.07		
8705	4530506.30	17.38	-41732.26	33.17	4474382.07	18.05
	44 50 2.77	0.81	359 28 20.07	1.50	108.90	3.21
		0.07	54.73	39.47		
		-2.12	144.73	12.66		
		87.87	146.65	3.18		
8706	4587887.34	3.36	419519.19	4.26	4396450.50	3.64
	43 51 8.73	0.13	5 13 28.67	0.19	226.34	2.74
		2.51	125.20	4.33		
		7.40	34.87	4.08		
		82.18	-126.21	2.71		

Table 5 (Continued)

8710	3818504.07	4.96	708051.43	5.12	5042640.13	4.74
	52 35 3.04	0.20	10 30 17.42	0.28	81.85	2.09
		-6.69	-156.28	6.29		
		-0.65	113.64	5.03		
		83.28	-161.89	2.92		
8711	4896386.88	1.75	1316170.55	2.27	3856670.24	2.17
	37 26 39.18	0.07	15 2 44.56	0.09	15.56	1.91
		-1.80	109.61	2.29		
		37.85	21.02	2.16		
		52.09	-162.70	1.75		
8712	4335518.63	17.61	1063083.44	30.07	4540932.63	19.42
	45 40 55.82	0.89	13 46 38.24	1.32	395.08	3.21
		-0.08	132.27	33.42		
		0.00	42.27	21.56		
		89.92	133.65	3.21		
8713	4628609.90	19.49	1471955.74	39.16	4120468.50	27.30
	40 29 58.72	1.16	17 38 28.73	1.57	196.53	3.22
		-0.10	133.07	44.42		
		-0.21	43.07	25.98		
		89.77	69.10	3.21		
8714	4885403.52	23.58	784066.50	29.46	4011526.62	32.33
	39 13 18.48	1.35	9 7 3.87	1.13	146.37	3.21
		0.11	-27.01	45.54		
		0.65	62.99	19.62		
		89.34	-126.53	3.20		
8715	4896390.93	1.76	1316178.78	2.28	3856662.36	2.18
	37 26 38.86	0.07	15 2 44.84	0.09	15.57	1.92
		-1.88	109.74	2.29		
		37.86	21.20	2.17		
		52.08	-162.68	1.75		
8716	4850674.55	8.07	-315907.32	7.52	4116626.97	9.97
	40 27 1.36	0.41	356 16 25.64	0.31	689.79	3.15
		0.97	21.94	13.41		
		-3.20	111.89	5.61		
		86.65	128.78	3.13		

Table 5 (Continued)

```
8717      4850674.61    8.08     -315910.03    7.52       4116626.69    9.97
         40 27  1.35    0.41   356 16 25.53    0.31           689.79    3.15

                        0.97       21.94        13.41
                       -3.21      111.88         5.61
                       86.65      128.75         3.13

8718      4146533.64    6.12      613109.83    6.50       4791487.60    5.56
         49  0 39.75    0.25     8 24 39.09    0.32           146.23    3.13

                        0.37      175.37         7.71
                        3.59       85.35         6.45
                       86.40      -88.81         3.11

8719      4883056.98    1.76     1306097.88    2.28       3879629.16    2.18
         37 41 35.53    0.07    14 58 28.82    0.09          1741.08    1.92

                       -1.98      109.63         2.29
                       38.07       21.18         2.17
                       51.86     -162.90         1.75

8720      3104204.46   10.54      998359.38    8.55       5463280.09    5.62
         59 20 16.53    0.32    17 49 42.89    0.66            41.98    3.13

                        0.91     -133.00        12.83
                       -0.40      137.01         6.45
                       89.00       70.71         3.12

8722      2591994.28   10.16    -1078495.16   18.33       5707863.39    5.85
         63 57 42.52    0.36   337 24 30.38    1.36             0.47    3.20

                        0.08       78.45        18.75
                       -1.83      168.45        10.56
                       88.17      170.97         3.18


NORMAL TERMINATION
```

4. COMBINED WEST-ISAGEX SOLUTION NO. 36

This adjustment is a combination solution using the optical observations from both WEST and ISAGEX. The ISAGEX normal equations were added to the previous set of the WEST 34 solution after appropriate scaling as described in [Reilly, et al., 1972 and Mueller, et al., 1973]. The scale factor was derived from a separate solution with minimum constraints. Since the ISAGEX data set contains no information on the statistics of the observations, the latter were treated with equal weights.

Only the preprocessed data as provided by Wolf Research and Development Corporation was used. During the formation of the normal equations, several blunders in observational data were indicated. A closer inspection of the data shows that all observations which satisfy the simultaneity criterion are GEOS II flashing light observations. The observation times show the characteristic four second interval from the zero to the twenty-fourth second of a minute. It is obvious that the blunders were a result of misidentifying the GEOS II flashes or timing errors. Attempts were made to correct this error by simply rearranging the observations. The results, however, are unsatisfactory, probably because such misidentification also affected the preprocessing. Thus, a mere rearranging of data does not rectify the situation.

Table 6 illustrates the additional simultaneous ISAGEX observations used in this adjustment data. Originally, several observations that satisfied the test distance criteria, were extracted for the stations 8019 (NICE FR) and 8031 (EDNBG). Their use in the adjustment caused an extraordinarily large shift of approximately 20 to 40m in each coordinate for the corresponding stations, even though the station identification seems to be correct, especially for station 8031 (EDNBG). But since no reasonable explanation could be found for this significant change, these observations have been deleted.

Station identification could be uniquely resolved for the stations 8010 (ZIMLD), 8031 (EDNBG) and 8034 (DELFY) through [Schuerer, 1972; McInnes, 1972 and Aardoom, 1972]. Since there is no special ISAGEX numbering system (see [Brachet, 1972]), it is assumed that the ISAGEX station 8011 (MALVRN), 8019 (NICEFR) and 9004 (SAN FERN) are identical to the NASA stations of the same numbers.

The coordinates as given in [Marsh, et al., 1975] were taken as approximate coordinates for stations 8721 (ONDREJOV) and 8723 (POTSDAM). The height constraints could be derived, after appropriate transformation, from MSL heights given in [Karsky, et al., 1974 and Brachet, 1973]. The undulation of Potsdam was taken as zero; while that for Ondrejov was interpolated. (See also Tables 1 and 2.) The values of the station coordinates as a result of this adjustment are given in Table 7.

Table 6

Distribution of ISAGEX Observations per Line

		8011	8034	8609	8721	8723	9004
ZIMLD	8010		13	16	11		13
MALVRN	8011		6			5	7
DELFY	8034			6	4		24
ST MICHEL	8609				8		12
POTSDAM	8721						5
ONDREJOV	8723						9

Table 7

Cartesian and Geodetic Coordinates
(Solution WEST - ISAGEX 36)

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: $u \equiv$ the Greenwich meridian as defined by the B.I.H.; $v \equiv \lambda = 90^\circ$ (E); $w \equiv$ 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 7 (Continued)

6006	2102929.05	2.07	721666.39	2.61	5958182.41	1.00
	69 39 45.17	0.07	18 56 26.83	0.24	113.13	0.69
		0.01	99.44	2.63		
		-0.13	-170.56	2.17		
		89.87	-167.77	0.69		
6016	4896388.85	1.30	1316171.20	2.17	3856668.64	1.62
	37 26 39.10	0.06	15 2 44.56	0.09	16.23	0.67
		-0.03	107.57	2.22		
		1.73	17.57	1.91		
		88.27	-163.39	0.67		
6065	4213564.02	1.62	820824.14	2.10	4702786.55	1.47
	47 48 4.58	0.07	11 1 24.44	0.10	960.04	0.43
		-0.37	-137.34	2.14		
		-0.21	132.65	2.11		
		89.58	-166.74	0.43		
8004	3818505.20	4.89	708049.15	5.07	5042640.20	3.66
	52 35 3.03	0.19	10 30 17.29	0.28	82.32	0.53
		-0.17	-155.46	6.14		
		-0.02	114.54	5.01		
		89.83	-160.58	0.53		
8009	3923397.97	3.18	299876.48	3.68	5002970.72	2.50
	52 0 6.39	0.13	4 22 14.81	0.19	41.03	0.69
		0.21	-174.44	3.98		
		0.08	95.56	3.69		
		89.77	-15.70	0.69		
8010	4331298.35	2.36	567502.32	3.58	4633114.47	2.16
	46 52 37.27	0.10	7 27 52.48	0.17	920.57	0.44
		0.03	81.00	3.63		
		0.07	171.00	3.12		
		89.93	-32.26	0.44		

Table 7 (Continued)

8011	3920169.55	2.69	-134745.00	2.52	5012719.45	2.19
	52 8 35.60	0.11	358 1 53.01	0.13	135.39	0.69
		-0.48	-155.77	3.62		
		0.52	114.23	2.18		
		89.29	-108.41	0.69		
8015	4578322.26	2.10	457962.32	3.45	4403189.27	2.18
	43 55 57.65	0.10	5 42 43.94	0.15	676.81	0.69
		0.52	94.79	3.45		
		0.32	4.79	2.94		
		89.39	-116.88	0.69		
8016	4198647.81	3.07	571417.65	3.96	4760144.81	2.76
	48 34 58.76	0.13	7 46 6.12	0.19	165.88	0.52
		-0.43	160.20	4.12		
		0.28	70.20	3.94		
		89.49	-166.16	0.52		
8019	4579462.46	2.94	586586.05	6.73	4386418.74	3.10
	43 43 33.27	0.14	7 17 57.49	0.30	394.73	0.70
		0.13	98.57	6.77		
		0.09	8.57	4.16		
		89.85	-115.60	0.70		
8030	4205628.97	4.24	163700.74	7.80	4776538.76	3.70
	48 48 22.13	0.18	2 13 44.64	0.38	183.25	0.44
		-0.02	86.56	7.82		
		0.03	176.56	5.58		
		89.97	34.03	0.44		
8031	3593859.57	9.46	-202757.45	6.47	5248061.70	6.36
	55 44 0.93	0.36	356 46 15.33	0.38	301.32	0.53
		-0.03	160.96	11.75		
		0.09	70.96	5.79		
		89.90	-126.40	0.53		
8032	4213543.23	1.62	820770.77	2.10	4702811.61	1.47
	47 48 5.86	0.07	11 1 22.11	0.10	958.04	0.43
		-0.37	-137.43	2.14		
		-0.21	132.57	2.11		
		89.58	-166.83	0.43		

Table 7 (Continued)

8033	4041862.78	4.62	620629.85	5.88	4878628.75	3.93
	50 13 11.42	0.20	8 43 46.60	0.29	188.12	0.53
		0.03	145.85	6.35		
		0.11	55.85	5.54		
		89.89	-110.84	0.53		
8034	3919688.91	3.18	298822.94	3.68	5005896.54	2.50
	52 2 41.00	0.13	4 21 34.53	0.19	22.27	0.69
		0.17	-174.45	3.98		
		0.07	95.55	3.69		
		89.81	-17.21	0.69		
8609	4578365.32	2.10	457946.52	3.45	4403145.28	2.18
	43 55 55.69	0.10	5 42 43.04	0.15	676.02	0.69
		0.52	94.79	3.45		
		0.32	4.79	2.94		
		89.39	-116.88	0.69		
8701	4194427.35	3.64	1162697.02	2.09	4647204.87	3.28
	47 4 0.75	0.15	15 29 36.23	0.11	492.22	0.53
		-0.19	-167.13	4.86		
		-0.04	102.87	2.12		
		89.80	-178.89	0.53		
8702	4027918.19	4.74	307000.05	7.68	4919436.46	4.05
	50 47 50.85	0.21	4 21 30.76	0.39	115.30	0.53
		-0.08	120.93	8.17		
		-0.27	-149.07	5.54		
		89.72	-166.00	0.53		
8703	3513633.03	6.82	778935.33	6.26	5248193.93	4.32
	55 44 20.34	0.25	12 29 58.97	0.39	52.41	0.53
		0.02	-144.90	8.42		
		-0.04	125.10	5.76		
		89.95	92.60	0.53		
8705	4530507.04	17.56	-41734.52	33.58	4474381.19	17.92
	44 50 2.73	0.82	359 28 19.97	1.52	108.82	0.53
		0.00	54.78	39.95		
		-0.05	144.78	12.67		
		89.95	146.77	0.53		

Table 7 (Continued)

8706	4587891.82	2.10	419519.25	3.45	4396446.79	2.18
	43 51 8.55	0.10	5 13 28.66	0.15	227.00	0.69
		0.18	94.46	3.45		
		0.21	4.46	2.94		
		89.72	-135.88	0.69		
8710	3818503.42	4.89	708050.48	5.07	5042640.36	3.66
	52 35 3.07	0.19	10 30 17.37	0.28	81.53	0.53
		-0.17	-155.45	6.14		
		-0.02	114.55	5.01		
		89.83	-160.67	0.53		
8711	4896387.24	1.30	1316170.77	2.17	3856670.81	1.62
	37 26 39.19	0.06	15 2 44.56	0.09	16.23	0.67
		-0.03	107.57	2.22		
		1.73	17.58	1.91		
		88.27	-163.39	0.67		
8712	4335518.00	17.72	1063083.85	30.46	4540933.17	19.51
	45 40 55.95	0.90	13 46 38.26	1.34	395.11	0.53
		-0.00	132.27	33.85		
		0.00	42.27	21.83		
		90.00	133.73	0.53		
8713	4628610.14	19.57	1471955.77	39.67	4120468.17	27.57
	40 29 58.70	1.18	17 38 28.73	1.59	196.50	0.53
		-0.00	133.11	44.99		
		-0.01	43.11	26.30		
		89.99	69.32	0.53		
8714	4885402.98	23.85	784067.24	29.82	4011527.38	32.58
	39 13 18.51	1.36	9 7 3.90	1.14	146.52	0.53
		0.00	-27.06	46.12		
		0.02	62.94	19.81		
		89.98	-126.70	0.53		
8715	4896391.28	1.30	1316179.00	2.17	3856662.93	1.62
	37 26 38.86	0.06	15 2 44.84	0.09	16.23	0.67
		-0.03	107.58	2.22		
		1.73	17.58	1.91		
		88.27	-163.39	0.67		

Table 7 (Continued)

8716	4850673.55	7.95	-315908.11	7.57	4116626.23	9.65
	40 27 1.36	0.41	356 16 25.61	0.31	688.59	0.53
		0.03	22.12	13.48		
		-0.06	112.12	5.61		
		89.93	134.05	0.53		
8717	4850673.61	7.95	-315910.81	7.57	4116625.95	9.65
	40 27 1.35	0.41	356 16 25.49	0.31	688.59	0.53
		0.03	22.12	13.48		
		-0.06	112.12	5.61		
		89.93	134.02	0.53		
8718	4146532.13	5.83	613108.77	6.42	4791487.56	5.08
	49 0 39.79	0.25	8 24 39.05	0.32	145.12	0.53
		0.01	176.85	7.72		
		0.08	86.85	6.41		
		89.92	-86.89	0.53		
8719	4883057.33	1.30	1306098.10	2.17	3879629.73	1.62
	37 41 35.54	0.06	14 58 28.82	0.09	1741.74	0.67
		-0.16	107.53	2.22		
		1.95	17.54	1.91		
		88.04	-167.09	0.67		
8720	3104203.00	10.41	998359.38	8.62	5463280.35	5.11
	59 20 16.58	0.32	17 49 42.92	0.66	41.49	0.53
		0.02	-132.95	12.91		
		-0.01	137.05	6.48		
		89.97	66.16	0.53		
8721	3978430.80	6.59	1051033.13	6.80	4857553.91	3.86
	49 55 16.14	0.19	14 47 54.49	0.39	514.73	3.02
		-5.84	57.19	8.88		
		8.40	146.33	4.17		
		79.75	1.64	2.86		
8722	2591995.29	10.24	-1078494.51	18.54	5707862.98	4.89
	63 57 42.50	0.36	337 24 30.45	1.37	0.40	0.53
		0.00	78.33	18.96		
		-0.05	168.33	10.61		
		89.95	171.00	0.53		

Table 7 (Continued)

```
8723     3800631.86   6.80      681944.19  12.31       5028839.89    4.31
         52 22 48.66  0.19   13  3 51.76    0.69           112.55    3.10

                     -1.68       77.12      13.40
                     -2.13      167.18       5.23
                     87.29      128.89       3.07

9004     5105579.79   2.84     -555246.51   4.78       3769675.36    3.53
         36 27 46.95  0.12   353 47 35.92   0.19            47.65    2.66

                      1.60       58.22       5.18
                     12.94      -32.15       3.10
                     76.96      155.13       2.63


NORMAL TERMINATION
```

5. DISCUSSION

Both solutions WEST 34 and WEST-ISAGEX 36 (W.I.36) are summarized in Table 8. The ISAGEX data set added three stations to the WEST 34 system. Station 9004 (SAN FERN), though an addition to WEST data, is already included in the WN14 solution. Due to the small number of ISAGEX observations, only a minor improvement could be gained by the addition of the ISAGEX data. Their positive influence is reflected in the standard deviations, particularly at the stations with ISAGEX observations. In Table 17 a three parameter transformation is shown between WEST 34 and WEST-ISAGEX 36. The residuals for some stations amount to the magnitude of their standard deviation, but there is no significant shift in the origin. A glance at Table 8 further shows that a number of stations could not be determined accurately. The coordinates of stations 8705 (BRDUX), 8712 (OPICI), 8713 (ORIAA) and 8714 (SRDIN) still exhibit extraordinarily large standard deviations. This is an immediate result of the increased variances in the observational data (see Table 4 [Ehrnsperger, 1974] for the standard errors stationwise, as obtained by the smoothing procedure.) The adjusted coordinates of 8711 (CATAN) could also be expected to exhibit a large standard deviation according to Table 4 [Ehrnsperger, 1974], but because this station has been connected to the nearby WN14 station, 6016 (CATANIA), by relative constraints, it does not exhibit a large variance. The large standard deviation of station 8722 (REKVK) is due to unfavorable geometric conditions and scarcity of observations. Similar reasoning would apply to stations 8716 (MADRD) and 8720 (LOVOA). A general characteristic of such stations is that the tie lines are ill-distributed (i.e., they are not well spread around 360°). This problem, of course, is unavoidable in a non-global satellite triangulation. But it can also be seen that the standard deviations of coordinates of common stations have decreased in many cases by a factor of one-half as compared to the corresponding WN14 values.

It is seen that the ISAGEX data add much strength to the station 8034 (DELFY), which is connected by relative constraints to the nearby WN14 station 8009 (DELFTH). Adjustments were performed applying no constraints to either of these stations (i.e., no station, height or relative constraints). Using only the WEST observations in the adjustment, it is found that station 8009 (DELFTH) shows no significant change in either the coordinates or the standard deviations; while the standard error in 8034 (DELFY) rapidly increases to 35 m in each direction and its coordinates also change significantly. In contrast, when the combined data is used, neither of the two stations shows any significant change in coordinates or standard deviations. In fact, station 8034 (DELFY) adjusted to the same position as obtained when using all constraints (especially in the case of relative constraints).

The consistency of the stations 8721 (ONDREJOV) and 8723 (POTSDAM) can be estimated from comparisons with various solutions. Two solutions have been published based on the geometric and dynamic data of the ISAGEX campaign. A coordinate comparison is given in Table 9. If the origin of the coordinate system of the solution in [Marsh, et al., 1975] is taken as being at the geocenter, these coordinates can be transformed to the WN14 system by adding the shifts $\Delta U = -21$ m, $\Delta V = -5$ m and $\Delta W = 2$ m. A similar comparison is possible with the coordinates given in [Gaposchkin, et al., 1975]. But for computations here, the transformation parameters from Table 27 are used to transform the solution. A further attempt at comparison can be made using ED50 coordinates. The ED50 coordinates for 8723 (POTSDAM) are taken from [Brachet, 1973]; while those of 8721 (ONDREJOV) from [Marsh, et al., 1975]. Marsh's height presumably refers to an ellipsoid centered at the geocenter. But in the comparison here it is necessary to have the actual height above the ED50 ellipsoid which is derived from MSL height as given in [Karsky, et al., 1974], plus the undulation referring to the Potsdam geoid. The result after transforming to the W.I.36 solution, is given in Table 9, which seems to confirm the weak determination of the two stations involved. This is a consequence of both the lack of observations and their ill-distribution. Marsh's and Gaposchkin's values for station 8723 (POTSDAM) seem to be in relatively good agreement.

Table 8

Summary of Cartesian Coordinates
(Solution WEST 34 and W.I. 36)

STATION		SOLUTION WEST-34						SOLUTION WEST-ISAGEX-36					
NO	NAME	U	V	W	σ_U	σ_V	σ_W	U	V	W	σ_U	σ_V	σ_W
6006	TROMSO	2102929.0	721666.4	5958181.8	2.2	2.7	2.4	2102929.1	721666.4	5958182.4	2.1	2.6	1.0
6016	CATANIA	4896388.5	1316171.0	3856668.1	1.7	2.3	2.2	4896388.8	1316171.2	3856668.6	1.3	2.2	1.6
6065	PEISEN	4213563.9	820824.8	4702785.6	1.9	2.2	2.1	4213564.0	820824.1	4702786.5	1.6	2.1	1.5
8004	BRNSG	3818505.9	708050.1	5042640.0	5.0	5.1	4.7	3818505.2	708049.2	5042640.2	4.9	5.1	3.7
8009	DELFTH	3923399.5	299883.0	5002971.2	4.2	5.2	4.0	3923398.0	299876.5	5002970.7	3.2	3.7	2.5
8010	ZIMLD	4331299.3	567503.6	4633113.2	3.5	4.9	3.6	4331298.3	567502.3	4633114.5	2.4	3.6	2.2
8011	MALVRN	3920172.4	-134744.0	5012722.2	3.1	2.6	3.4	3920169.5	-134745.0	5012719.5	2.7	2.5	2.2
8015	HAUTE PROVENCE	4578317.8	457962.2	4403193.0	3.4	4.3	3.6	4578322.3	457962.3	4403189.3	2.1	3.4	2.2
8016	STRBG	4188648.1	571418.2	4760143.7	3.2	4.1	3.8	4188647.8	571417.7	4760144.8	3.1	4.0	2.8
8019*	NICEFR	4579462.5	586587.1	4386418.7	3.6	6.9	3.8	4579462.5	586586.0	4386418.7	2.9	6.7	3.1
8030	MUDONI	4205629.7	163702.5	4776538.9	4.7	7.9	4.1	4205629.0	163700.7	4776538.8	4.2	7.8	3.7
8031	EDNBG	3593859.0	-202757.0	5248060.5	9.4	6.4	7.0	3593859.6	-202757.4	5248061.7	9.5	6.5	6.4
8032	HOPBG	4213543.1	820771.4	4702810.6	1.9	2.2	2.1	4213543.2	820770.8	4702811.6	1.6	2.1	1.5
8033	FRNFT	4041864.4	620630.4	4878629.4	4.9	6.0	4.6	4041862.8	620629.9	4878628.7	4.6	5.9	3.9
8034	DELFY	3919690.4	298829.4	5005897.1	4.2	5.2	4.1	3919688.9	298822.9	5005896.5	3.2	3.7	2.5
8609	ST.MICHEL FR							4578365.3	457946.5	4403145.3	2.1	3.4	2.2
8701	GRAZA	4194425.7	1162696.8	4647199.6	3.9	2.2	4.2	4194427.3	1162697.0	4647204.9	3.6	2.1	3.3
8702	BRXOR	4027918.9	307002.0	4919436.3	4.8	7.7	5.3	4027918.2	307000.1	4919436.5	4.7	7.7	4.1
8703	COPHN	3513633.9	778936.2	5248194.0	7.0	6.2	5.0	3513633.0	778935.3	5248193.9	6.8	6.3	4.3
8705	BRDUX	4530506.3	-41732.3	4474382.1	17.4	33.2	18.0	4530507.0	-41734.5	4474381.2	17.6	33.6	17.9
8706	GOULT	4587887.3	419519.2	4396450.5	3.4	4.3	3.6	4587891.8	419519.2	4396446.8	2.1	3.4	2.2
8710	WSNDF	3818504.1	708051.4	5042640.1	5.0	5.1	4.7	3818503.4	708050.5	5042640.4	4.9	5.1	3.7
8711	CATAN	4896386.9	1316170.5	3856670.2	1.8	2.3	2.2	4896387.2	1316170.8	3856670.8	1.3	2.2	1.6
8712	OPICI	4335518.6	1063083.4	4540932.6	17.6	30.1	19.4	4335518.0	1063083.8	4540933.2	17.7	30.5	19.5
8713	ORIAA	4628609.9	1471955.7	4120468.5	19.5	39.2	27.3	4628610.1	1471955.8	4120468.2	19.6	39.7	27.6
8714	SRDIN	4885403.5	784066.5	4011526.6	23.6	29.5	32.3	4885403.0	784067.2	4011527.4	23.9	29.8	32.6
8715	TANIA	4896390.9	1316178.8	3856662.4	1.8	2.3	2.2	4896391.3	1316179.0	3856662.9	1.3	2.2	1.6
8716	MADRD	4850674.5	-315907.3	4116627.0	8.1	7.5	10.0	4850673.5	-315908.1	4116626.2	7.9	7.6	9.7
8717	MADRI	4850674.6	-315910.0	4116626.7	8.1	7.5	10.0	4850673.6	-315910.8	4116626.0	7.9	7.6	9.7
8718	KLSRH	4146533.6	613109.8	4791487.6	6.1	6.5	5.6	4146532.1	613108.8	4791487.6	5.8	6.4	5.1
8719	CATNA	4883057.0	1306097.9	3879629.2	1.8	2.3	2.2	4883057.3	1306098.1	3879629.7	1.3	2.2	1.6
8720	LOVOA	3104204.5	998359.4	5463280.1	10.5	8.6	5.6	3104203.0	998359.4	5463280.4	10.4	8.6	5.1
8721	ONDREJOV							3978430.8	1051033.1	4857553.9	6.6	6.8	3.9
8722	REKVK	2591994.3	-1078495.2	5707863.4	10.2	18.3	5.8	2591995.3	-1078494.5	5707863.0	10.2	18.5	4.9
8723	POTSDAM							3800631.9	881944.2	5028839.9	6.8	12.3	4.3
9004	SAN FERNANDO							5105579.8	-555246.5	3769675.4	2.8	4.8	3.5

[redacted]

Table 9

Coordinate Comparison for ONDREJOV and POTSDAM

COORDINATE DIFFERENCES			
Station	Δu (m)	Δv (m)	Δw (m)
8721	-11.67	16.30	3.56
8723	-35.22	37.25	49.28
[Marsh, et al., 1975] - W.I.36			
8721	11.83	-22.33	20.68
8723	-44.03	29.41	35.00
[Gaposchkin, et al., 1975] - W.I.36			
8721	-42.14	93.69	14.89
8723	-18.82	39.96	8.72
ED 50 - W.I.36			

A summary of transformation parameters for solution WEST-ISAGEX 36 with respect to various other systems is given in Table 10. The results of the individual transformations reflected in this summary table, are presented in Tables 17 and 21 through 32. In all cases the standard Molodenskii and Bursa transformation models have been used. In Appendix III a detailed discussion on the differences between the two models is given. Tables 18 through 20 present the results of transformation between WEST 34 and other systems.

The transformation with respect to the common stations of the WN14 system indicates no significant shift or rotation for the W. I. 36 solution as intended. The residuals in the transformation between WN14 and W.I.36, however, show systematic corrections for the coordinates of various stations which are especially significant in the y coordinate (Table 29). The newly derived translation parameters for the ED50 (Table 22), with respect to the geocenter, are (Molodenskii transformation model):

$$\begin{array}{rcl} -\ 94.1 + 21 & \approx & 73\,\mathrm{m} \\ -\ 115.5 + 5 & \approx & -110\,\mathrm{m} \\ -\ 125.3 - 2 & \approx & 123\,\mathrm{m} \end{array}$$

where 21m, 5m and -2m are the coordinates of the WN14 origin with respect to the geocenter. The translation parameters are in good agreement with the other solutions, giving appropriate consideration to

Table 10

Transformation Parameters between Other Systems and WI36

System	ED50	NGS[1]	SE 3[2]	WN14	GEM 6[3]	WEST 34
Transformation Parameter	25 Stations	3 Stations	7 Stations	10 Stations	4 Stations	24 Stations
		Bursa Translation Parameters[4]				
ΔU (m)[5]	-123.9 ± 18.8	6.2 ± 20.0	-14.7 ± 18.0	2.4 ± 10.0	-40.2 ± 8.8	
ΔV (m)[5]	-112.2 ± 30.6	-93.0 ± 77.9	-31.7 ± 27.6	13.0 ± 21.8	-33.4 ± 15.2	
ΔW (m)[5]	-152.7 ± 18.8	9.0 ± 10.3	21.1 ± 18.7	6.2 ± 8.9	11.6 ± 9.3	
		Molodenskii Translation Parameters[4]				
ΔU (m)	-94.1 ± 3.4	-9.2 ± 2.7	-8.2 ± 2.5	0.2 ± 1.7	-19.5 ± 2.0	0.0 ± 0.3
ΔV (m)	-115.5 ± 3.3	-10.0 ± 3.3	-15.3 ± 2.9	0.7 ± 2.4	-30.7 ± 2.2	-0.6 ± 0.4
ΔW (m)	-125.3 ± 3.5	16.0 ± 3.5	9.7 ± 2.6	0.1 ± 1.9	6.1 ± 2.0	0.2 ± 0.3
Δ (ppm)	6.12 ± 2.77	0.90 ± 1.62	-0.32 ± 2.45	-1.19 ± 1.42	1.56 ± 1.35	
ω ($''$)[6]	0.70 ± 0.77	-1.68 ± 1.58	-0.23 ± 0.68	0.04 ± 0.50	-0.66 ± 0.37	
ψ ($''$)[6]	-0.15 ± 0.65	0.55 ± 0.53	-0.38 ± 0.67	-0.12 ± 0.31	-0.73 ± 0.31	
ϵ ($''$)[6]	-0.17 ± 0.86	2.10 ± 2.13	0.53 ± 0.78	-0.47 ± 0.63	-0.53 ± 0.45	
α ($''$)[7]	0.63 ± 0.58					
ξ ($''$)[7]	-0.18 ± 0.64					
η ($''$)[7]	-0.32 ± 1.00					
$\hat{\sigma}_0^2$	1.03	1.07	0.99	1.00	1.04	
Factor[8]	—[9]	2.10	0.70	2.40	0.09	

[1] Coordinates for common stations from [Schmid, 1974].

[2] Coordinates for common stations from [Gaposchkin, 1974].

[3] Coordinates for common stations from [Lerch, et al., 1974].

[4] See Appendix III.

[5] If (geocenter-datum) is sought, add to the tabulated values of ΔU, ΔV, ΔW the respective quantites 21 m, 5 m and -2 m.

[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.

[7] The positive directions of the axes considered at the geodetic initial point are south, east, and along the ellipsoidal normal outwards with the respective rotations about these axes as η, ξ, α.

[8] Factor by which the variances of the systems had to be scaled in order to obtain the variance of unit weight $\hat{\sigma}_0^2$ close to unity.

[9] Variance of each coordinate in the European datum is 144 m^2.

the variances. However, these do not have geometrical significance as explained in Appendix III. Also see [Anderle, 1974 and Weightman, 1975]. A graphical representation of the residuals is given in Figures 4, 5 and 6.

The transformation parameters with respect to the solutions NGS and GEM 6 should not be overemphasized since there is a lack of an adequate number of common stations.

Height constraints have been used very successfully in the WN14 global solution. The use of weighted height constraints provides a unique tool to select the scale to fit some criterion. In a non-global satellite triangulation, as in the present case, height constraints are only used to strengthen stations at the edge of the triangulation area, or stations with insufficient observations. Solution WEST 34 has been repeated without the use of any height constraints (WEST 35) and is given in Appendices I and II along with the transformation between WEST 35 and WEST 34. There is no significant shift between the systems, although a rotation around the W and U axes seems to be present. The height residuals are large for all weakly determined points. But also two supposedly well determined stations, 8031 (EDNBG) and 8701 (GRAZA), exhibit a large residual in height.

The scale factor for the European datum was sought with respect to the satellite system by using the original ED50 coordinates instead of the revised coordinates as explained in [Weightman, 1975]. He indicates the possibility that current publications give revised coordinates for the terminal station of the European base lines, which are based on the base line adjustment. This seems to be partly confirmed in Table 11, which shows the difference between the lengths, as computed from ED50 coordinates (Table 1) and values for the base lines as obtained from traverses.

Table 11

Comparison of Base Line Length and ED Chords

STATION				ED 50 minus traverse length	
From		To		(m)	ppm
6006	TROMSO	6016	CATANIA	2.36	0.67
6006	TROMSO	8032	HOPBG	0.39	0.16
8032	HOPBG	8711	CATAN	-10.44	9.09
8011	MALVRN	8032	HOPBG	-1.04	1.00
8032	HOPBG	8701	GRAZA	0.24	0.69

Latitude Differences After Transforming ED50 to W.I.36 (in Meters)
7 Parameter Transformation (W.I.36-ED50)

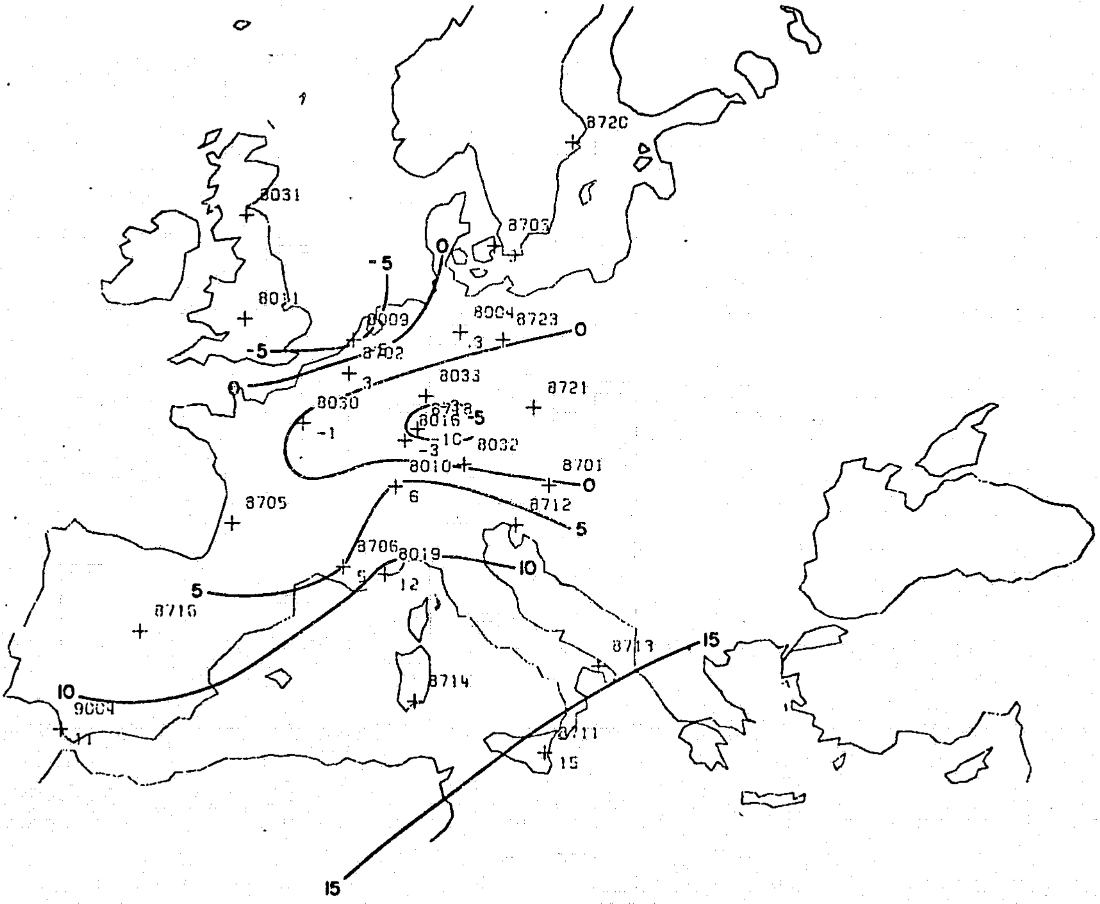

Fig. 4

Longitude Differences After Transforming ED50 to W.I.36 (in Meters)

7 Parameter Transformation (W.I.36-ED50)

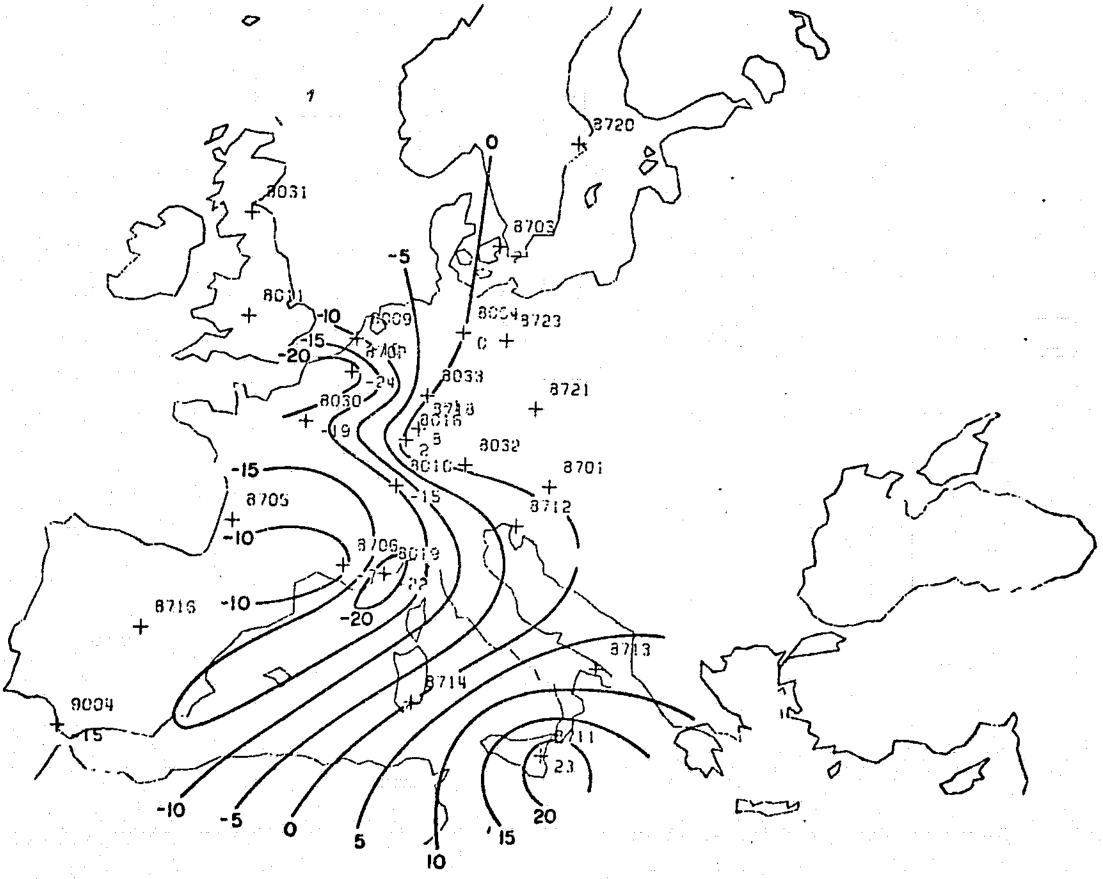

Fig. 5

Height Differences After Transforming ED50 to W.I.36 (In Meters)

7 Parameter Transformation (W.I.36-ED50)

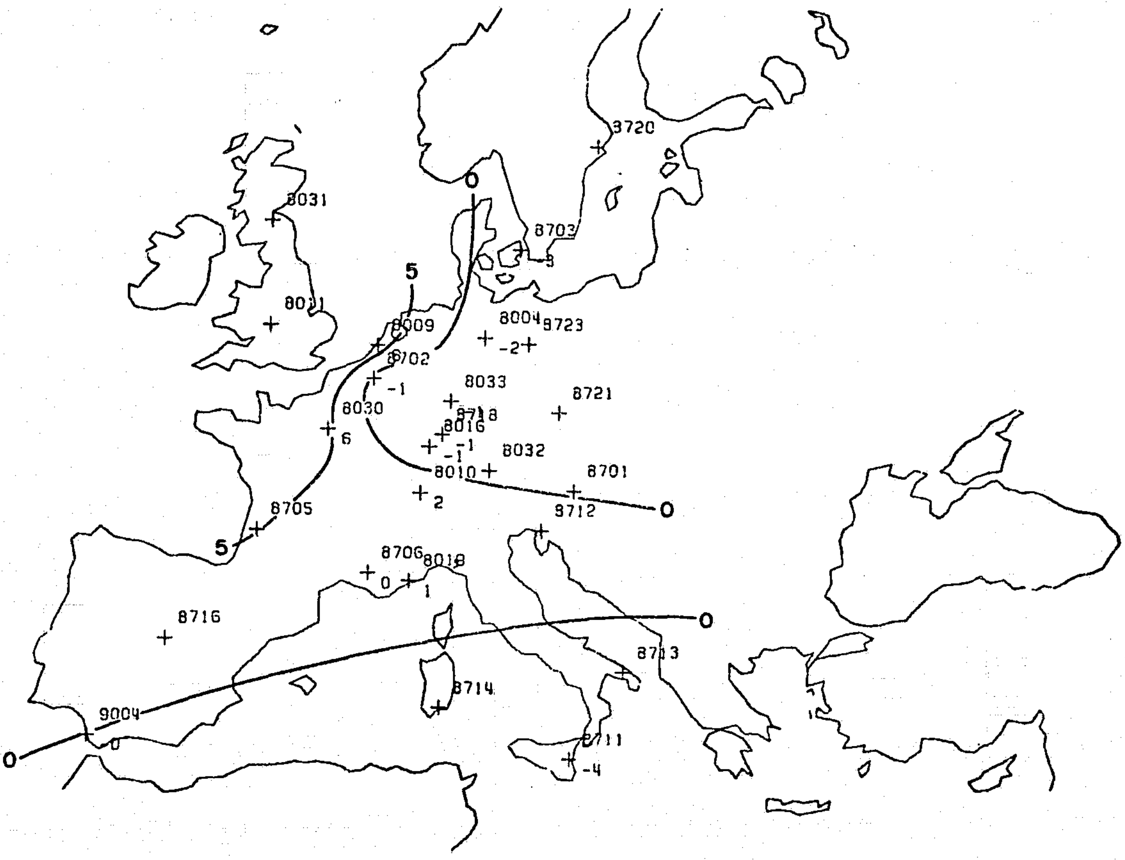

Fig. 6

The conclusions drawn from Table 11 are, of course, not based on the best evidence. But due to lack of additional information, it is assumed that all but the coordinates of station 8711 (CATAN) are revised coordinates. The originality of the CATAN coordinates seems to be confirmed when computing the distance between 6016 (CATANIA), as given in [NASA, 1973] and 8711 (CATAN), as given in [Ehrnsperger, 1974]. The computed distance is 14.59m as opposed to the 2.76m given in Circular Letter No. 37 [WEST, 1966-1972]. The difference of -10.44m in Table 11 might also be interpreted such that the southern terminal point of the base line is 8715 (TANIA), since this station is approximately 12m south of 8711 (CATAN) [WEST, 1966-1972]. But comparing the adjusted chords and their measured values (Table 12), it can be seen that this interpretation is probably wrong. Notice that the last two chords which are actually parts of the chord 6006 (TROMSO) - 6016 (CATANIA), were not constrained in the W.I. 36 solution.

Table 12

Comparison of Adjusted Chords

LINE	Given Length - Adjusted (W.I.36) (m)	ppm
6006-6016	-1.32	0.37
8011-8032	-3.68	0.35
8032-8701	-.32	0.92
6006-8032	0.75	0.30
8032-8711	-0.48	0.40

Thus it was concluded that station 8711 (CATAN) is the only base line terminal station which can be used in subsequent scale factor investigations. In addition, those stations which are weakly determined were also excluded for the same considerations. In summary, the following stations were excluded:

6006 TROMSO
8032 HOPBG
8011 MALVRN
8701 GRAZA*
8705 BRDUX*
8712 OPICI
8713 ORIAA
8714 SRDIN
8716 MADRD
8720 LOVOA
8222 REKVK*

* See additional comments in Table 1.

Table 13

Differences between Satellite and Ground Survey Chord Lengths (Meters)
(Satellite - Survey)

Station No.	8004	8009	8010	8016	8019	8030	8031	8033	8702	8703	8706	8711	8718
8009	14.8												
8010	6.2	- 7.4											
8016	7.9	8.7	- 5.9										
8019	2.5	-12.1	- 3.3	-10.1									
8030	21.6	1.5	3.5	24.4	- 6.4								
8031	-25.1	-31.8	-36.6	-20.9	-40.3	-30.1							
8033	7.5	9.4	- 2.6	0.5	- 6.8	19.4	-24.7						
8702	24.5	- 7.3	5.5	26.1	- 1.8	1.1	-45.1	26.1					
8703	2.6	18.9	8.8	10.7	5.6	22.2	-16.0	10.2	21.7				
8706	7.4	- 3.3	- 0.5	- 0.7	-14.6	4.3	-26.5	- 0.2	5.0	9.9			
8711	1.8	8.1	18.2	- 1.2	33.2	23.9	-19.1	- 1.1	22.5	0.9	21.0		
8718	12.3	19.0	- 7.2	- 0.5	-13.7	29.7	-12.4	6.6	36.8	15.1	- 3.7	-10.7	
9004	13.4	- 1.8	3.1	9.4	- 0.3	- 4.0	-12.1	7.6	- 3.5	15.3	7.4	45.2	9.0

The remaining station coordinates were used to perform a standard seven parameter Molodenskii transformation resulting in a scale factor of 1.74± 3.70 ppm. Compared to the previous value of 6.12± 2.77ppm, there seems to be a significant change, which gave reason to further investigate the individual stations. After comparing chords it was found that the chord differences starting from 8031 (EDNBG) were systematically different from others. Deleting this station and repeating the transformation, a scale factor of 5.92± 3.54 ppm was obtained. This result clearly shows the weak determination of the scale factor and gives support to the high variance attached to it. Table 13 gives the chord differences between W.I.36 and ED 50 systems. It is readily seen that there is a great dispersion in the scale factor.

A similar result was found by [Marsh, et al., 1971]. He also investigated specific areas within Europe. According to [NASA, 1973], the adjustment of the Central European Network was carried out between 1945 and 1947. This triangulation network covers the region that lies from 47° to 56° North latitude and between 6° and 27° East longitude. The Central European Network was extended by the addition of two separate adjustments of large networks of triangulation known as the Southwestern Block and Northern Block. The Central Network was substantially held fixed and, with the addition of the two blocks, forms the European Triangulation based on what is now designated as the European datum. Tables 14, 15 and 16 are modest attempts to represent the scale factor within these three blocks.

Differences between Satellite and Ground Survey
Chord Lengths (meters)
(Satellite - Ground Survey)

Table 14

Northern Block

	8009	8030	8031
8030	1.5		
8031	-31.8	-30.1	
8702	- 7.3	1.1	-45.1

Table 15

Central Block

	8004	8016	8033	8703
8016	7.9			
8033	7.5	0.5		
8703	2.6	10.7	10.2	
8718	12.3	-0.5	6.6	15.1

Table 16

Southwestern Block

	8010	8019	8706	8711
8019	- 3.3			
8706	- 0.5	-14.6		
8711	18.2	33.2	21.0	
9004	3.1	- 0.3	7.4	45.2

From the above three tables the following conclusions might be in order:

1) In both the Northern and the Southwestern Blocks there seems to be a large variation in chord length differences. The differences tend to be generally negative in the Northern Block.

2) In the Central Block the variations are relatively small and the differences are generally positive.

In conclusion, the above analysis has yielded slightly improved values of coordinates of the European stations in the WN14 solution. Two stations could be added to the WN14 solution. In the absence of any statistics, the use of the seven image data in analysis has been deferred until the reduced data for all the WEST plates is available. At that stage the whole data may merit fresh attention.

Table 17

Transformation

```
WEST 34  -TO-  W.I.36 ( 3 PARAMETER)
***************************************


                SOLUTION FOR 3 TRANSLATION PARAMETERS
                          (UNITS - METERS)


                      (USING VARIANCES ONLY)


        DU                       DV                       DW
      METERS                   METERS                   METERS

   0.27492892D-01          -0.59863477D+00          0.21750085D+00

      ± 0.30                   ± 0.35                   ± 0.29


                   VARIANCE - COVARIANCE MATRIX


      MO2=  0.09

   0.87695880D-01          0.0                      0.0

   0.0                     0.12217634D+00           0.0

   0.0                     0.0                      0.86764366D-01



                   COEFFICIENTS OF CORRELATION


   0.10000000D+01          0.0                      0.0

   0.0                     0.10000000D+01           0.0

   0.0                     0.0                      0.10000000D+01
```

Table 17 (Continued)

RESIDUALS V

	V1(WEST 34)				V2(W.I.36)			V1 - V2		
6006	0.0	0.3	0.3	6006	-0.0	-0.3	-0.1	0.1	0.6	0.4
8004	-0.3	-0.2	0.0	8004	0.3	0.2	-0.0	-0.7	-0.4	0.0
8009	-1.0	-3.9	-0.5	8009	0.6	2.0	0.2	-1.5	-5.9	-0.7
8010	-0.7	-0.4	0.8	8010	0.3	0.2	-0.3	-1.0	-0.6	1.1
8011	-1.6	-0.2	-2.1	8011	1.3	0.2	0.9	-2.9	-0.4	-3.0
8016	-0.2	0.0	0.6	8016	0.2	-0.0	-0.3	-0.3	0.0	0.9
8019	-0.0	-0.2	-0.1	8019	0.0	0.2	0.1	-0.0	-0.4	-0.1
8030	-0.4	-0.6	-0.2	8030	0.3	0.6	0.2	-0.7	-1.2	-0.4
8031	0.3	0.1	0.6	8031	-0.3	-0.1	-0.5	0.6	0.1	1.0
8032	0.0	-0.0	0.5	8032	-0.0	0.0	-0.3	0.1	-0.0	0.8
8033	-0.9	0.0	-0.5	8033	0.8	-0.0	0.4	-1.7	0.1	-0.9
8701	0.9	0.4	3.1	8701	-0.8	-0.4	-1.9	1.6	0.8	5.0
8702	-0.4	-0.7	-0.1	8702	0.4	0.7	0.0	-0.7	-1.3	-0.1
8703	-0.5	-0.2	-0.2	8703	0.4	0.2	0.1	-0.9	-0.3	-0.3
8705	0.4	-0.8	-0.5	8705	-0.4	0.8	0.5	0.7	-1.7	-1.1
8706	3.2	0.4	-2.9	8706	-1.3	-0.3	1.0	4.5	0.7	-3.9
8711	0.2	0.4	0.2	8711	-0.1	-0.4	-0.1	0.3	0.8	0.4
8712	-0.3	0.5	0.2	8712	0.3	-0.5	-0.2	-0.7	1.0	0.3
8713	0.1	0.3	-0.3	8713	-0.1	-0.3	0.3	0.2	0.6	-0.5
8714	-0.3	0.7	0.3	8714	0.3	-0.7	-0.3	-0.6	1.3	0.5
8716	-0.5	-0.1	-0.5	8716	0.5	0.1	0.5	-1.0	-0.2	-1.0
8718	-0.8	-0.2	-0.1	8718	0.7	0.2	0.1	-1.5	-0.5	-0.3
8720	-0.8	0.3	0.0	8720	0.7	-0.3	-0.0	-1.5	0.6	0.0
8722	0.5	0.6	-0.4	8722	-0.5	-0.6	0.3	1.0	1.2	-0.6

UNIT OF RESIDUALS (METERS)

Table 18

Transformation

```
ED-50     -TO-   WEST 34( 3 PARAMETER)
******************************************

              SOLUTION FOR 3 TRANSLATION PARAMETERS
                        (UNITS - METERS)


                     (USING VARIANCES ONLY)


       DU                       DV                       DW
     METERS                   METERS                   METERS

  -0.93528768D+02          -0.11679806D+03          -0.12670268D+03

     ± 2.88                   ± 3.00                   ± 2.86

                   VARIANCE - COVARIANCE MATRIX


     MO2=  1.03

   0.83177967D+01           0.0                      0.0

   0.0                      0.89799371D+01           0.0

   0.0                      0.0                      0.81659603D+01


                   COEFFICIENTS OF CORRELATION


   0.10000000D+01           0.0                      0.0

   0.0                      0.10000000D+01           0.0

   0.0                      0.0                      0.10000000D+01
```

Table 18 (Continued)

RESIDUALS V

	V1(ED-50)				V2(WEST 34)			V1 - V2		
6006	-18.3	29.1	6.0	6006	0.6	-1.4	-0.2	-18.9	30.5	6.2
8004	-3.3	0.8	1.4	8004	0.6	-0.1	-0.2	-3.9	0.9	1.7
8009	7.5	-5.1	3.5	8009	-0.9	1.0	-0.4	8.4	-6.1	3.9
8010	1.3	-14.7	2.7	8010	-0.1	2.5	-0.2	1.4	-17.2	3.0
8011	14.4	-4.1	-0.4	8011	-0.9	0.2	0.0	15.3	-4.3	-0.4
8016	2.1	1.0	-4.1	8016	-0.2	-0.1	0.4	2.3	1.1	-4.6
8019	-1.4	-19.3	5.8	8019	0.1	6.4	-0.6	-1.5	-25.7	6.4
8030	4.7	-15.1	4.3	8030	-0.7	6.6	-0.5	5.4	-21.7	4.8
8031	6.2	16.2	-6.9	8031	-3.9	-4.7	2.3	10.1	20.9	-9.3
8032	-9.5	9.5	13.7	8032	0.2	-0.3	-0.4	-9.7	9.8	14.1
8033	2.5	-1.3	-1.5	8033	-0.4	0.3	0.2	2.9	-1.6	-1.7
8701	0.8	5.9	-9.7	8701	-0.1	-0.2	1.2	0.8	6.1	-10.9
8702	-1.6	-18.3	1.7	8702	0.2	7.5	-0.3	-1.8	-25.8	2.0
8703	-4.3	3.0	2.2	8703	1.5	-0.8	-0.4	-5.8	3.9	2.6
8705	-0.3	2.1	-0.2	8705	0.6	-16.0	0.4	-0.9	18.1	-0.6
8706	-4.1	-10.9	4.2	8706	0.3	1.4	-0.4	-4.4	-12.3	4.5
8711	-10.9	17.4	2.4	8711	0.2	-0.6	-0.1	-11.1	18.0	2.4
8712	-0.5	5.4	-2.6	8712	1.1	-33.7	6.8	-1.6	39.1	-9.4
8713	-4.5	-1.7	3.8	8713	11.9	18.5	-19.9	-16.4	-20.2	23.7
8714	-8.2	11.4	3.7	8714	31.7	-68.7	-26.9	-39.9	80.1	30.6
8716	27.8	-21.1	-29.3	8716	-12.6	8.3	20.2	40.4	-29.4	-49.6
8718	6.0	6.3	-6.3	8718	-1.6	-1.9	1.4	7.6	8.2	-7.7
8720	-2.2	-1.4	1.4	8720	1.7	0.7	-0.3	-3.8	-2.2	1.7
8722	-4.2	5.0	4.2	8722	3.0	-11.6	-1.0	-7.2	16.6	5.1

UNIT OF RESIDUALS (METERS)

Table 19

Transformation

```
  ED-50    -TO-   WEST 34( MOL MODEL  )
 ***************************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                           (USING VARIANCES ONLY)

             DU        DV        DW       DELTA      OMEGA     PSI     EPSILON
           METERS    METERS    METERS   (X1.D+6)   SECONDS  SECONDS  SECONDS

          -94.12   -114.17   -125.66      6.17       0.32     -0.16     0.09

          ± 3.50    ± 3.28    ± 3.59    ± 3.02     ± 0.86    ± 0.73   ± 0.98

                        VARIANCE - COVARIANCE MATRIX
                        ----------------------------

      S02=  1.03

   0.123D+02 -0.234D+00  0.212D+01 -0.217D-05  0.725D-05 -0.392D-05 -0.465D-05
  -0.234D+00  0.107D+02 -0.398D+00  0.312D-05  0.131D-05  0.228D-06  0.228D-05
   0.212D+01 -0.398D+00  0.129D+02  0.177D-05  0.454D-05 -0.369D-05 -0.981D-05
  -0.217D-05  0.312D-05  0.177D-05  0.914D-11 -0.384D-12  0.160D-12 -0.487D-12
   0.725D-05  0.131D-05  0.454D-05 -0.384D-12  0.172D-10 -0.321D-11 -0.103D-10
  -0.392D-05  0.228D-06 -0.369D-05  0.160D-12 -0.321D-11  0.125D-10  0.412D-11
  -0.465D-05  0.228D-05 -0.981D-05 -0.487D-12 -0.103D-10  0.412D-11  0.228D-10

                        COEFFICIENTS OF CORRELATION
                        ---------------------------

   0.100D+01 -0.204D-01  0.168D+00 -0.204D+00  0.499D+00 -0.316D+00 -0.278D+00
  -0.204D-01  0.100D+01 -0.338D-01  0.314D+00  0.962D-01  0.197D-01  0.146D+00
   0.168D+00 -0.338D-01  0.100D+01  0.163D+00  0.305D+00 -0.291D+00 -0.572D+00
  -0.204D+00  0.314D+00  0.163D+00  0.100D+01 -0.306D-01  0.149D-01 -0.337D-01
   0.499D+00  0.962D-01  0.305D+00 -0.306D-01  0.100D+01 -0.219D+00 -0.519D+00
  -0.316D+00  0.197D-01 -0.291D+00  0.149D-01 -0.219D+00  0.100D+01  0.245D+00
  -0.278D+00  0.146D+00 -0.572D+00 -0.337D-01 -0.519D+00  0.245D+00  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
 ----------------------------------------
           GREENWICH, EAST, AND CIO. THE ROTATIONS
           ---------------------------------------
           PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
           ------------------------------------------------------
```

Table 19 (Continued)

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

RESIDUALS V*

	V1(ED-50)				V2(WEST 34)			V1 - V2		
6006	-8.1	24.6	-1.9	6006	0.3	-1.2	0.1	-8.4	25.8	-2.0
8004	-2.7	-0.5	0.4	8004	0.5	0.1	-0.1	-3.2	-0.6	0.5
8009	8.2	-4.1	2.6	8009	-1.0	0.8	-0.3	9.2	-4.9	2.9
8010	-0.5	-14.4	4.3	8010	0.0	2.4	-0.4	-0.5	-16.9	4.7
8011	15.7	-0.4	-1.6	8011	-1.0	0.0	0.1	16.8	-0.4	-1.7
8016	1.1	1.0	-3.4	8016	-0.1	-0.1	0.3	1.1	1.1	-2.8
8019	-4.3	-18.8	8.9	8019	0.4	6.2	-0.9	-4.7	-25.0	9.8
8030	4.1	-13.3	4.8	8030	-0.6	5.8	-0.6	4.8	-19.1	5.4
8031	8.3	19.0	-9.2	8031	-5.1	-5.5	3.1	13.5	24.5	-12.3
8032	-11.1	8.1	14.9	8032	0.3	-0.3	-0.5	-11.4	8.4	15.4
8033	2.2	-1.7	-1.5	8033	-0.4	0.4	0.2	2.5	-2.1	-1.7
8701	-1.0	2.4	-8.2	8701	0.1	-0.1	1.0	-1.1	2.5	-9.2
8702	-1.4	-17.4	1.3	8702	0.2	7.1	-0.3	-1.6	-24.5	1.6
8703	-2.6	1.0	-0.0	8703	0.9	-0.3	0.0	-3.4	1.3	-0.1
8705	-0.9	2.6	0.6	8705	2.0	-20.0	-1.4	-2.9	22.6	2.0
8706	-7.0	-9.4	7.2	8706	0.5	1.2	-0.7	-7.5	-10.6	7.8
8711	-16.7	14.4	9.4	8711	0.4	-0.5	-0.3	-17.1	15.0	9.7
8712	-1.3	5.0	-1.9	8712	2.9	-31.4	5.0	-4.2	36.4	-6.9
8713	-5.8	-2.1	4.7	8713	15.3	22.7	-24.4	-21.2	-24.8	29.2
8714	-9.3	11.4	4.4	8714	35.8	-68.8	-32.2	-45.1	80.2	36.6
8716	25.6	-16.2	-26.4	8716	-11.6	6.4	18.2	37.1	-22.6	-44.7
8718	5.3	6.1	-5.9	8718	-1.4	-1.8	1.3	6.6	7.9	-7.1
8720	0.3	-4.5	-2.0	8720	-0.2	2.3	0.4	0.5	-6.8	-2.5
8722	2.0	7.2	-1.5	8722	-1.4	-16.7	0.4	3.4	23.9	-1.9

UNIT OF RESIDUALS (METERS)

* Residuals in the Cartesian coordinate system.

Table 19 (Continued)

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

RESIDUALS V
SPHERICAL*

	V1(ED-50)				V2(WEST 34)			V1 - V2		
6006	-0.98	25.89	-1.7	6006	0.15	-1.24	0.0	-1.13	27.14	-1.7
8004	2.43	-0.03	-1.3	8004	-0.41	0.01	0.2	2.84	-0.04	-1.6
8009	-4.56	-4.75	6.9	8009	0.56	0.85	-0.8	-5.12	-5.60	7.7
8010	4.63	-14.25	1.5	8010	-0.52	2.40	-0.0	5.15	-16.66	1.6
8011	-13.40	0.12	8.4	8011	0.88	-0.01	-0.5	-14.29	0.14	8.9
8016	-3.16	0.83	-1.8	8016	0.29	-0.10	0.2	-3.45	0.93	-2.0
8019	11.04	-18.07	1.3	8019	-1.47	6.11	0.2	12.52	-24.19	1.1
8030	0.44	-13.44	6.0	8030	-0.07	5.84	-0.7	0.51	-19.28	6.7
8031	-11.14	19.48	-3.5	8031	5.74	-5.77	-0.1	-16.88	25.25	-3.4
8032	16.94	10.07	4.8	8032	-0.47	-0.32	-0.2	17.41	10.39	5.0
8033	-2.39	-2.02	0.1	8033	0.36	0.48	-0.0	-2.75	-2.50	0.1
8701	-5.31	2.62	-6.2	8701	0.62	-0.11	0.8	-5.93	2.73	-7.0
8702	2.95	-17.20	-0.7	8702	-0.76	7.09	0.3	3.70	-24.29	-1.0
8703	1.86	1.58	-1.3	8703	-0.65	-0.47	0.5	2.51	2.04	-1.8
8705	1.11	2.60	-0.3	8705	-2.50	-19.94	0.6	3.62	22.54	-0.8
8706	10.56	-8.74	-0.6	8706	-0.93	1.13	0.0	11.48	-9.87	-0.7
8711	14.97	18.28	-4.1	8711	-0.37	-0.59	-0.0	15.34	18.87	-4.1
8712	-1.26	5.17	-1.4	8712	6.85	-31.15	0.3	-8.11	36.32	-1.7
8713	7.61	-0.27	-1.6	8713	-32.55	16.98	0.5	40.16	-17.25	-2.1
8714	8.08	12.73	-2.9	8714	-40.40	-73.56	-1.4	48.48	86.29	-1.5
8716	-37.34	-14.51	3.1	8716	21.64	5.60	2.7	-58.98	-20.10	0.3
8718	-8.44	5.24	-0.4	8718	2.04	-1.56	-0.1	-10.49	6.90	-0.2
8720	-0.10	-4.38	-2.3	8720	-0.18	2.25	0.6	0.09	-6.63	-2.9
8722	0.17	7.38	-1.8	8722	-4.45	-16.00	2.6	4.63	23.38	-4.4

UNIT OF RESIDUALS (METERS)

*The spherical residuals represent the residuals in the Cartesian coordinate system as transformed into the curvilinear (φ, λ, h) system.

Table 20

Transformation

```
ED-50    -TO-  WEST 34( VEIS MODEL )
*************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                              (USING VARIANCES ONLY)

              DU       DV       DW      DELTA     ALPHA     KSI      ETA
            METERS   METERS   METERS  (X1.D+6)  SECONDS  SECONDS  SECONDS

           -94.12  -114.17  -125.66     6.17      0.28    -0.18    -0.16

           ± 3.50   ± 3.28   ± 3.59   ± 3.02    ± 0.63   ± 0.69   ± 1.17

                         VARIANCE - COVARIANCE MATRIX
                         ----------------------------

      SO2=  1.03

  0.123D+02 -0.234D+00  0.212D+01 -0.217D-05  0.244D-05 -0.277D-05 -0.871D-05

 -0.234D+00  0.107D+02 -0.398D+00  0.312D-05  0.243D-05 -0.294D-06  0.100D-05

  0.212D+01 -0.398D+00  0.129D+02  0.177D-05 -0.274D-05 -0.138D-05 -0.110D-04

 -0.217D-05  0.312D-05  0.177D-05  0.914D-11 -0.572D-12  0.266D-12 -0.113D-12

  0.244D-05  0.243D-05 -0.274D-05 -0.572D-12  0.939D-11  0.239D-12  0.583D-12

 -0.277D-05 -0.294D-06 -0.138D-05  0.266D-12  0.239D-12  0.112D-10  0.162D-11

 -0.871D-05  0.100D-05 -0.110D-04 -0.113D-12  0.583D-12  0.162D-11  0.319D-10

                         COEFFICIENTS OF CORRELATION
                         ---------------------------

  0.100D+01 -0.204D-01  0.168D+00 -0.204D+00  0.227D+00 -0.236D+00 -0.440D+00

 -0.204D-01  0.100D+01 -0.338D-01  0.314D+00  0.241D+00 -0.268D-01  0.542D-01

  0.168D+00 -0.338D-01  0.100D+01  0.163D+00 -0.249D+00 -0.114D+00 -0.542D+00

 -0.204D+00  0.314D+00  0.163D+00  0.100D+01 -0.618D-01  0.263D-01 -0.659D-02

  0.227D+00  0.241D+00 -0.249D+00 -0.618D-01  0.100D+01  0.233D-01  0.337D-01

 -0.236D+00 -0.268D-01 -0.114D+00  0.263D-01  0.233D-01  0.100D+01  0.859D-01

 -0.440D+00  0.542D-01 -0.542D+00 -0.659D-02  0.337D-01  0.859D-01  0.100D+01
```

Table 21

Transformation

```
 ED-50     -TO-   W.I.36 ( 3 PARAMETER)
***************************************


              SOLUTION FOR 3 TRANSLATION PARAMETERS
                        (UNITS - METERS)


                      (USING VARIANCES ONLY)


         DU                      DV                      DW
       METERS                  METERS                  METERS

  -0.94066831D+02        -0.11914556D+03         -0.12646272D+03

      ± 2.84                  ± 2.95                  ± 2.78


                   VARIANCE - COVARIANCE MATRIX


       MO2=   1.07

   0.80413891D+01          0.0                     0.0

   0.0                     0.87118834D+01          0.0

   0.0                     0.0                     0.77358910D+01


                    COEFFICIENTS OF CORRELATION


   0.10000000D+01          0.0                     0.0

   0.0                     0.10000000D+01          0.0

   0.0                     0.0                     0.10000000D+01
```

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

Table 21 (Continued)

RESIDUALS V

	V1(ED-50)				V2(W.I.36)			V1 - V2		
6006	-17.8	31.3	6.5	6006	0.5	-1.5	-0.0	-18.3	32.8	6.6
8004	-3.4	2.0	1.5	8004	0.6	-0.3	-0.1	-4.0	2.3	1.6
8009	7.0	-9.4	3.0	8009	-0.5	0.9	-0.1	7.5	-10.2	3.2
8010	0.9	-14.7	3.9	8010	-0.0	1.3	-0.1	0.9	-16.1	4.0
8011	12.4	-2.8	-3.3	8011	-0.6	0.1	0.1	13.0	-3.0	-3.4
8016	2.3	2.6	-3.5	8016	-0.2	-0.3	0.2	2.5	2.9	-3.7
8019	-0.9	-18.5	5.8	8019	0.1	5.8	-0.4	-1.0	-24.3	6.2
8030	4.6	-14.8	4.1	8030	-0.6	6.3	-0.4	5.2	-21.1	4.4
8031	6.9	17.6	-6.4	8031	-4.3	-5.1	1.8	11.2	22.8	-8.3
8032	-9.0	11.2	14.6	8032	0.2	-0.3	-0.2	-9.1	11.6	14.9
8033	1.6	0.2	-2.3	8033	-0.2	-0.0	0.2	1.8	0.2	-2.6
8701	2.8	8.4	-5.5	8701	-0.2	-0.3	0.4	3.0	8.6	-5.9
8702	-1.7	-18.0	1.7	8702	0.3	7.4	-0.2	-1.9	-25.4	1.9
8703	-4.6	4.2	2.0	8703	1.5	-1.1	-0.3	-6.1	5.3	2.3
8705	0.1	2.1	-0.5	8705	-0.3	-16.1	1.2	0.4	18.2	-1.7
8706	0.6	-9.2	0.6	8706	-0.0	0.8	-0.0	0.6	-9.9	0.6
8711	-10.1	20.0	2.7	8711	0.1	-0.7	-0.0	-10.2	20.6	2.8
8712	-0.5	5.6	-2.5	8712	1.1	-36.2	6.6	-1.7	41.8	-9.1
8713	-4.3	-1.5	3.7	8713	11.4	16.4	-19.4	-15.7	-17.9	23.1
8714	-8.1	11.6	3.7	8714	31.9	-71.6	-27.4	-39.9	83.1	31.1
8716	27.8	-19.9	-30.7	8716	-12.2	7.9	19.8	40.0	-27.8	-50.6
8718	5.3	7.4	-6.8	8718	-1.3	-2.1	1.2	6.6	9.5	-8.0
8720	-2.7	0.1	1.5	8720	2.0	-0.1	-0.3	-4.8	0.2	1.8
8722	-3.3	5.8	3.9	8722	2.4	-13.8	-0.6	-5.6	19.6	4.5
9004	-6.0	-21.1	2.4	9004	0.3	3.3	-0.2	-6.3	-24.5	2.6

UNIT OF RESIDUALS (METERS)

Table 22

Transformation

```
ED-50    -TO-  W.I.36 ( MOL MODEL  )
****************************************

        SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
        -------------------------------------------------------------
                           (USING VARIANCES ONLY)

          DU       DV       DW      DELTA      OMEGA     PSI     EPSILON
        METERS   METERS   METERS  (X1.D+6)   SECONDS  SECONDS  SECONDS

        -94.10  -115.53  -125.32    6.12       0.70    -0.15      0.17

        ± 3.45   ± 3.26   ± 3.48  ± 2.77     ± 0.77   ± 0.65   ± 0.86

                        VARIANCE - COVARIANCE MATRIX
                        ----------------------------

      SO2=  1.03

   0.119D+02 -0.179D+00  0.171D+01 -0.225D-05  0.627D-05 -0.300D-05 -0.347D-05

  -0.179D+00  0.106D+02 -0.388D+00  0.301D-05  0.161D-05  0.172D-06  0.227D-05

   0.171D+01 -0.388D+00  0.121D+02  0.182D-05  0.356D-05 -0.254D-05 -0.817D-05

  -0.225D-05  0.301D-05  0.182D-05  0.766D-11 -0.215D-12  0.232D-12 -0.376D-12

   0.627D-05  0.161D-05  0.356D-05 -0.215D-12  0.140D-10 -0.713D-12 -0.769D-11

  -0.300D-05  0.172D-06 -0.254D-05  0.232D-12 -0.713D-12  0.984D-11  0.103D-11

  -0.347D-05  0.227D-05 -0.817D-05 -0.376D-12 -0.769D-11  0.103D-11  0.175D-10

                        COEFFICIENTS OF CORRELATION
                        ---------------------------

   0.100D+01 -0.159D-01  0.142D+00 -0.236D+00  0.486D+00 -0.278D+00 -0.240D+00

  -0.159D-01  0.100D+01 -0.342D-01  0.334D+00  0.132D+00  0.168D-01  0.166D+00

   0.142D+00 -0.342D-01  0.100D+01  0.189D+00  0.273D+00 -0.233D+00 -0.561D+00

  -0.236D+00  0.334D+00  0.189D+00  0.100D+01 -0.208D-01  0.267D-01 -0.325D-01

   0.486D+00  0.132D+00  0.273D+00 -0.208D-01  0.100D+01 -0.607D-01 -0.490D+00

  -0.278D+00  0.168D-01 -0.233D+00  0.267D-01 -0.607D-01  0.100D+01  0.787D-01

  -0.240D+00  0.166D+00 -0.561D+00 -0.325D-01 -0.490D+00  0.787D-01  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
----------------------------------------
       GREENWICH, EAST, AND CIO. THE ROTATIONS
       ---------------------------------------
       PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
       ------------------------------------------------------
```

Table 22 (Continued)

RESIDUALS V*

	V1(ED-50)				V2(W.I.36)			V1 - V2		
6006	-7.8	22.6	-1.6	6006	0.2	-1.1	0.0	-8.0	23.7	-1.6
8004	-3.0	-0.2	0.3	8004	0.5	0.0	-0.0	-3.5	-0.2	0.3
8009	8.2	-9.0	1.7	8009	-0.6	0.8	-0.1	8.7	-9.9	1.8
8010	-0.9	-14.4	5.2	8010	0.0	1.3	-0.2	-0.9	-15.6	5.4
8011	15.0	0.1	-5.1	8011	-0.8	-0.0	0.2	15.8	0.1	-5.2
8016	1.3	2.4	-3.0	8016	-0.1	-0.3	0.2	1.4	2.7	-3.2
8019	-4.0	-17.5	8.7	8019	0.2	5.5	-0.6	-4.2	-23.0	9.3
8030	4.8	-13.2	4.1	8030	-0.6	5.6	-0.4	5.4	-18.7	4.5
8031	9.9	19.3	-9.2	8031	-6.1	-5.6	2.6	16.0	24.9	-11.8
8032	-11.0	9.7	15.7	8032	0.2	-0.3	-0.2	-11.2	10.0	16.0
8033	1.2	-0.7	-2.6	8033	-0.2	0.2	0.3	1.4	-0.8	-2.8
8701	-0.0	4.8	-3.9	8701	0.0	-0.1	0.3	-0.0	4.9	-4.2
8702	-1.1	-17.5	1.0	8702	0.2	7.2	-0.1	-1.3	-24.6	1.1
8703	-3.1	0.9	-0.4	8703	1.0	-0.2	0.1	-4.1	1.2	-0.5
8705	-0.2	2.6	0.1	8705	0.4	-20.5	-0.2	-0.5	23.2	0.3
8706	-2.1	-6.9	3.4	8706	0.1	0.6	-0.1	-2.2	-7.5	3.5
8711	-17.4	18.4	9.8	8711	0.2	-0.6	-0.2	-17.6	19.0	9.9
8712	-1.6	5.3	-1.8	8712	3.5	-34.0	4.9	-5.2	39.3	-6.7
8713	-6.0	-1.8	4.6	8713	16.0	19.7	-24.1	-22.0	-21.5	28.6
8714	-9.2	11.8	4.4	8714	36.3	-72.8	-32.4	-45.5	84.6	36.8
8716	26.6	-14.2	-28.2	8716	-11.7	5.6	18.2	38.3	-19.8	-46.4
8718	4.5	6.9	-6.5	8718	-1.1	-2.0	1.2	5.6	8.9	-7.6
8720	-0.7	-4.5	-2.1	8720	0.5	2.3	0.4	-1.2	-6.9	-2.4
8722	4.6	6.9	-2.8	8722	-3.3	-16.4	0.5	8.0	23.3	-3.3
9004	-8.0	-11.9	8.2	9004	0.4	1.9	-0.7	-8.5	-13.8	8.9

UNIT OF RESIDUALS (METERS)

*Residuals in the Cartesian coordinate system.

Table 22 (Continued)

RESIDUALS V*
SPHERICAL

	V1(ED-50)				V2(W.I.36)			V1 - V2		
6006	-0.54	23.90	-1.5	6006	0.12	-1.08	-0.0	-0.66	24.98	-1.5
8004	2.53	0.38	-1.6	8004	-0.41	-0.06	0.3	2.94	0.44	-1.9
8009	-4.80	-9.60	5.9	8009	0.35	0.89	-0.4	-5.15	-10.49	6.3
8010	5.59	-14.11	1.9	8010	-0.26	1.26	0.0	5.85	-15.38	1.9
8011	-14.97	0.58	5.2	8011	0.70	-0.03	-0.3	-15.67	0.61	5.5
8016	-3.22	2.24	-1.2	8016	0.20	-0.25	0.0	-3.42	2.49	-1.3
8019	10.58	-16.83	1.6	8019	-1.07	5.43	0.3	11.64	-22.26	1.3
8030	-0.48	-13.35	5.9	8030	0.03	5.58	-0.5	-0.51	-18.94	6.5
8031	-12.44	19.82	-2.7	8031	6.27	-5.94	-1.1	-18.70	25.76	-1.5
8032	17.16	11.62	5.7	8032	-0.26	-0.33	-0.1	17.42	11.95	5.7
8033	-2.45	-0.84	-1.3	8033	0.29	0.19	0.1	-2.74	-1.03	-1.4
8701	-3.58	4.62	-2.0	8701	0.23	-0.14	0.2	-3.81	4.76	-2.2
8702	2.52	-17.35	-0.8	8702	-0.63	7.12	0.4	3.14	-24.47	-1.1
8703	2.10	1.57	-2.0	8703	-0.73	-0.46	0.6	2.83	2.03	-2.5
8705	0.20	2.62	-0.1	8705	-0.54	-20.54	0.2	0.74	23.16	-0.3
8706	4.34	-6.72	0.4	8706	-0.16	0.56	0.0	4.51	-7.28	0.4
8711	15.03	22.29	-3.6	8711	-0.17	-0.64	-0.1	15.19	22.93	-3.5
8712	-1.06	5.52	-1.5	8712	6.73	-33.89	0.2	-7.79	39.41	-1.7
8713	7.55	0.11	-1.8	8713	-32.09	13.94	0.5	39.64	-13.84	-2.3
8714	7.97	13.10	-2.8	8714	-40.50	-77.67	-1.7	48.47	90.78	-1.1
8716	-39.25	-12.39	2.6	8716	21.64	4.86	2.7	-60.90	-17.25	-0.0
8718	-8.40	6.16	-1.3	8718	1.78	-1.79	-0.0	-10.18	7.95	-1.3
8720	0.69	-4.12	-2.8	8720	-0.83	2.08	0.9	1.52	-6.20	-3.7
8722	-2.67	8.13	-1.8	8722	-2.69	-16.47	1.8	0.02	24.60	-3.7
9004	10.56	-12.73	-0.5	9004	-0.71	1.93	-0.2	11.28	-14.66	-0.3

UNIT OF RESIDUALS (METERS)

*The spherical residuals represent the residuals in the Cartesian coordinate system as transformed into the curvilinear (φ, λ, h) system.

Table 23

Transformation

```
ED-50    -TO-  W.I.36 ( VEIS MODEL )
*************************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                            (USING VARIANCES ONLY)

            DU        DV        DW      DELTA      ALPHA     KSI      ETA
          METERS    METERS    METERS  (XI.D+6)   SECONDS  SECONDS  SECONDS

          -94.10   -115.53   -125.32    6.12       0.63    -0.18    -0.32

          ± 3.45   ± 3.26    ± 3.48   ± 2.77     ± 0.58   ± 0.64   ± 1.00
                        VARIANCE - COVARIANCE MATRIX
                        ----------------------------

      SO2=  1.03

   0.119D+02 -0.179D+00  0.171D+01 -0.225D-05  0.249D-05 -0.214D-05 -0.704D-05

  -0.179D+00  0.106D+02 -0.388D+00  0.301D-05  0.265D-05 -0.347D-06  0.801D-06

   0.171D+01 -0.388D+00  0.121D+02  0.182D-05 -0.239D-05 -0.630D-06 -0.893D-05

  -0.225D-05  0.301D-05  0.182D-05  0.766D-11 -0.362D-12  0.311D-12 -0.117D-12

   0.249D-05  0.265D-05 -0.239D-05 -0.362D-12  0.796D-11  0.358D-12 -0.227D-12

  -0.214D-05 -0.347D-06 -0.630D-06  0.311D-12  0.358D-12  0.978D-11 -0.124D-11

  -0.704D-05  0.801D-06 -0.893D-05 -0.117D-12 -0.227D-12 -0.124D-11  0.237D-10


                        COEFFICIENTS OF CORRELATION
                        ---------------------------

   0.100D+01 -0.159D-01  0.142D+00 -0.236D+00  0.256D+00 -0.199D+00 -0.420D+00

  -0.159D-01  0.100D+01 -0.342D-01  0.334D+00  0.288D+00 -0.340D-01  0.504D-01

   0.142D+00 -0.342D-01  0.100D+01  0.189D+00 -0.244D+00 -0.579D-01 -0.528D+00

  -0.236D+00  0.334D+00  0.189D+00  0.100D+01 -0.464D-01  0.360D-01 -0.873D-02

   0.256D+00  0.288D+00 -0.244D+00 -0.464D-01  0.100D+01  0.406D-01 -0.165D-01

  -0.199D+00 -0.340D-01 -0.579D-01  0.360D-01  0.406D-01  0.100D+01 -0.818D-01

  -0.420D+00  0.504D-01 -0.528D+00 -0.873D-02 -0.165D-01 -0.818D-01  0.100D+01
```

Table 24

Transformation

```
ED-50    -TO-  W.I.36 ( BURSA       )
****************************************

        SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
        -------------------------------------------------------------
                              (USING VARIANCES ONLY)

          DU        DV        DW      DELTA      OMEGA     PSI     EPSILON
        METERS    METERS    METERS  (X1.D+6)   SECONDS   SECONDS   SECONDS

       -123.91   -112.22   -152.66    6.12       0.70     -0.15      0.17

       ±18.82    ±30.64    ±18.80   ± 2.77     ± 0.77    ± 0.65    ± 0.86

                            VARIANCE - COVARIANCE MATRIX
                            ----------------------------

     SO2=  1.03

  0.354D+03 -0.695D+02 -0.372D+02 -0.300D-04 -0.888D-05  0.462D-04  0.994D-05
 -0.695D+02  0.939D+03 -0.503D+01 -0.267D-05  0.938D-04 -0.794D-05 -0.115D-03
 -0.372D+02 -0.503D+01  0.353D+03 -0.379D-04  0.568D-06 -0.402D-04  0.526D-05
 -0.300D-04 -0.267D-05 -0.379D-04  0.766D-11 -0.215D-12  0.232D-12 -0.376D-12
 -0.888D-05  0.938D-04  0.568D-06 -0.215D-12  0.140D-10 -0.713D-12 -0.769D-11
  0.462D-04 -0.794D-05 -0.402D-04  0.232D-12 -0.713D-12  0.984D-11  0.103D-11
  0.994D-05 -0.115D-03  0.526D-05 -0.376D-12 -0.769D-11  0.103D-11  0.175D-10

                            COEFFICIENTS OF CORRELATION
                            ---------------------------

  0.100D+01 -0.121D+00 -0.105D+00 -0.576D+00 -0.126D+00  0.783D+00  0.126D+00
 -0.121D+00  0.100D+01 -0.873D-02 -0.315D-01  0.817D+00 -0.827D-01 -0.895D+00
 -0.105D+00 -0.873D-02  0.100D+01 -0.729D+00  0.806D-02 -0.682D+00  0.668D-01
 -0.576D+00 -0.315D-01 -0.729D+00  0.100D+01 -0.208D-01  0.267D-01 -0.325D-01
 -0.126D+00  0.817D+00  0.806D-02 -0.208D-01  0.100D+01 -0.607D-01 -0.490D+00
  0.783D+00 -0.827D-01 -0.682D+00  0.267D-01 -0.607D-01  0.100D+01  0.787D-01
  0.126D+00 -0.895D+00  0.668D-01 -0.325D-01 -0.490D+00  0.787D-01  0.100D+01
NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
---------------------------------------------
       GREENWICH, EAST, AND CIO. THE ROTATIONS
       -----------------------------------------
       PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
       -------------------------------------------------------
```

REPRODUCIBILITY
ORIGINAL PAGE

Table 25

Transformation

```
NGS      -TO-  W.I.36 ( MOL MODEL  )
***************************************

      SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
      -------------------------------------------------------------
                         (USING VARIANCES ONLY)

         DU       DV       DW      DELTA     OMEGA     PSI    EPSILON
       METERS   METERS   METERS  (X1.D+6)  SECONDS  SECONDS  SECONDS

       -9.17   -10.04    15.98     0.90     -1.68     0.55     2.10

      ± 2.68  ± 3.30   ± 3.49   ± 1.62   ± 1.58   ± 0.53   ± 2.13

                      VARIANCE - COVARIANCE MATRIX
                      ----------------------------

    SO2=  1.07

  0.717D+01  0.259D+01  0.283D+01  0.100D-05 -0.978D-05  0.254D-05  0.127D-04

  0.259D+01  0.109D+02  0.477D+01 -0.401D-06 -0.164D-04  0.414D-05  0.210D-04

  0.283D+01  0.477D+01  0.122D+02 -0.267D-06 -0.170D-04  0.551D-05  0.237D-04

  0.100D-05 -0.401D-06 -0.267D-06  0.263D-11 -0.190D-13 -0.326D-12 -0.797D-13

 -0.978D-05 -0.164D-04 -0.170D-04 -0.190D-13  0.585D-10 -0.146D-10 -0.756D-10

  0.254D-05  0.414D-05  0.551D-05 -0.326D-12 -0.146D-10  0.669D-11  0.199D-10

  0.127D-04  0.210D-04  0.237D-04 -0.797D-13 -0.756D-10  0.199D-10  0.106D-09

                      COEFFICIENTS OF CORRELATION
                      ---------------------------

  0.100D+01  0.292D+00  0.302D+00  0.230D+00 -0.478D+00  0.367D+00  0.459D+00

  0.292D+00  0.100D+01  0.413D+00 -0.748D-01 -0.649D+00  0.484D+00  0.617D+00

  0.302D+00  0.413D+00  0.100D+01 -0.472D-01 -0.636D+00  0.610D+00  0.657D+00

  0.230D+00 -0.748D-01 -0.472D-01  0.100D+01 -0.153D-02 -0.778D-01 -0.476D-02

 -0.478D+00 -0.649D+00 -0.636D+00 -0.153D-02  0.100D+01 -0.740D+00 -0.959D+00

  0.367D+00  0.484D+00  0.610D+00 -0.778D-01 -0.740D+00  0.100D+01  0.745D+00

  0.459D+00  0.617D+00  0.657D+00 -0.476D-02 -0.959D+00  0.745D+00  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
---------------------------------------------
        GREENWICH, EAST, AND CIO. THE ROTATIONS
        ----------------------------------------
        PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
        -------------------------------------------------------
```

Table 25 (Continued)

RESIDUALS V

V1(NGS)				V2(W.I.36)				V1 - V2		
6006	-0.5	1.1	-0.9	6006	0.2	-0.5	0.0	-0.7	1.7	-1.0
6016	-1.9	1.4	-0.4	6016	0.3	-0.6	0.1	-2.2	1.9	-0.4
6065	2.4	-2.3	1.2	6065	-0.5	0.9	-0.2	3.0	-3.1	1.3

UNIT OF RESIDUALS (METERS)

Table 26

Transformation

```
NGS       -TO-   W.I.36 ( BURSA       )
****************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                              (USING VARIANCES ONLY)

            DU       DV       DW     DELTA      OMEGA     PSI     EPSILON
          METERS   METERS   METERS  (X1.D+6)   SECONDS  SECONDS   SECONDS

           6.19    -92.95    8.96     0.90      -1.68     0.55      2.10

          ±19.97   ±77.89   ±10.30   ± 1.62    ± 1.58   ± 0.53    ± 2.13

                        VARIANCE - COVARIANCE MATRIX
                        ----------------------------

      SO2=  1.07

   0.399D+03 -0.128D+04  0.370D+02 -0.116D-04 -0.127D-03  0.474D-04  0.169D-03
  -0.128D+04  0.607D+04 -0.187D+03 -0.226D-05  0.586D-03 -0.151D-03 -0.798D-03
   0.370D+02 -0.187D+03  0.106D+03 -0.113D-04 -0.173D-04 -0.484D-05  0.277D-04
  -0.116D-04 -0.226D-05 -0.113D-04  0.263D-11 -0.190D-13 -0.326D-12 -0.797D-13
  -0.127D-03  0.586D-03 -0.173D-04 -0.190D-13  0.585D-10 -0.146D-10 -0.756D-10
   0.474D-04 -0.151D-03 -0.484D-05 -0.326D-12 -0.146D-10  0.669D-11  0.199D-10
   0.169D-03 -0.798D-03  0.277D-04 -0.797D-13 -0.756D-10  0.199D-10  0.106D-09

                        COEFFICIENTS OF CORRELATION
                        ---------------------------

   0.100D+01 -0.823D+00  0.180D+00 -0.358D+00 -0.829D+00  0.918D+00  0.818D+00
  -0.823D+00  0.100D+01 -0.233D+00 -0.179D-01  0.983D+00 -0.748D+00 -0.993D+00
   0.180D+00 -0.233D+00  0.100D+01 -0.678D+00 -0.220D+00 -0.182D+00  0.261D+00
  -0.358D+00 -0.179D-01 -0.678D+00  0.100D+01 -0.153D-02 -0.778D-01 -0.476D-02
  -0.829D+00  0.983D+00 -0.220D+00 -0.153D-02  0.100D+01 -0.740D+00 -0.959D+00
   0.918D+00 -0.748D+00 -0.182D+00 -0.778D-01 -0.740D+00  0.100D+01  0.745D+00
   0.818D+00 -0.993D+00  0.261D+00 -0.476D-02 -0.959D+00  0.745D+00  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
 ------------------------------------------
        GREENWICH, EAST, AND CIO. THE ROTATIONS
        ---------------------------------------
        PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
        -----------------------------------------------------
```

Table 27

Transformation

```
SAO III   -TO-  W.I.36 ( MOL MODEL  )
************************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                             (USING VARIANCES ONLY)

            DU       DV       DW      DELTA     OMEGA     PSI    EPSILON
          METERS   METERS   METERS  (X1.D+6)  SECONDS  SECONDS   SECONDS

          -8.17   -15.30     9.68    -0.32     -0.23    -0.38      0.53

         ± 2.53   ± 2.88   ± 2.60   ± 2.45    ± 0.68   ± 0.67    ± 0.78
                          VARIANCE - COVARIANCE MATRIX
                          ----------------------------

      SO2=   0.99

   0.640D+01 -0.236D+00  0.629D+00 -0.182D-05  0.393D-05 -0.121D-05 -0.168D-05

  -0.236D+00  0.829D+01 -0.199D+00  0.319D-05  0.152D-05 -0.305D-06  0.272D-05

   0.629D+00 -0.199D+00  0.674D+01  0.175D-05  0.175D-05 -0.932D-06 -0.505D-05

  -0.182D-05  0.319D-05  0.175D-05  0.598D-11  0.575D-12 -0.136D-12  0.463D-12

   0.393D-05  0.152D-05  0.175D-05  0.575D-12  0.110D-10  0.480D-11 -0.643D-11

  -0.121D-05 -0.305D-06 -0.932D-06 -0.136D-12  0.480D-11  0.107D-10 -0.537D-11

  -0.168D-05  0.272D-05 -0.505D-05  0.463D-12 -0.643D-11 -0.537D-11  0.143D-10


                          COEFFICIENTS OF CORRELATION
                          ---------------------------

   0.100D+01 -0.325D-01  0.959D-01 -0.294D+00  0.469D+00 -0.146D+00 -0.176D+00

  -0.325D-01  0.100D+01 -0.266D-01  0.453D+00  0.160D+00 -0.325D-01  0.250D+00

   0.959D-01 -0.266D-01  0.100D+01  0.276D+00  0.203D+00 -0.110D+00 -0.515D+00

  -0.294D+00  0.453D+00  0.276D+00  0.100D+01  0.710D-01 -0.170D-01  0.501D-01

   0.469D+00  0.160D+00  0.203D+00  0.710D-01  0.100D+01  0.444D+00 -0.514D+00

  -0.146D+00 -0.325D-01 -0.110D+00 -0.170D-01  0.444D+00  0.100D+01 -0.435D+00

  -0.176D+00  0.250D+00 -0.515D+00  0.501D-01 -0.514D+00 -0.435D+00  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
------------------------------------------
         GREENWICH, EAST, AND CIO. THE ROTATIONS
         ---------------------------------------
         PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
         ------------------------------------------------------
```

Table 27 (Continued)

RESIDUALS V

	V1(SAO III)				V2(W.I.36)			V1 - V2		
6006	-13.6	1.6	-7.5	6006	0.5	-0.1	0.1	-14.1	1.7	-7.5
6016	-14.0	8.8	-4.8	6016	0.3	-0.5	0.2	-14.2	9.3	-5.0
8010	1.1	-1.8	2.1	8010	-0.6	2.4	-1.0	1.7	-4.2	3.1
8011	6.7	1.7	-7.1	8011	-0.4	-0.1	0.3	7.1	1.8	-7.4
8015	1.2	0.6	-0.2	8015	-1.8	-2.4	0.3	3.0	3.1	-0.5
8019	-5.0	-10.7	-3.3	8019	0.6	6.4	0.4	-5.6	-17.1	-3.7
9004	-1.5	-0.1	0.4	9004	1.9	0.2	-0.7	-3.4	-0.2	1.0

UNIT OF RESIDUALS (METERS)

Table 28

Transformation

```
SAO III   -TO-  W.I.36 ( BURSA        )
****************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                              (USING VARIANCES ONLY)

             DU       DV       DW      DELTA      OMEGA     PSI    EPSILON
           METERS   METERS   METERS  (X1.D+6)   SECONDS  SECONDS  SECONDS

          -14.66   -31.67    21.12    -0.32      -0.23    -0.38     0.53

          ±18.04   ±27.56   ±18.68   ± 2.45     ± 0.68   ± 0.67    ± 0.78

                           VARIANCE - COVARIANCE MATRIX
                           ----------------------------

      SO2=   0.99

   0.325D+03  0.181D+03 -0.914D+02 -0.281D-04  0.151D-04  0.455D-04 -0.236D-04

   0.181D+03  0.759D+03 -0.230D+03 -0.148D-05  0.776D-04  0.453D-04 -0.919D-04

  -0.914D+02 -0.230D+03  0.349D+03 -0.254D-04 -0.265D-04 -0.496D-04  0.271D-04

  -0.281D-04 -0.148D-05 -0.254D-04  0.598D-11  0.575D-12 -0.136D-12  0.463D-12

   0.151D-04  0.776D-04 -0.265D-04  0.575D-12  0.110D-10  0.480D-11 -0.643D-11

   0.455D-04  0.453D-04 -0.496D-04 -0.136D-12  0.480D-11  0.107D-10 -0.537D-11

  -0.236D-04 -0.919D-04  0.271D-04  0.463D-12 -0.643D-11 -0.537D-11  0.143D-10


                           COEFFICIENTS OF CORRELATION
                           ---------------------------

   0.100D+01  0.365D+00 -0.271D+00 -0.638D+00  0.252D+00  0.773D+00 -0.346D+00

   0.365D+00  0.100D+01 -0.446D+00 -0.219D-01  0.849D+00  0.503D+00 -0.883D+00

  -0.271D+00 -0.446D+00  0.100D+01 -0.556D+00 -0.428D+00 -0.813D+00  0.384D+00

  -0.638D+00 -0.219D-01 -0.556D+00  0.100D+01  0.710D-01 -0.170D-01  0.501D-01

   0.252D+00  0.849D+00 -0.428D+00  0.710D-01  0.100D+01  0.444D+00 -0.514D+00

   0.773D+00  0.503D+00 -0.813D+00 -0.170D-01  0.444D+00  0.100D+01 -0.435D+00

  -0.346D+00 -0.883D+00  0.384D+00  0.501D-01 -0.514D+00 -0.435D+00  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
 -----------------------------------------
        GREENWICH, EAST, AND CIO. THE ROTATIONS
        ---------------------------------------
        PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
        ------------------------------------------------------
```

Table 29

Transformation

```
 WN-14    -TO-  W.I.36 ( MOL MODEL   )
**************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                             (USING VARIANCES ONLY)

            DU        DV        DW       DELTA      OMEGA     PSI      EPSILON
          METERS    METERS    METERS   (X1.D+6)    SECONDS  SECONDS   SECONDS

            0.19      0.68      0.12     -1.19       0.04     -0.12     -0.47

          ± 1.73    ± 2.41    ± 1.93    ± 1.42     ± 0.50    ± 0.31    ± 0.63

                         VARIANCE - COVARIANCE MATRIX
                         ----------------------------

      SO2=  1.00

  0.301D+01 -0.887D-01  0.107D-01  0.991D-07  0.397D-06 -0.377D-06 -0.317D-06

 -0.887D-01  0.580D+01 -0.156D+00 -0.125D-06 -0.121D-05  0.748D-07  0.131D-05

  0.107D-01 -0.156D+00  0.374D+01  0.139D-06  0.515D-06  0.157D-06 -0.106D-05

  0.991D-07 -0.125D-06  0.139D-06  0.202D-11  0.859D-13 -0.233D-12  0.734D-13

  0.397D-06 -0.121D-05  0.515D-06  0.859D-13  0.579D-11 -0.281D-12 -0.459D-11

 -0.377D-06  0.748D-07  0.157D-06 -0.233D-12 -0.281D-12  0.227D-11  0.266D-12

 -0.317D-06  0.131D-05 -0.106D-05  0.734D-13 -0.459D-11  0.266D-12  0.934D-11

                         COEFFICIENTS OF CORRELATION
                         ---------------------------

  0.100D+01 -0.212D-01  0.320D-02  0.402D-01  0.950D-01 -0.144D+00 -0.598D-01

 -0.212D-01  0.100D+01 -0.335D-01 -0.366D-01 -0.210D+00  0.206D-01  0.178D+00

  0.320D-02 -0.335D-01  0.100D+01  0.507D-01  0.111D+00  0.539D-01 -0.179D+00

  0.402D-01 -0.366D-01  0.507D-01  0.100D+01  0.251D-01 -0.109D+00  0.169D-01

  0.950D-01 -0.210D+00  0.111D+00  0.251D-01  0.100D+01 -0.775D-01 -0.624D+00

 -0.144D+00  0.206D-01  0.539D-01 -0.109D+00 -0.775D-01  0.100D+01  0.577D-01

 -0.598D-01  0.178D+00 -0.179D+00  0.169D-01 -0.624D+00  0.577D-01  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
-------------------------------------------
        GREENWICH, EAST, AND CIO. THE ROTATIONS
        ---------------------------------------
        PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
        ------------------------------------------------------
```

Table 29 (Continued)

RESIDUALS V

	V1(WN-14)				V2(W.I.36)			V1 - V2		
6006	-1.3	-0.3	1.9	6006	0.4	0.1	-0.1	-1.7	-0.5	2.0
6016	1.3	-2.0	-1.2	6016	-0.3	0.8	0.3	1.5	-2.8	-1.4
6065	-0.6	-5.0	1.7	6065	0.2	1.5	-0.3	-0.8	-6.5	2.0
8009	-0.1	6.1	-3.3	8009	0.0	-0.3	0.2	-0.1	6.4	-3.5
8010	-8.0	9.6	6.2	8010	0.6	-0.8	-0.4	-8.6	10.4	6.6
8011	14.9	57.6	-12.5	8011	-0.6	-0.7	0.5	15.5	58.3	-13.1
8015	0.6	22.3	-5.0	8015	-0.1	-1.7	0.5	0.6	24.1	-5.5
8019	-0.2	8.4	-0.2	8019	0.0	-2.5	0.0	-0.2	10.9	-0.2
8030	1.6	12.6	-0.3	8030	-0.3	-3.4	0.1	1.9	16.1	-0.4
9004	-0.0	18.9	1.3	9004	0.0	-1.8	-0.4	-0.0	20.7	1.8

UNIT OF RESIDUALS (METERS)

Table 30

Transformation

```
WN-14    -TO-  W.I.36 ( BURSA      )
****************************************

SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
-------------------------------------------------------------
                    (USING VARIANCES ONLY)

  DU       DV       DW      DELTA     OMEGA     PSI     EPSILON
 METERS   METERS   METERS  (X1.D+6)  SECONDS  SECONDS  SECONDS

  2.41    12.98     6.24    -1.19     0.04    -0.12     -0.47

 ±10.00  ±21.82   ± 8.89   ± 1.42   ± 0.50   ± 0.31   ± 0.63

                 VARIANCE - COVARIANCE MATRIX
                 ----------------------------

     SO2=  1.00

 0.100D+03 -0.364D+02 -0.704D-01 -0.959D-05 -0.604D-05  0.115D-04  0.439D-05

-0.364D+02  0.476D+03 -0.266D+02 -0.177D-05  0.447D-04 -0.217D-05 -0.620D-04

-0.704D-01 -0.266D+02  0.791D+02 -0.833D-05 -0.247D-05 -0.810D-05  0.514D-05

-0.959D-05 -0.177D-05 -0.833D-05  0.202D-11  0.859D-13 -0.233D-12  0.734D-13

-0.604D-05  0.447D-04 -0.247D-05  0.859D-13  0.579D-11 -0.281D-12 -0.459D-11

 0.115D-04 -0.217D-05 -0.810D-05 -0.233D-12 -0.281D-12  0.227D-11  0.266D-12

 0.439D-05 -0.620D-04  0.514D-05  0.734D-13 -0.459D-11  0.266D-12  0.934D-11


                 COEFFICIENTS OF CORRELATION
                 ---------------------------

 0.100D+01 -0.167D+00 -0.792D-03 -0.674D+00 -0.251D+00  0.764D+00  0.144D+00

-0.167D+00  0.100D+01 -0.137D+00 -0.570D-01  0.851D+00 -0.659D-01 -0.930D+00

-0.792D-03 -0.137D+00  0.100D+01 -0.659D+00 -0.115D+00 -0.604D+00  0.189D+00

-0.674D+00 -0.570D-01 -0.659D+00  0.100D+01  0.251D-01 -0.109D+00  0.169D-01

-0.251D+00  0.851D+00 -0.115D+00  0.251D-01  0.100D+01 -0.775D-01 -0.624D+00

 0.764D+00 -0.659D-01 -0.604D+00 -0.109D+00 -0.775D-01  0.100D+01  0.577D-01

 0.144D+00 -0.930D+00  0.189D+00  0.169D-01 -0.624D+00  0.577D-01  0.100D+01
NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
-----------------------------------------
      GREENWICH, EAST, AND CIO. THE ROTATIONS
      ---------------------------------------
      PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
      ------------------------------------------------------
```

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

Table 31

Transformation

```
GEM 6    -TO-  W.I.36 ( MOL MODEL   )
******************************************

     SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
     -------------------------------------------------------------
                       (USING VARIANCES ONLY)

       DU        DV        DW      DELTA      OMEGA     PSI     EPSILON
     METERS    METERS    METERS  (X1.D+6)   SECONDS  SECONDS   SECONDS

     -19.53    -30.67     6.09     1.56      -0.66    -0.73     -0.53

     ± 1.98    ± 2.25   ± 2.00   ± 1.35    ± 0.37   ± 0.31    ± 0.45

                    VARIANCE - COVARIANCE MATRIX
                    ----------------------------

    SO2=  1.04

  0.390D+01 -0.901D-01  0.290D-01 -0.458D-06  0.739D-06 -0.868D-06 -0.356D-06
 -0.901D-01  0.507D+01 -0.173D+00  0.184D-06 -0.312D-06 -0.131D-06  0.124D-05
  0.290D-01 -0.173D+00  0.399D+01  0.601D-06  0.409D-06 -0.145D-06 -0.901D-06
 -0.458D-06  0.184D-06  0.601D-06  0.182D-11  0.209D-12  0.505D-13 -0.744D-14
  0.739D-06 -0.312D-06  0.409D-06  0.209D-12  0.319D-11  0.473D-12 -0.198D-11
 -0.868D-06 -0.131D-06 -0.145D-06  0.505D-13  0.473D-12  0.223D-11 -0.595D-12
 -0.356D-06  0.124D-05 -0.901D-06 -0.744D-14 -0.198D-11 -0.595D-12  0.483D-11

                    COEFFICIENTS OF CORRELATION
                    ---------------------------

  0.100D+01 -0.203D-01  0.735D-02 -0.172D+00  0.209D+00 -0.294D+00 -0.820D-01
 -0.203D-01  0.100D+01 -0.385D-01  0.606D-01 -0.775D-01 -0.391D-01  0.251D+00
  0.735D-02 -0.385D-01  0.100D+01  0.223D+00  0.115D+00 -0.485D-01 -0.205D+00
 -0.172D+00  0.606D-01  0.223D+00  0.100D+01  0.868D-01  0.251D-01 -0.251D-02
  0.209D+00 -0.775D-01  0.115D+00  0.868D-01  0.100D+01  0.177D+00 -0.504D+00
 -0.294D+00 -0.391D-01 -0.485D-01  0.251D-01  0.177D+00  0.100D+01 -0.181D+00
 -0.820D-01  0.251D+00 -0.205D+00 -0.251D-02 -0.504D+00 -0.181D+00  0.100D+01
NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
---------------------------------------------
       GREENWICH, EAST, AND CIO. THE ROTATIONS
       -----------------------------------------
       PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
       -------------------------------------------------------
```

Table 31 (Continued)

RESIDUALS V

	V1(GEM 6)				V2(W.I.36)			V1 - V2		
6006	-0.8	4.6	-0.7	6006	0.2	-1.6	0.0	-1.0	6.2	-0.7
6016	-1.6	-0.8	0.1	6016	0.4	0.5	-0.0	-2.0	-1.4	0.1
6065	0.3	-3.2	2.6	6065	-0.1	1.1	-0.4	0.4	-4.3	3.1
9004	0.2	0.1	-0.1	9004	-1.9	-3.1	2.3	2.1	3.2	-2.4

UNIT OF RESIDUALS (METERS)

Table 32

Transformation

```
GEM 6    -TO-  W.I.36 ( BURSA       )
*******************************************

          SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
          -------------------------------------------------------------
                              (USING VARIANCES ONLY)

            DU       DV       DW      DELTA     OMEGA    PSI     EPSILON
          METERS   METERS   METERS  (X1.D+6)   SECONDS SECONDS  SECONDS

          -40.22   -33.38    11.63     1.56     -0.66    -0.73    -0.53

          ± 8.82   ±15.24   ± 9.34   ± 1.35   ± 0.37   ± 0.31   ± 0.45
                            VARIANCE - COVARIANCE MATRIX
                            ----------------------------

       SO2=  1.04

  0.778D+02  0.102D+02 -0.481D+01 -0.805D-05 -0.538D-06  0.900D-05 -0.150D-05

  0.102D+02  0.232D+03 -0.368D+02 -0.392D-06  0.223D-04  0.462D-05 -0.298D-04

 -0.481D+01 -0.368D+02  0.872D+02 -0.816D-05 -0.419D-05 -0.102D-04  0.560D-05

 -0.805D-05 -0.392D-06 -0.816D-05  0.182D-11  0.209D-12  0.505D-13 -0.744D-14

 -0.538D-06  0.223D-04 -0.419D-05  0.209D-12  0.319D-11  0.473D-12 -0.198D-11

  0.900D-05  0.462D-05 -0.102D-04  0.505D-13  0.473D-12  0.223D-11 -0.595D-12

 -0.150D-05 -0.298D-04  0.560D-05 -0.744D-14 -0.198D-11 -0.595D-12  0.483D-11

                            COEFFICIENTS OF CORRELATION
                            ---------------------------

  0.100D+01  0.755D-01 -0.584D-01 -0.677D+00 -0.342D-01  0.684D+00 -0.772D-01

  0.755D-01  0.100D+01 -0.259D+00 -0.191D-01  0.818D+00  0.203D+00 -0.890D+00

 -0.584D-01 -0.259D+00  0.100D+01 -0.649D+00 -0.251D+00 -0.736D+00  0.273D+00

 -0.677D+00 -0.191D-01 -0.649D+00  0.100D+01  0.868D-01  0.251D-01 -0.251D-02

 -0.342D-01  0.818D+00 -0.251D+00  0.868D-01  0.100D+01  0.177D+00 -0.504D+00

  0.684D+00  0.203D+00 -0.736D+00  0.251D-01  0.177D+00  0.100D+01 -0.181D+00

 -0.772D-01 -0.890D+00  0.273D+00 -0.251D-02 -0.504D+00 -0.181D+00  0.100D+01
 NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
---------------------------------------------
        GREENWICH, EAST, AND CIO. THE ROTATIONS
        ---------------------------------------
        PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
        ------------------------------------------------------
```

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APPENDIX I

CARTESIAN AND GEODETIC COORDINATES

(Solution WEST35)

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: $u \equiv$ the Greenwich meridian as defined by the B.I.H.; $v \equiv \lambda = 90^\circ$ (E); $w \equiv$ 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.

6006	2102928.90	2.30	721666.28	2.68	5958181.55	2.86
	69 39 45.16	0.07	18 56 26.82	0.25	112.26	2.92
		87.35	21.30	2.92		
		-0.55	99.26	2.68		
		2.59	-170.76	2.22		
6016	4896388.39	1.84	1316170.88	2.28	3856667.89	2.28
	37 26 39.09	0.07	15 2 44.55	0.09	15.36	2.12
		48.56	-7.14	2.30		
		12.47	97.37	2.28		
		38.73	-162.42	1.81		
6065	4213563.66	2.05	820824.47	2.20	4702785.16	2.46
	47 48 4.56	0.07	11 1 24.46	0.11	958.82	2.32
		51.48	14.04	2.47		
		-1.24	102.48	2.19		
		38.50	-168.51	2.05		
8004	3818505.10	5.83	708051.35	5.36	5042642.31	9.52
	52 35 3.06	0.22	10 30 17.40	0.29	84.18	8.89
		59.94	20.97	9.72		
		29.93	-153.30	5.78		
		2.48	115.27	5.05		
8009	3923401.40	4.81	299883.04	5.23	5002973.63	5.35
	52 0 6.34	0.16	4 22 15.14	0.27	45.73	5.21
		24.70	117.19	5.46		
		51.98	-8.85	5.35		
		26.90	-139.32	4.54		
8010	4331299.42	4.19	567503.65	4.95	4633112.83	4.90
	46 52 37.21	0.15	7 27 52.54	0.23	920.22	4.65
		-20.94	123.95	5.06		
		47.95	59.06	4.81		
		34.50	-161.30	4.16		

```
8011    3920174.14   3.62     -134743.75   2.69    5012725.51   4.77
        52  8 35.61  0.12    358  1 53.08  0.14       142.97   4.72

                    62.16        31.94      4.99
                    27.41      -158.96      3.63
                    -4.50       113.37      2.26


8015    4578318.14   3.79      457961.82   4.31    4403193.46   4.15
        43 55 57.84  0.13      5 42 43.93  0.19       676.73   3.82

                    15.79       111.05      4.38
                    26.72        12.87      4.21
                    58.30      -131.71      3.64


8016    4188649.22   3.89      571417.93   4.19    4760143.75   5.55
        48 34 58.70  0.15      7 46  6.13  0.20       166.04   5.04

                    53.17        11.96      5.58
                    11.15       117.22      4.21
                    34.57      -144.98      3.83


8019    4579462.47   4.25      586586.81   6.97    4386418.77   4.47
        43 43 33.26  0.14      7 17 57.52  0.31       394.83   4.50

                     8.27        98.17      6.98
                    61.04        -7.07      4.50
                    27.54      -167.49      4.20


8030    4205632.55   6.26      163702.89   8.02    4776541.56   5.77
        48 48 22.10  0.19      2 13 44.74  0.39       187.76   6.26

                    -9.34        85.27      8.09
                    65.15       154.46      6.30
                    22.81        -0.76      5.63


8031    3593853.84  10.02     -202758.88   6.51    5248053.62  12.13
        55 44  0.93  0.38    356 46 15.23  0.39       291.46  10.20

                    27.44       -11.68     12.82
                    57.64       133.35      9.67
                   -15.80        69.87      5.65


8032    4213542.86   2.06      820771.07   2.20    4702810.23   2.47
        47 48  5.84  0.07     11  1 22.13  0.11       956.82   2.32

                    51.51        13.98      2.48
                    -1.28       102.37      2.19
                    38.46      -168.65      2.06
```

```
8033     4041868.23    6.26       620631.85   6.27       4878635.20    7.25
        50 13 11.41    0.20     8 43 46.66    0.30          196.71     7.51

                      69.61        74.59        7.74
                      -6.36       147.13        6.44
                      19.28      -125.11        5.45


8034     3919692.35    4.81       298829.50   5.23       5005899.45    5.35
        52  2 40.96    0.16     4 21 34.86    0.27           26.98     5.22

                      24.69       117.20        5.46
                      52.01        -8.87        5.35
                      26.87      -139.33        4.54


8701     4194418.40    5.16      1162693.39   2.53       4647182.33    7.61
        47  4  0.48    0.17    15 29 36.17    0.12          469.19     7.63

                      68.28        10.34        8.00
                      21.69      -166.55        4.69
                       1.07       103.02        2.20


8702     4027920.76    5.37       307002.41   7.73       4919441.96   10.97
        50 47 50.89    0.27     4 21 30.87    0.39          121.29     9.09

                      46.93       -15.98       11.07
                      22.82       100.76        7.81
                      34.20      -152.62        5.03


8703     3513637.60    9.58       778937.20   6.33       5248201.26   10.75
        55 44 20.34    0.25    12 29 59.02    0.40           61.20    11.76

                      82.06       -93.78       11.83
                      -4.82      -146.56        8.59
                       6.30       123.97        5.80


8705     4530504.22   21.34       -41723.13  33.91       4474399.67   45.54
        44 50  3.23    1.06   359 28 20.48    1.54          119.77    38.37

                      47.38        15.76       46.13
                     -26.71        72.62       37.81
                      30.43       145.43       11.02


8706     4587887.69    3.79       419518.77   4.31       4396450.97    4.15
        43 51  8.74    0.14     5 13 28.65    0.19          226.89     3.82

                      15.45       111.03        4.38
                      26.67        13.06        4.21
                      58.54      -132.12        3.64
```

```
8710     3818503.32   5.82      708052.67   5.36      5042642.47   9.52
        52 35  3.10   0.22    10 30 17.49   0.29           83.39   8.89

                    59.95       20.93        9.72
                    29.93     -153.24        5.77
                     2.52      115.30        5.05

8711     4896386.79   1.85     1316170.44   2.28      3856670.06   2.29
        37 26 39.18   0.07    15  2 44.55   0.09           15.36   2.13

                    48.35       -8.09        2.31
                    13.01       96.97        2.28
                    38.70     -162.37        1.82

8712     4335514.42  29.88     1063081.54  30.79      4540929.32  34.88
        45 40 55.85   0.90    13 46 38.20   1.35          389.55  37.76

                    66.09      -46.11       38.59
                    23.88      130.93       33.19
                     1.10     -138.59       21.61

8713     4628620.82  61.20     1471951.97  40.91      4120480.49  56.71
        40 29 58.82   1.17    17 38 28.44   1.98          211.37  71.77

                    61.48      -75.02       79.11
                    23.40      142.20       41.65
                    15.37       45.37       25.30

8714     4885390.86  30.59      784057.56  31.96      4011490.51  59.59
        39 13 17.86   1.58     9  7  3.58   1.19          112.75  48.13

                    44.19       -0.69       59.75
                    34.53      131.30       40.23
                    26.04     -119.06       17.88

8715     4896390.83   1.86     1316178.67   2.29      3856662.17   2.29
        37 26 38.85   0.07    15  2 44.83   0.09           15.36   2.14

                    48.23       -8.64        2.31
                    13.32       96.74        2.29
                    38.68     -162.33        1.83

8716     4850690.58  11.76     -315908.83   7.56      4116651.39  16.72
        40 27  1.63   0.44   356 16 25.63   0.31          717.89  15.53

                    53.53       11.78       17.16
                    35.36     -151.99       12.23
                     7.79      112.44        5.58
```

```
8717      4850690.64  11.77    -315911.54   7.56   4116651.11  16.72
         40 27  1.62   0.44  356 16 25.51   0.31       717.88  15.53

                     53.54      11.78       17.16
                     35.35    -152.00       12.23
                      7.78     112.44        5.58

8718      4146546.32  10.32     613115.18   7.59   4791501.83  11.51
         49  0 39.73   0.25    8 24 39.26   0.34       165.70  13.71

                     76.05      91.42       14.04
                     -1.46     175.51        7.75
                    -13.87      85.15        6.29

8719      4883056.88   1.86    1306097.78   2.29   3879628.98   2.29
         37 41 35.53   0.07   14 58 28.82   0.09      1740.87   2.14

                     48.55      -8.39        2.31
                     13.08      96.87        2.29
                     38.47    -162.49        1.83

8720      3104216.61  14.17     998356.71   8.62   5463292.92  12.40
         59 20 16.45   0.33   17 49 42.49   0.68        58.50  14.38

                     52.52    -130.78       15.67
                     37.41      45.12       11.88
                      1.98     136.64        6.49

8722      2591994.43  10.90   -1078496.29  18.45   5707868.71  30.88
         63 57 42.58   0.47  337 24 30.31   1.36         5.50  29.38

                     70.01       0.15       31.04
                     -3.59      80.22       18.72
                     19.64     168.94        9.96

NORMAL TERMINATION
```

Appendix II

Transformation

```
WEST 35  -TO-  WEST 34( MOL MODEL  )
************************************

        SOLUTION FOR 3 TRANSLATION, 1 SCALE AND 3 ROTATION PARAMETERS
        -------------------------------------------------------------
                           (USING VARIANCES ONLY)

          DU       DV       DW      DELTA     OMEGA    PSI     EPSILON
        METERS   METERS   METERS  (X1.D+6)  SECONDS  SECONDS  SECONDS

        -0.15     0.23    -0.23    -0.01     0.52    -0.11    -0.76

       ± 0.58   ± 0.62   ± 0.68   ± 0.52   ± 0.20   ± 0.13   ± 0.26

                       VARIANCE - COVARIANCE MATRIX
                       ----------------------------

     SO2=  0.23

  0.335D+00 -0.684D-02  0.393D-02  0.420D-07  0.863D-07 -0.186D-07 -0.791D-07
 -0.684D-02  0.387D+00 -0.530D-02  0.327D-07 -0.129D-06  0.180D-07  0.679D-07
  0.393D-02 -0.530D-02  0.467D+00 -0.182D-07  0.631D-07  0.452D-07 -0.135D-06
  0.420D-07  0.327D-07 -0.182D-07  0.269D-12 -0.171D-13 -0.395D-13  0.203D-13
  0.863D-07 -0.129D-06  0.631D-07 -0.171D-13  0.952D-12 -0.196D-12 -0.891D-12
 -0.186D-07  0.180D-07  0.452D-07 -0.395D-13 -0.196D-12  0.392D-12  0.236D-12
 -0.791D-07  0.679D-07 -0.135D-06  0.203D-13 -0.891D-12  0.236D-12  0.162D-11

                       COEFFICIENTS OF CORRELATION
                       ---------------------------

  0.100D+01 -0.190D-01  0.993D-02  0.140D+00  0.153D+00 -0.513D-01 -0.107D+00
 -0.190D-01  0.100D+01 -0.125D-01  0.101D+00 -0.213D+00  0.463D-01  0.859D-01
  0.993D-02 -0.125D-01  0.100D+01 -0.514D-01  0.946D-01  0.106D+00 -0.156D+00
  0.140D+00  0.101D+00 -0.514D-01  0.100D+01 -0.339D-01 -0.122D+00  0.307D-01
  0.153D+00 -0.213D+00  0.946D-01 -0.339D-01  0.100D+01 -0.320D+00 -0.718D+00
 -0.513D-01  0.463D-01  0.106D+00 -0.122D+00 -0.320D+00  0.100D+01  0.297D+00
 -0.107D+00  0.859D-01 -0.156D+00  0.307D-01 -0.718D+00  0.297D+00  0.100D+01
NOTE : THE POSITIVE AXES ARE TOWARDS MEAN
-----------------------------------------
        GREENWICH, EAST, AND CIO. THE ROTATIONS
        ---------------------------------------
        PRINTED ARE ABOUT 3RD, 2ND, AND 1ST AXES RESPECTIVELY.
        ------------------------------------------------------
```

RESIDUALS V *

	V1(WEST 35)				V2(WEST 34)			V1 - V2		
6006	-0.1	-0.4	-0.1	6006	0.1	0.4	0.1	-0.2	-0.8	-0.2
8004	0.6	-0.6	-1.5	8004	-0.4	0.6	0.4	1.0	-1.2	-1.9
8009	-0.4	0.0	-0.2	8009	0.3	-0.0	0.1	-0.6	0.1	-0.4
8010	0.4	-0.1	1.0	8010	-0.3	0.1	-0.6	0.7	-0.3	1.6
8011	0.4	-0.0	0.2	8011	-0.3	0.0	-0.1	0.6	-0.1	0.3
8016	-0.2	0.1	0.8	8016	0.1	-0.1	-0.4	-0.4	0.2	1.1
8019	0.5	-0.1	0.7	8019	-0.4	0.1	-0.5	0.9	-0.2	1.2
8030	-0.7	-0.2	0.0	8030	0.4	0.2	-0.0	-1.1	-0.3	0.0
8031	4.0	1.1	7.9	8031	-3.6	-1.0	-2.6	7.6	2.1	10.5
8032	0.2	0.0	0.4	8032	-0.2	-0.0	-0.3	0.4	0.1	0.6
8033	-2.0	-0.8	-3.5	8033	1.2	0.7	1.4	-3.2	-1.5	-4.9
8701	4.2	1.7	12.5	8701	-2.4	-1.3	-3.8	6.6	3.0	16.3
8702	-0.3	-0.2	-2.9	8702	0.2	0.2	0.7	-0.6	-0.3	-3.6
8703	-2.4	-0.5	-5.9	8703	1.3	0.5	1.3	-3.7	-0.9	-7.2
8705	2.7	-4.8	-12.1	8705	-1.8	4.6	1.9	4.5	-9.4	-14.0
8706	0.5	0.0	0.8	8706	-0.4	-0.0	-0.6	1.0	0.0	1.4
8711	-0.3	-0.8	-0.6	8711	0.3	0.8	0.5	-0.6	-1.5	-1.1
8712	2.8	0.7	2.1	8712	-1.0	-0.7	-0.6	3.8	1.4	2.7
8713	-11.0	1.3	-11.3	8713	1.1	-1.2	2.6	-12.1	2.4	-13.9
8714	8.3	4.2	28.4	8714	-4.9	-3.6	-8.4	13.3	7.9	36.8
8716	-7.9	0.4	-11.2	8716	4.8	-0.4	8.4	-12.7	0.7	-19.7
8718	-9.5	-3.1	-11.9	8718	2.6	2.3	1.3	-12.1	-5.4	-13.3
8720	-8.3	1.2	-11.5	8720	4.6	-1.2	2.4	-12.8	2.5	-13.8
8722	2.3	0.3	1.1	8722	-2.0	-0.3	-0.0	4.3	0.5	1.1

UNIT OF RESIDUALS (METERS)

* Residuals in the Cartesian coordinate system.

REPRODUCIBILITY OF
ORIGINAL PAGE IS PO

RESIDUALS V
SPHERICAL *

	V1(WEST 35)				V2(WEST 34)			V1 - V2		
6006	0.17	-0.34	-0.2	6006	-0.17	0.34	0.1	0.34	-0.67	-0.3
8004	-1.28	-0.73	-0.9	8004	0.48	0.65	0.1	-1.76	-1.38	-1.0
8009	0.13	0.07	-0.4	8009	-0.12	-0.06	0.3	0.25	0.13	-0.7
8010	0.41	-0.20	1.0	8010	-0.18	0.18	-0.6	0.59	-0.38	1.6
8011	-0.16	-0.02	0.4	8011	0.14	0.02	-0.3	-0.29	-0.05	0.7
8016	0.66	0.13	0.4	8016	-0.33	-0.11	-0.2	0.99	0.24	0.6
8019	0.14	-0.18	0.8	8019	-0.11	0.16	-0.6	0.25	-0.34	1.4
8030	0.55	-0.14	-0.5	8030	-0.31	0.15	0.3	0.87	-0.29	-0.7
8031	1.19	1.29	8.8	8031	1.42	-1.24	-4.1	-0.23	2.54	12.9
8032	0.07	-0.00	0.4	8032	-0.03	-0.00	-0.3	0.10	-0.00	0.9
8033	-0.62	-0.46	-4.1	8033	-0.13	0.51	1.9	-0.49	-0.97	-6.0
8701	5.17	0.48	12.2	8701	-0.65	-0.61	-4.6	5.83	1.09	16.8
8702	-1.59	-0.14	-2.5	8702	0.24	0.15	0.7	-1.83	-0.29	-3.2
8703	-1.29	0.06	-6.3	8703	-0.43	0.17	1.8	-0.86	-0.12	-8.1
8705	-10.54	-4.78	-6.6	8705	2.65	4.58	0.0	-13.19	-9.37	-6.6
8706	0.21	-0.05	0.9	8706	-0.16	0.04	-0.7	0.37	-0.09	1.7
8711	-0.15	-0.66	-0.7	8711	0.13	0.66	0.7	-0.28	-1.33	-1.4
8712	-0.65	0.01	3.5	8712	0.35	-0.42	-1.2	-1.00	0.43	4.8
8713	-2.05	4.55	-15.0	8713	1.53	-1.45	2.2	-3.59	6.00	-17.3
8714	16.42	2.87	24.9	8714	-3.04	-2.78	-9.5	19.46	5.65	34.4
8716	-3.43	-0.15	-13.3	8716	3.28	-0.04	9.2	-6.71	-0.11	-22.5
8718	-0.41	-1.70	-15.5	8718	-1.31	1.91	2.9	0.90	-3.61	-18.3
8720	0.60	3.71	-13.7	8720	-2.22	-2.56	4.1	2.82	6.27	-17.7
8722	-1.34	1.11	1.8	8722	1.54	-1.00	-0.8	-2.87	2.11	2.6

UNIT OF RESIDUALS (METERS)

* The spherical residuals represent the residuals in the Cartesian coordinate system as transformed into the curvilinear (φ, λ, h) system.

Appendix III (Referenced in Section 5)

Part 1

A DISCUSSION ON TRANSFORMATION MODELS

1. Introduction

The availability of geocentric station coordinates obtained by satellite geodesy made it possible to compute the relative positions of the ellipsoids which are used in classical triangulations with respect to an earth centered ellipsoid. The coordinate system of the latter is the Average Terrestrial system (AT), where the z axis is directed toward the average north terrestrial pole as defined by the International Polar Motion Service (IPMS) and is commonly known as the Conventional International Origin (CIO). The zx plane is parallel to the mean Greenwich astronomic meridian as defined by the Bureau International de l'Heure (BIH). The classical triangulation is computed in the geodetic coordinate system (u, v, w), with the w axis directed toward the North Pole and the wu plane coinciding with the geodetic Greenwich meridian.

Several procedures for transformations have been published in recent years. A summary of the three most commonly used models is given in [Badekas, 1969]. Some clarifying remarks about these models are given here. One additional transformation model, although intended for a different purpose, has been suggested by [Vanicek, 1974 and 1975].

2. Transformation Model 1 (Bursa)

This model was introduced in [Bursa, 1962 and Wolf, 1963]. It treats the Cartesian coordinates as observations and the seven transformation parameters, (three shifts, one scale and three rotation angles), as quantities to be solved for in a least squares adjustment.

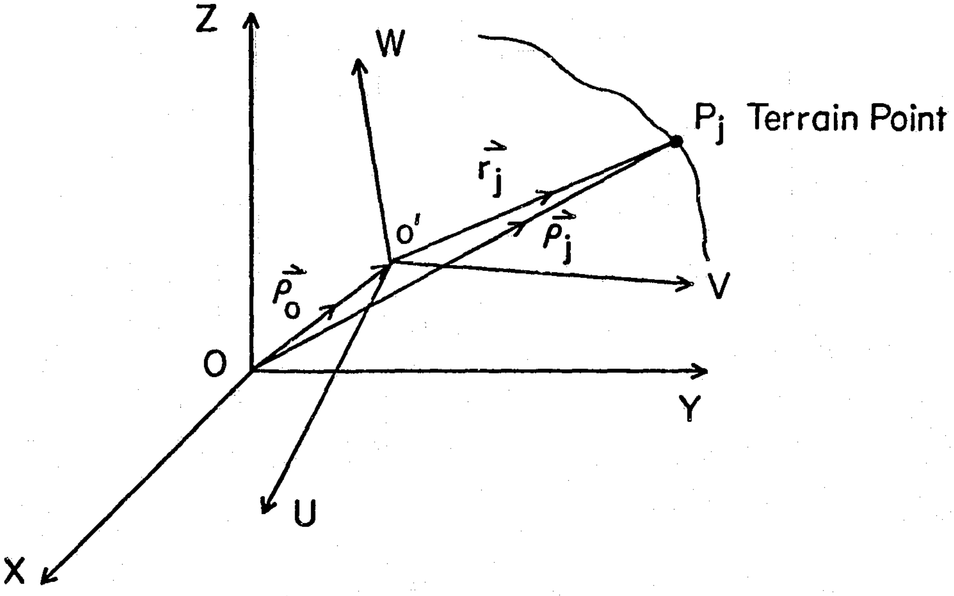

Fig. 1

Bursa Model

The notation is as follows:

X, Y, Z : Average Terrestrial coordinate system (satellite system) with origin at 0.

U, V, W : Geodetic coordinate system with origin at 0'.

P_j : Terrain point.

$\vec{\rho}_0$: Shift vector between the origins 0 and 0' in the satellite system.

$\vec{r}_j$: Position vector of P_j in the geodetic system.

$\vec{\rho}_j$: Position vector of P_j in the satellite system.

The transformation of point P_j is described in the satellite system by the equation

$$F_j \equiv \vec{\rho}_0 + (1+k) R \vec{r}_j - \vec{\rho}_j = 0 \qquad (1)$$

where R is the product of three orthogonal rotation matrices and k denotes the scale factor. Because only differential rotations are being considered, the sequence of rotations is irrelevant. Deleting small terms of the second order and mixed terms, one arrives at a rotation matrix of the form

$$R \cong I+Q = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + \begin{bmatrix} 0 & \omega & -\psi \\ -\omega & 0 & \epsilon \\ \psi & -\epsilon & 0 \end{bmatrix} = \begin{bmatrix} 1 & \omega & -\psi \\ -\omega & 1 & \epsilon \\ \psi & -\epsilon & 1 \end{bmatrix} . \tag{2}$$

The rotation angles ω, ψ, ϵ, when positive, represent counterclockwise rotations about the respective W, V, U axes, as viewed from the end of the positive axis. If the term $kQ\vec{r}_j$ in Eq.(1) is ignored, one obtains the expression

$$F_j \equiv \vec{\rho}_0 + \vec{r}_j - \vec{\rho}_j + k\vec{r}_j + Q\vec{r}_j = 0 \tag{3}$$

which forms the mathematical model for a least squares solution. Here, the model [Uotila, 1967] used is of the form

$$F(L_a , X_a) = 0 \tag{4}$$

where L_a denotes the adjusted observations and X_a denotes the estimates of parameters. The linearized form gives

$$BV + AX + W = 0 \tag{5}$$

in which $B = \partial F/\partial L_a$, $A = \partial F/\partial X_a$ and $W = F(L_b, X_0)$. L_b denotes the observations, e.g., the Cartesian coordinates in both the satellite and the geodetic coordinate system ($\vec{\rho}_j$ and $\vec{r}_j$) and X_0 denotes the approximate values for the parameters ($\vec{\rho}_0$ k, ω, ψ, ϵ). That part of Eq. (5) which pertains to point P_j can be written as

$$\overset{B_j}{\begin{bmatrix} 1 & 0 & 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & -1 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 \end{bmatrix}} \overset{V_j}{\begin{bmatrix} V_u \\ V_v \\ V_w \\ V_x \\ V_y \\ V_z \end{bmatrix}_j} + \overset{A_j}{\begin{bmatrix} 1 & 0 & 0 & U & V & -W & 0 \\ 0 & 1 & 0 & V & -U & 0 & W \\ 0 & 0 & 1 & W & 0 & U & -V \end{bmatrix}_j} \cdot \overset{X}{\begin{bmatrix} DX \\ DY \\ DZ \\ k \\ \omega \\ \psi \\ \epsilon \end{bmatrix}} + \overset{W_j}{\begin{bmatrix} U - X \\ V - Y \\ W - Z \end{bmatrix}_j} = 0 . \tag{6}$$

3. Transformation Model 2 (Molodenskii)

The model described in this section is attributed to Molodenskii. At first glance it looks very much like Bursa's model as expressed in Eq. (1). One may also be inclined to use a figure similar to Figure 1 to interpret or even to setup the transformation equation. The purpose of the discussion here is to clarify this type of misinterpretation. The Molodenskii transformation equation is commonly stated as

$$F_j = \vec{\rho}_0 + \vec{r}_k + (1+k)\,R\vec{r}_{kj} - \vec{\rho}_j = 0 \tag{7}$$

where $\vec{\rho}_0$: is usually interpreted as the shift vector between the origins of the two ellipsoids in the satellite system.

$\vec{r}_k$: is the vector of the initial point in the geodetic system. It is assumed that the components refer to a coordinate system that is already parallel to the satellite system. In practical computation, however, it is simply the vector of the initial point expressed in the geodetic system. Thus the transformation of $\vec{r}_k$ from geodetic to satellite system is ignored.

R : is the same as in Eq. (2).

$\vec{r}_{kj} = \vec{r}_j - \vec{r}_k$: is the relative position vector of the point P_j with respect to the initial point P_k in the geodetic system.

$\vec{\rho}_j$: is the position vector of P_j in the satellite system.

If the term $kQ\vec{r}_{kj}$ is deleted from Eq. (7), then one obtains the new expression

$$F_j \equiv \vec{\rho}_0 + \vec{r}_j - \vec{\rho}_j + k\vec{r}_{kj} + Q\vec{r}_{kj} = 0\,. \tag{8}$$

The analog to Eq. (6) reads

$$\begin{array}{ccccccccc}
B_J & V_J & + & A_{MJ} & X & + & W_J & = & 0 \\
\begin{bmatrix} 1 & 0 & 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & -1 & 0 \\ 0 & 0 & 1 & 0 & 0 & -1 \end{bmatrix} &
\begin{bmatrix} V_u \\ V_v \\ V_w \\ V_x \\ V_y \\ V_z \end{bmatrix}_J & + &
\left[\begin{array}{ccc|cccc} 1 & 0 & 0 & (U-U_0) & (V-V_0) & -(W-W_0) & 0 \\ 0 & 1 & 0 & (V-V_0) & -(U-U_0) & 0 & (W-W_0) \\ 0 & 0 & 1 & (W-W_0) & 0 & (U-U_0) & -(V-V_0) \end{array}\right]_J &
\begin{bmatrix} DX \\ DY \\ DZ \\ k \\ \omega \\ \psi \\ \epsilon \end{bmatrix} & + &
\begin{bmatrix} U-X \\ V-Y \\ W-Z \end{bmatrix}_J & = & 0
\end{array} \tag{9}$$

where $\vec{r}_k = \begin{bmatrix} U_0 \\ V_0 \\ W_0 \end{bmatrix}$ is the position vector of the initial point.

4. Transformation Model 3 (Veis)

This model (usually referred to as the Veis Model), is identical to Model No. 2 (Molodenskii model) except for the axes about which the rotations occur. The point of rotation is again the initial point of triangulation [Veis, 1960]. The first axis is tangent to the geodetic meridian with positive direction toward the South; the second axis is perpendicular to the meridian plane and is positive eastward and the z axis is along the geodetic normal with its positive direction upward forming a right-handed system with axes one and two. Thus, the only difference between the Molodenskii and Veis models is that the rotations in the Veis model are familiar quantities: for example, a rotation about the third axis corresponds to a rotation in azimuth.

5. Comparison between Models 1 and 2 (or 3)

$\vec{r}_T$ represents the vector of "translation" as obtained by the various models. A simple comparison between Eq. (1) and (7) indicates that

$$\left.\begin{aligned} \vec{r}_{T\,(\text{BURSA})} &= \vec{\rho}_0 \\ \vec{r}_{T\,(\text{MOLODENSKII})} &= \vec{\rho}_0 - \vec{r}_k + (1+k)\,R\,\vec{r}_k\,. \end{aligned}\right\} \tag{10}$$

Eq. (10) is very important as far as the geometric interpretation is concerned. Clearly, $\vec{r}_{T\,(\text{MOLODENSKII})}$ is not the vector between the origins of the two coordinate systems, but rather a function of the scale, the rotations and the choice of the point of rotation $\vec{r}_k$. Eq. (10) is based on the knowledge that both models give identical values for the scale and rotation parameters as shown in the following paragraphs. In both cases the same adjustment model is used. The only difference is the design matrix A, as can be seen from Eq. (6) and (9). If, respectively, A_M and A denote the design matrices of the Molodenskii and Bursa models and they are partitioned into (3 x 3) and (3 x 4) submatrices, then one has

$$A_M = [\bar{I} \mid \bar{A}_M] = \left[\begin{array}{c|c} I & A_{M1} \\ I & A_{M2} \\ \vdots & \vdots \\ I & A_{Mr} \end{array}\right] = \left[\begin{array}{c|c} I & A_1 - D \\ I & A_2 - D \\ \vdots & \vdots \\ I & A_r - D \end{array}\right] \qquad (11)$$

where r is the number of stations to be transformed. Both design matrices differ only by the submatix D, which is the same for every station. If Eq. (5) is partitioned in a similar manner, and assuming there is a block diagonal variance-covariance matrix (no correlation between the coordinates of different stations), the normal equations can be conveniently solved using the general formulas for the inverse of partitioned matrices [Uotila, 1967]. Generally, if

$$N = \begin{bmatrix} N_{11} & N_{12} \\ N'_{12} & N_{22} \end{bmatrix}$$

has full rank and N_{11} and N_{22} are square and non-singular, then

$$\begin{bmatrix} N_{11} & N_{12} \\ N'_{12} & N_{22} \end{bmatrix}^{-1} = \left[\begin{array}{c|c} N_{11}^{-1} + N_{11}^{-1} N_{12} (N_{22} - N'_{12} N_{11}^{-1} N_{12})^{-1} N'_{12} N_{11}^{-1} & -N_{11}^{-1} N_{12} (N_{22} - N'_{12} N_{11}^{-1} N_{12})^{-1} \\ \hline -(N_{22} - N'_{12} N_{11}^{-1} N_{12})^{-1} N'_{12} N_{11}^{-1} & (N_{22} - N'_{12} N_{11}^{-1} N_{12})^{-1} \end{array}\right] . \qquad (12)$$

If one minimizes the norm $V'PV$ subject to the condition (5), one obtains the well known equations

$$X = -(A'M^{-1}A)^{-1}A'M^{-1}W \tag{13}$$

$$V = -P^{-1}B'M^{-1}(AX+W) \tag{14}$$

where $$M = BP^{-1}B' \tag{15}$$

and P^{-1} is the variance-covariance matrix of observations which is taken to be block diagonal. Since B has the form indicated in Eq.(6), M has the form

$$M = \begin{bmatrix} P_1^{-1} & & 0 \\ & \ddots & \\ 0 & & P_r^{-1} \end{bmatrix} \quad \text{where} \quad P_i^{-1} = \frac{1}{\sigma_0^2}[\Sigma_{G_i} + \Sigma_{S_i}] ,$$

σ_0^2 being the a priori variance of unit weight and Σ_{G_i} and Σ_{S_i} being the variance-covariance matrix of geodetic and satellite coordinates, respectively, at point i. With the notation

$$S = [\Sigma A_i' P_i A_i - (\Sigma P_i A_i)' (\Sigma P_i)^{-1} (\Sigma P_i A_i)]^{-1}, \tag{16}$$

one can express the normal matrix of the Molodenskii model with the help of Eq. (12) as

$$(A_M' M_M^{-1} A)^{-1} \equiv \left[\begin{array}{c:c} (\Sigma P_i)^{-1} + (\Sigma P_i)^{-1}(\Sigma P_i A_i - \Sigma P_i D)\, S (\Sigma P_i A_i - \Sigma P_i D)' (\Sigma P_i)^{-1} & -(\Sigma P_i)^{-1}(\Sigma P_i A_i - \Sigma P_i D)\; S \\ \hdashline -S\; (\Sigma P_i A_i - \Sigma P_i D)' (\Sigma P_i)^{-1} & S \end{array}\right], \tag{17}$$

all summations being taken over r, where r is the number of points to be transformed.

Continuing the solution of Eq. (13), one obtains

$$\begin{aligned} X_{M1} = {} & [(\Sigma P_i)^{-1} + (\Sigma P_i)^{-1} (\Sigma A_i' P_i)'\; S\; (\Sigma A_i' P_i)(\Sigma P_i)^{-1}] (\Sigma P_i W_i) \\ & - (\Sigma P_i)^{-1} (\Sigma A_i' P_i)' S\; (\Sigma A_i' P_i W_i) \\ & + DS[(\Sigma A_i' P_i W_i) - (\Sigma A_i' P_i)(\Sigma P_i)^{-1} (\Sigma P_i W_i)] . \end{aligned} \tag{18}$$

$$X_{M2} = X_2 = S\; [\Sigma (A_i' P_i W_i) - (\Sigma P_i A_i)' (\Sigma P_i)^{-1} (\Sigma P_i W_i)] . \tag{19}$$

In Eq. (18) the term within the last brackets [ ] is not equal to zero. The parameter vector X is partitioned into X_1 and X_2. The subscript M distinguishes the solution in the Molodenskii model from the solution in the Bursa model. According to partitioning, X_{M1} contains the translation parameters and X_{M2} contains the scale and the rotation parameters. It is readily seen from the above equations that X_{M1} does depend on the submatrix D and X_{M2} does not. In fact, the first two terms of Eq.(18) represent exactly the solution which is obtained when using the Bursa model.

Next it is proven that the product AX is also independent of the submatrix D. AX is invariant in the two systems:

$$\Rightarrow \quad (I \mid A_1)\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} = (I \mid A_1 - D)\begin{pmatrix} X_{M1} \\ X_2 \end{pmatrix} \tag{20}$$

$$\Rightarrow \quad X_1 + A_1 X_2 = X_{M1} + A_1 X_2 - D X_2$$

$$\Rightarrow \quad X_1 = X_{M1} - D X_2 \tag{21}$$

However, from Eq. (18), we have

$$X_{M1} = X_1 + DS[\;],$$

where the brackets [] denote the last term on R.H.S. of Eq.(18).

$$\therefore \quad X_{M1} - DX_2 = X_1 + DS[\;] - DX_2 . \tag{22}$$

If X_2 of Eq.(19) is substituted in Eq.(22), it is then seen that the last two terms of Eq.(22) cancel, thus proving the identity (20). Therefore, the products

$$A_M X_M \text{ and } A X$$

are invariant, and as a result both transformation models yield the same residuals. Note also that Eq. (21) is equivalent to the second equation in (10) — considering that the mixed (small) terms were neglected in the mathematical model of the adjustment.

The final step is proving that the direct transformation from one system to the other yields identical results when either of the two solution vectors and its corresponding variance-covariance matrix is used. It has already been proven that

$$\vec{r}_T = (I A_{MT}) \begin{pmatrix} X_{M1} \\ X_{M2} \end{pmatrix} = (I A_T) \begin{pmatrix} X_1 \\ X_2 \end{pmatrix} \tag{23}$$

holds where the subscript T denotes the point P_T which is to be transformed. Also, $\vec{r}_T$ is the position vector of point T in the new system; A_{MT} consists of the componenets of the station vector in the old system and it is just a matter of matrix multiplication that shows the variance-covariance matrix Σ_{X_T} is indeed invariant. One has

$$\Sigma_{X_T} = (I A_{MT})\, \Sigma_{X_M} \begin{pmatrix} I \\ A'_{MT} \end{pmatrix} . \tag{24}$$

Since

$$\Sigma_{X_M} = (A'_M M^{-1} A_M)^{-1} , \tag{25}$$

one can use the identity (17) to carry out the operations necessary in Eq. (24). The result is

$$\begin{aligned} \Sigma_{X_T} = {} & (\overset{r}{\Sigma} P_i)^{-1} + (\overset{r}{\Sigma} P_i)^{-1} (\overset{r}{\Sigma} P_i A_i) S (\overset{r}{\Sigma} P_i A_i)' (\overset{r}{\Sigma} P_i)^{-1} \\ & - 2 (\overset{r}{\Sigma} P_i)^{-1} (\overset{r}{\Sigma} P_i A_i) S A'_T + A_T S A'_T \ . \end{aligned} \tag{26}$$

Once again, Eq. (26) is independent of the submatrix D. It is identical to the expression obtained when substituting A_T (instead of A_{MT}) in Eq. (24). Even if variances are attached to the coordinates to be transformed, the complete error propagation yields a variance-covariance matrix which is independent of the submatrix D.

Conclusions:

1) It has been shown that the so-called Molodenskii and Bursa transformation models give the same scale factor, rotation angles and residuals. Nevertheless, they give different translation parameters. It has been shown that

while the Bursa model immediately gives geometrically meaningful shifts between the origins of the two Cartesian coordinate systems, the translation parameters computed from Model 2 need to be suitably modified to give the same shifts. For example, the translation parameters of Table 10 are related by Eq. 10 or Eq. 21, respectively.

2) It is true that Model 2 gives significantly smaller correlation coefficients between its parameters. However, the correlation coefficients in Models 1 and 2 cannot be compared since the meaning of the respective parameters is different.

3) In the previous derivations no use was made of any specific pattern of the submatrix D. Therefore all the above conclusions are valid for any rotation point (intersection of axes about which the rotations are defined). Model 2 (which specifies the initial point as the rotation point), therefore, is just one special case of an infinite number of possible models, differing only in the location of the rotation point.

4) If one is interested in obtaining transformation parameters only to transform an arbitrary set of points from one system to another, no geometrical interpretation needs to be attached to the transformation parameters. Either model can be used since both give identical results.

5) At this point the question that should be raised is whether or not the so-called Molodenskii model as treated in [Badekas, 1969] is, indeed, treated identically in [Molodenskii, 1962].

6) The first four conclusions listed here are also valid for the Veis model.

7) When transforming a system of non-global coverage, it can be shown that a three parameter transformation yields shift vectors with magnitudes that are close to the ones obtained by a seven parameter transformation (Molodenskii). A three parameter transformation, therefore, should be used with great discretion, particularly when the systems have a large difference in scale.

Appendix III

Part 2

RECOVERY OF SCALE FACTOR AND ROTATION ANGLES FROM CHORD COMPARISONS

It is well known that the chord between two points expressed in terms of three-dimensional Cartesian coordinates is invariant with respect to a shift or rotation of the coordinate system. This makes it possible to independently determine the scale factor from chord comparisons and the rotation angles from comparisons of the directions of the chords. However, care has to be taken that all the correlations between various chords are included. In addition, for scale factor computations in a network of n points, one should use only those (3n - 6) chords which determine the three-dimensional configuration completely. Any additional chords do not contribute scale information, but instead are dependent on the other chords. This becomes clear if it is remembered that the given set of station coordinates merely determines a polyhedron uniquely. Since the chords are derived directly from the station coordinates, one can at most use only as many chords as are needed to uniquely determine the polyhedron.

To appreciate how only (3n - 6) chords can be chosen to determine the scale factor, consider the case of 5 stations with coordinates known in the two systems. The station coordinates in each system are treated as observations with their variances and covariances. In obtaining a scale factor from chords, if one treats the chords as derived observations from the station coordinates of 5 stations, one can generate 10 chords. But if all these 10 chords are taken as observations, the variance-covariance matrix of observations becomes singular. This can be proven as follows:

Let X_i, Y_i, Z_i $(i = 1, 5)$ be the given coordinates of the 5 stations.

Let L_k $(k = 1, 10)$ be the derived chords. Then

$$L_k = \sqrt{(X_j - X_i)^2 + (Y_j - Y_i)^2 + (Z_j - Z_i)^2} \qquad i \neq j\ ,\ j > i\ . \tag{27}$$

If Σ_L represents the variance-covariance matrix of the 10 chords, then

$$\Sigma_L = G \Sigma_X G' \tag{28}$$

where Σ_X is the 15 x 15 variance-covariance matrix of the station coordinates and

$$G = \begin{bmatrix} \frac{\partial L_k}{\partial X_j} & \frac{\partial L_k}{\partial Y_j} & \frac{\partial L_k}{\partial Z_j} & \frac{\partial L_k}{\partial X_i} & \frac{\partial L_k}{\partial Y_i} & \frac{\partial L_k}{\partial Z_i} \end{bmatrix} \tag{29}$$

has the size 10 x 15 and takes the form

$$G = \begin{array}{ccc|ccc|ccc|ccc|ccc}
X_1 & Y_1 & Z_1 & X_2 & Y_2 & Z_2 & X_3 & Y_3 & Z_3 & X_4 & Y_4 & Z_4 & X_5 & Y_5 & Z_5 \\
\hline
\frac{-\Delta X_1}{L_1} & \frac{-\Delta Y_1}{L_1} & \frac{-\Delta Z_1}{L_1} & \frac{\Delta X_1}{L_1} & \frac{\Delta Y_1}{L_1} & \frac{\Delta Z_1}{L_1} & & & & & & & & & \\
 & & & \frac{-\Delta X_2}{L_2} & \frac{-\Delta Y_2}{L_2} & \frac{-\Delta Z_2}{L_2} & \frac{\Delta X_2}{L_2} & \frac{\Delta Y_2}{L_2} & \frac{\Delta Z_2}{L_2} & & & & & & \\
\frac{-\Delta X_3}{L_3} & \frac{-\Delta Y_3}{L_3} & \frac{-\Delta Z_3}{L_3} & & & & \frac{\Delta X_3}{L_3} & \frac{\Delta Y_3}{L_3} & \frac{\Delta Z_3}{L_3} & & & & & & \\
 & & & & & & \frac{-\Delta X_4}{L_4} & \frac{-\Delta Y_4}{L_4} & \frac{-\Delta Z_4}{L_4} & \frac{\Delta X_4}{L_4} & \frac{\Delta Y_4}{L_4} & \frac{\Delta Z_4}{L_4} & & & \\
 & & & \frac{-\Delta X_5}{L_5} & \frac{-\Delta Y_5}{L_5} & \frac{-\Delta Z_5}{L_5} & & & & \frac{\Delta X_5}{L_5} & \frac{\Delta Y_5}{L_5} & \frac{\Delta Z_5}{L_5} & & & \\
\frac{-\Delta X_6}{L_6} & \frac{-\Delta Y_6}{L_6} & \frac{-\Delta Z_6}{L_6} & & & & & & & \frac{\Delta X_6}{L_6} & \frac{\Delta Y_6}{L_6} & \frac{\Delta Z_6}{L_6} & & & \\
\frac{-\Delta X_7}{L_7} & \frac{-\Delta Y_7}{L_7} & \frac{-\Delta Z_7}{L_7} & & & & & & & & & & \frac{\Delta X_7}{L_7} & \frac{\Delta Y_7}{L_7} & \frac{\Delta Z_7}{L_7} \\
 & & & \frac{-\Delta X_8}{L_8} & \frac{-\Delta Y_8}{L_8} & \frac{-\Delta Z_8}{L_8} & & & & & & & \frac{\Delta X_8}{L_8} & \frac{\Delta Y_8}{L_8} & \frac{\Delta Z_8}{L_8} \\
 & & & & & & \frac{-\Delta X_9}{L_9} & \frac{-\Delta Y_9}{L_9} & \frac{-\Delta Z_9}{L_9} & & & & \frac{\Delta X_9}{L_9} & \frac{\Delta Y_9}{L_9} & \frac{\Delta Z_9}{L_9} \\
 & & & & & & & & & \frac{-\Delta X_{10}}{L_{10}} & \frac{-\Delta Y_{10}}{L_{10}} & \frac{-\Delta Z_{10}}{L_{10}} & \frac{\Delta X_{10}}{L_{10}} & \frac{\Delta Y_{10}}{L_{10}} & \frac{\Delta Z_{10}}{L_{10}}
\end{array}$$

where

$$\begin{aligned} \Delta X_k &= X_j - X_i \qquad j > i \\ \Delta Y_k &= Y_j - Y_i \\ \Delta Z_k &= Z_j - Z_i \quad . \end{aligned} \tag{30}$$

The order can easily be ascertained from a glance at the G matrix, e.g., $\Delta X_8 = X_5 - X_2$. Although the matrix G is of the size 10 x 15, it has only a rank of 9 because the rows considered as vectors form a dependent set. Specifically, when the chords are considered as vectors it can be seen, for example, that

$$\vec{L}_{10} = \begin{bmatrix} \Delta X_{10} \\ \Delta Y_{10} \\ \Delta Z_{10} \end{bmatrix} = \begin{bmatrix} X_5 - X_4 \\ Y_5 - Y_4 \\ Z_5 - Z_4 \end{bmatrix} = \begin{bmatrix} X_5 - X_1 + X_1 - X_4 \\ Y_5 - Y_1 + Y_1 - Y_4 \\ Z_5 - Z_1 + Z_1 - Z_4 \end{bmatrix} = \begin{bmatrix} \Delta X_7 \\ \Delta Y_7 \\ \Delta Z_7 \end{bmatrix} - \begin{bmatrix} \Delta X_6 \\ \Delta Y_6 \\ \Delta Z_6 \end{bmatrix} = \vec{L}_7 - \vec{L}_6 \quad . \tag{31}$$

Thus, row 10 (chord 10) is a linear combination of row 7 (chord 7) and row 6 (chord 6). This was numerically tested and is also evident from the fact that 6 chords of 4 stations determine a three-dimensional figure uniquely and three more chords are adequate to fix the fifth point.

Since the rank of G is 9, that of Σ_L can at most be 9, causing a rank deficiency of 1 in the 10 × 10 matrix Σ_L, irrespective of whether Σ_X is a full or diagonal matrix. Thus, in general, for n stations one can at most use (3n - 6) chords to compute the scale. Of course there are many sets of (3n - 6) chords which could be chosen to determine the scale. They are all equivalent as far as scale factor computation is concerned.

The rotation angles can be computed separately in a similar manner since all the rotational information of the coordinates is also present in the chords. When giving the direction of a chord by two independent angles, (e.g., Greenwich Hour Angle/Declination), one should again use only as many directional angles as are needed to determine the shape of the polyhedron completely. The same computational procedures are obtained when one eliminates in the transformation equation, the translations and rotations or the translations and scale, respectively.

The subject matter of this Appendix is treated in greater detail in a separate report [Leick and van Gelder, in press].

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Appendix IV

FORTRAN IV PROGRAM WITH SUBROUTINES

```
C               PROBLEM  CODE  DEFINITIONS
C
C     COLUMN   MEANING
C        1. OVERALL PROBLEM CODE
C            PCODE(1)=1  MEANS   OPTICAL  PROGRAM,GEOMETRIC MODE, OSU FORMAT
C                     2  MEANS  RANGE,GEOMETRIC MODE
C                     3  MEANS  SOLUTION ONLY RUN
C                     4 MEANS ORBITAL MODE,OPTICAL OBSERVATIONS
C                     5  MEANS ORBITAL MODE,RANGE OBSERVATIONS
C                     6  MEANS ORBITAL MODE,MIXED OBSERVATIONS.
C            PCODE(1)=7  MEANS   OPTICAL  PROGRAM,GEOMETRIC MODE, GEOS FORMAT
C        2. PERFORM SOLUTION?
C            PCODE(2)=1  MEANS YES
C                     0  MEANS NO
C            PCODE(1)=3 IMPLIES PCODE(2)=1
C        3. MAXIMUM NUMBER OF ITERATIONS?
C            PCODE(1) MUST EQUAL 1, 2, OR 7
C            PCODE(2) MUST EQUAL 1,
C            PCODE(5) MUST EQUAL 1,  FOR ONE OR MORE COMPLETE ITERATIONS
C        5. FORM NORMALS?
C
C                PROCESSING CODES
C                                         1 MEANS YES,  0 MEANS NO
C        6. SIMULATE GUIDE MATRIX?
C        7. PRINT NORMALS?
C        8. PERFORM  SUMMARY BY OBSERVED LINES?
C        9. PUNCH NORMALS IN ASD FORMAT?
C       10. SUMMARIZE RESULTS
C             PCODE(10)=0 DO NOT PRINT SUMMARY
C                      =1 PRINT THE DX'S AND STANDARD DEVIATIONS
C                      =2 PRINTS THE X,Y,Z'S AND STANDARD DEVIATIONS
C                      =3 PRINTS THE LATITUDE,LONGITUDE AND HEIGHT
C                      =4 PRINTS BOTH X,Y,Z & LAT.,LONG, & H
C       11. PRINT SATELLITE POSITION FOR EACH EVENT?
C             0 MEANS NO
C             1 MEANS PRINT XYZ AND GEODETIC COORDINATES
C             2 MEANS PRINT XYZ ONLY
C             3 MEANS PRINT GEODETIC COORDINATES ONLY
C       12. THIS PARAMETER DESCRIBES WHERE THE STANDARD DEVIATIONS OF THE
C             INDIVIDUAL OBSERVATIONS (USED TO FORM THE WEIGHTS) ARE TO BE FOUND
C             PCODE(12)=0 MEANS TO READ THE OBSERVATIONAL STANDARD DEVIATION
C             FROM THE CARD CONTAINING THE OBSERVATION.
C             PCODE(12)=1 MEANS TO ASSOCIATE A SINGLE STANDARD DEVIATION WITH
C             ALL OBSERVATIONS FROM A GIVEN STATION.** THE STANDARD DEVIATIONS
C             TO BE ASSOCIATID WITH EACH STATION ARE GIVEN IN COLUMNS 73-79 OF
C             THE CARD CONTAINING THE INPUT COORDINATES OF THE STATION.
C             PCODE(12)=2 MEANS TO ASSOCIATE A SINGLE STANDARD DEVIATION WITH
C             ALL OBSERVATIONS.** THIS NUMBER IS FOUND IN COLS. 21-30 OF THE
C             CARD CONTAINING THE TEST DISTANCE (OPTICAL) OR TEST VARIANCE
C             (RANGE).
C             ** IN THE CASE OF OPTICAL OBSERVARTIONS, THIS NUMBER IS INTERPRETE
C             AS THE STANDARD DEVIAION OF THE DECLINATION AND OF THE RIGHT
C             ASCENSION TIMES THE COSINE OF THE DECLINATION, AND THE
C             COVARIANCE IS SET TO ZERO.
C           PCODE(12)=3 MEANS TO READ ONLY THE DIAGONAL ELEMENTS OF THE
C           VARIANCE-COVARIANCE MATRIX (CPGS CORRELATED DATA ONLY)
C       13. COMPUTE AND PRINT CORRELATION MATRIX FOR EACH STATION
C           ( C&GS CORRELATED DATA ONLY).
```

```
C      CODES WHICH APPLY TO ORBITAL MODE PROCESSING ONLY
C       14. TREAT COORDINATES OF CENTER OF MASS AS UNKNOWNS? (ORBITAL MODE ONLY)
C       15. PUNCH UPDATED ORBIT ELEMENTS?  (ORBITAL MODE ONLY)
C
C
C        SOLUTION CODES
C
C       16. WRITE NORMALS AND INVERSE DURING SOLUTION PROCESSING?
C              0 MEANS PRINT NOTHING
C              1 MEANS PRINT PIVOT ELEMENTS
C              2 MEANS ALSO PRINT NORMALS AND INVERSE
C              3 MEANS ALSO PRINT REARRANGED NROMALS AND INVERSE
C       17. PUNCH ADJUSTED STATION XYZ AND VARIANCES FOR INPUT TO BADEKAS'
C              DATUM TRANSFORMATION PROGRAM?
C       18. PUNCH ADJUSTED STATION POSITIONS?
C       19. COMPUTE EIGENVECTORS OF VARIANCE-COVARIANCE MATRIX
C       20. COMPUTE CORRELATION COEFFICIENTS
C
      COMMON/NSTA/NSTA
      INTEGER*2 ENDSIG/1HE/,CONTIN
      INTEGER*2 PCODE(20)
      COMMON/PCODES/PCODE
      REAL*8 TITLE(10)
    3 CONTINUE
      WRITE(6,6001)
 6001 FORMAT(1H1,20(/))
    4 READ(5,5001) TITLE,CONTIN
 5001 FORMAT(9A8,A7,A1)
      IF(CONTIN.EQ.ENDSIG) GO TO 5
      WRITE(6,6012) TITLE
 6012 FORMAT(30X,9A8,A7)
      GO TO 4
    5 CONTINUE
C
      READ(5,5050) PCODE
 5050 FORMAT(80I1)
      WRITE(6,6050) PCODE
 6050 FORMAT(////10X,'PROBLEM CODES',10X,20I1)
      CALL STAIN
      CALL READIN
      CALL ASD360
      CALL FORMRN
      STOP
      END
      DOUBLE PRECISION FUNCTION DPDOT(X,Y,N)
      DOUBLE PRECISION X(N),Y(N)
      DPDOT=0.0
      DO 10 I=1,N
   10 DPDOT=DPDOT+X(I)*Y(I)
      RETURN
      END
```

```
      SUBROUTINE STAIN
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/PCODES/PCODE
      INTEGER ENDSIG/1HE/,CONTIN
      COMMON/NSTA/NSTA
      COMMON/STAORD/KORDER(150)
      INTEGER STANAM,IDS*2
      INTEGER*2 PLUS/1H+/
      INTEGER*2 ISGNP,IPHID,IPHIM,LONGD,LONGM,ISGNL
      COMMON/STALOC/STAUVW(3,150),DATPRM(2,15),DATNAM(4,15),
     1STANAM(5,150),IDS(150)
      COMMON/STAPLH/STAPLH(2,150)
      COMMON/OBSD/OBSD(150),OVOBSD
      MAXSTA=150
      WRITE(6,6000)
 6000 FORMAT(1H1)
 6001 FORMAT(1H1,20(/))
      WRITE(6,6002)
 6002 FORMAT(/////4X,29HDATUMS INVOLVED IN ADJUSTMENT,//)
C  INPUT DATUMS
   10 READ(5,5002) IDD,AE,BE,CONTIN
 5002 FORMAT(I2,2F12.3,53X,A1)
      IF(CONTIN.EQ.ENDSIG) GO TO 30
      DATPRM(1,IDD)=AE
      DATPRM(2,IDD)=BE
      READ(5,5003)(DATNAM(I,IDD),I=1,4)
 5003 FORMAT(4A8)
      WRITE(6,6003) IDD,(DATNAM(I,IDD),I=1,4),(DATPRM(I,IDD),I=1,2)
 6003 FORMAT(6H0DATUM,I3,3X,4A8,3HA= ,F10.2,12H METERS  B= ,F10.2,
     17H METERS)
      GO TO 10
C
   30 CONTINUE
C         STATION INPUT
      WRITE(6,6005)
 6005 FORMAT(1H1///40X,29HINPUT COORDINATES OF STATIONS)
      KSTA=0
   35 KSTA=KSTA+1
      READ(5,5005)IDD,IDTS,(STANAM(I,KSTA),I=1,5),ISGNP,IPHID,IPHIM,PHIS
     1,LONGD,LONGM,FLONGS,H,CONTIN
 5005 FORMAT(I4,I2,4A4,A2,A1,2(2I3,F8.4), F10.2,16X,A1)
      IF(CONTIN.EQ.ENDSIG) GO TO 50
      PHI=ANRADD(ISGNP,IPHID,IPHIM,PHIS)
      ISGNL=PLUS
      FLONG=ANRADD(ISGNL,LONGD,LONGM,FLONGS)
      KORDER(KSTA)=IDD
      IDS(KSTA)=IDTS
      STAPLH(1,KSTA)=PHI
      STAPLH(2,KSTA)=FLONG
      CALL UVWD(DATPRM(1,IDTS),DATPRM(2,IDTS),PHI,FLONG,H,STAUVW(1,KSTA)
     1,STAUVW(2,KSTA),STAUVW(3,KSTA))
      WRITE(6,6006)IDD,(STANAM(I,KSTA),I=1,5),IDTS,(DATNAM(I,IDTS),I=1,4
     1),ISGNP,IPHID,IPHIM,PHIS,ISGNL,LONGD,LONGM,FLONGS,H
 6006 FORMAT(1H0,I4,8X,4A4,A2,10X,5HDATUM,I4,4X,4A8/10X,20HGEODETIC COOR
     1DINATES,2(6X,A1,2I3,F8.4),F12.4)
      WRITE (6,6007) (STAUVW(I,KSTA),I=1,3)
 6007 FORMAT(10X,21HCARTESIAN COORDINATES,3F16.3)
      GO TO 35
   50 CONTINUE
      NSTA=KSTA-1
      NSTAUN=3*NSTA
      RETURN
```

```
      SUBROUTINE READIN
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER*2 PCODE(20)
      COMMON/PCODES/PCODE
      INTEGER*4 ENDSIG/1HE/,CONTIN,DELCOD(2)/1H ,1H*/,ECODE
      INTEGER*2 PLUS/]H+/
      INTEGER*2 ISGNP,IPHID,IPHIM,LONGD,LONGM,ISGNL
      INTEGER*2 ID(50),KEY(50),IHR(50),MIN(50),IDAY(50),IYR(50),IGHH(50)
     1,IGHM(50),ISGND(50),IDECD(50),IDECM(50),IDAT(50,11)
      COMMON/DEDITC/         GHA (50),DEC(50),U(3,50),S(3),D(50),
     1SDC(3,50),EVSUM,STAXYZ(3,50),GOI,
     2TD,KSTATE(50),IPASS(50),NSTE,NSUSED,ECODE
      COMMON/NSTA/NSTA
      COMMON/STAORD/KORDER(150)
      INTEGER STANAM,IDS*2
      COMMON/STALOC/STAUVW(3,150),DATPRM(2,15),DATNAM(4,15),
     1STANAM(5,150),IDS(150)
      DIMENSION MONTH(50)
      EQUIVALENCE(ID(1),IDAT(1,1)),(KEY(1),IDAT(1,2)),(IHR(1),IDAT(1,3))
     1,(MIN(1),IDAT(1,4)),(IDAY(1),IDAT(1,5)),(IYR(1),IDAT(1,6)),(IGHH(1
     2),IDAT(1,7)),(IGHM(1),IDAT(1,8)),(ISGND(1),IDAT(1,9)),(IDECD(1),ID
     3AT(1,10)),(IDECM(1),IDAT(1,11))
      DIMENSION DAT(50,6),        DECS(50),VARGHA(50),VARDEC(50),COVGHD(5
     10),GHAS(50),SEC(50)
      EQUIVALENCE(SEC(1),DAT(1,1)),(GHAS(1),DAT(1,2)),(DECS(1),DAT(1,3))
     1,(VARGHA(1),DAT(1,4)),(VARDEC(1),DAT(1,5)),(COVGHD(1),DAT(1,6))
      COMMON/OBSD/OBSD(150),OVOBSD
    3 MAXSTE=50
      PI=3.14159265358979300
      RHO=180.D0/PI
      SPR=RHO*3600.D0
      PI2=2.D0*PI
      WPWSP=0.D0
C
      READ(5,5004) TD
      WRITE(6,6004) TD
 5004 FORMAT(F20.2,F10.2)
 6004 FORMAT(//20X,'TEST DISTANCE =',F20.2,'     SECONDS OF ARC')
      WRITE(3) TD
C     START DATA INPUT
      IEVENT=0
      KEVENT=0
      EPR=0.0
      IS=0
C
C
C  ENTER HERE FOR A NEW OBSERVATION
C
  200 IS=IS+1
C  READ DATA CARD
  211 CONTINUE
      READ(5,5000,END=901)  ID(IS),IYR(IS),MONTH(IS),IDAY(IS),IHR(IS),
     1MIN(IS),
     2SEC(IS),IGHH(IS),IGHM(IS),GHAS(IS),ISGND(IS),IDECD(IS),IDECM(IS),
     3DECS(IS),         VARGHA(IS),VARDEC(IS),COVGHD(IS),CONTIN
 5000 FORMAT(1X,I4,1X,5I2,F3.0,5X,2I2,F7.4,5X,A1,2I2,F7.4,1X,2F6.3,
     CF7.3,7X,A1)
C
      IF(CONTIN.EQ.ENDSIG) GO TO 250
      DDT=DFLOAT(MJD(IDAY(IS),MONTH(IS),IYR(IS)))
      DDT=DDT + (DFLOAT((IHR(IS)*60 + MIN(IS))*60) + SEC(IS))/86400.
      IF(IS.LE.1) GO TO 212
```

```
C  THIS TEST SHOULD BE TRUE ONLY FOR THE FIRST CARD OF THE FIRST EVENT.
C
CHECK FOR END OF EVENT, ALLOWING 0.5 MILLISECOND DISCREPANCY.
      IF(DABS(DDT-EPR).GT.0.58D-8) GO TO 250
C
C  ENTER HERE TO BEGIN A NEW EVENT
C        THE FIRST ENTRY OF THE EVENT SHOULD ALWAYS BE MADE WIHT IS=1
  212 CONTINUE
      IDD=ID(IS)
      KSTA=KSTAID(IDD)
      IF(KSTA.GT.0) GO TO 220
      WRITE(6,6042) ID(IS),IHR(IS),MIN(IS),SEC(IS),IDAY(IS),MONTH(IS),
     1IYR(IS)
      GO TO 211
  220 CONTINUE
      KSTATE(IS)=KSTA
      EPR=DDT
      GO TO 200
C
C  END OF INPUT FOR THIS EVENT. BEGIN PROCESSING
  250 CONTINUE
      NSTE = IS - 1
      IEVENT = IEVENT + 1
 6042 FORMAT(5X,'STATION NUMBER NOT FOUND IN INPUT LIST',I5,3X,2I3,
     1F8.4,3X,I3,A3,I2,'OBSERVATION IGNORED')
      DO 270 IS =1,NSTE
      ISGNL = PLUS
      GHA(IS)=ANRADD(ISGNL,IGHH(IS),IGHM(IS),GHAS(IS))*15.D0
      DEC(IS)=ANRADD(ISGND(IS),IDECD(IS),IDECM(IS),DECS(IS))
  270 CONTINUE
      WRITE(3) IEVENT,NSTE,EPR,
     1((IDAT(IS,J),J=1,11),MONTH(IS),(DAT(IS,J),J=1,6),GHA (IS),DEC(IS),
     2KSTATE(IS),IS=1,NSTE),CONTIN
C  TEST FOR END OF INPUT
      IF(CONTIN.EQ.ENDSIG) GO TO 700
C  PREPARE FOR NEXT EVENT
      DO 610 I=1,6
  610 DAT(1,I)=DAT(NSTE+1,I)
      MONTH(1)=MONTH(NSTE+1)
      DO 611 I=1,11
  611 IDAT(1,I)=IDAT(NSTE+1,I)
C   RETURN TO START A NEW EVENT
      IS=1
      GO TO 212
C
  700 RETURN
C
C  ERROR EXITS
  901 CONTINUE
C  ENTER HERE IF END SIGNAL CARD IS MISSING FROM INPUT DATA DECK
      CONTIN= ENDSIG
      GO TO 250
      END
```

```
      SUBROUTINE ASD360
C   S/360 VERSION OF ASD FOR OPTICAL SATELLITE DIRECTIONS
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER*2 PCODE(20)
      COMMON/PCODES/PCODE
      INTEGER*4 ENDSIG/1HE/,CONTIN,DELCOD(2)/1H ,1H*/,ECODE
      INTEGER*2 PLUS/1H+/
      INTEGER*2 ISGNP,IPHID,IPHIM,LONGD,LONGM,ISGNL
      INTEGER*2 ID(50),KEY(50),IHR(50),MIN(50),IDAY(50),IYR(50),IGHH(50)
     1,IGHM(50),ISGND(50),IDECD(50),IDECM(50),IDAT(50,11)
      COMMON/DEDITC/        GHA (50),DEC(50),U(3,50),S(3),D(50),
     1SDC(3,50),EVSUM,STAXYZ(3,50),GQI,
     2TD,KSTATE(50),IPASS(50),NSTE,NSUSED,ECODE
      COMMON/NSTA/NSTA
      INTEGER STANAM,IDS*2
      DIMENSION MONTH(50)
      COMMON/STALOC/STAUVW(3,150),DATPRM(2,15),DATNAM(4,15),
     1STANAM(5,150),IDS(150)
      COMMON/STAORD/KORDER(150)
      EQUIVALENCE(ID(1),IDAT(1,1)),(KEY(1),IDAT(1,2)),(IHR(1),IDAT(1,3))
     1,(MIN(1),IDAT(1,4)),(IDAY(1),IDAT(1,5)),(IYR(1),IDAT(1,6)),(IGHH(1
     1),IDAT(1,7)),(IGHM(1),IDAT(1,8)),(ISGND(1),IDAT(1,9)),(IDECD(1),ID
     3AT(1,10)),(IDECM(1),IDAT(1,11))
      DIMENSION DAT(50,6),        DECS(50),VARGHA(50),VARDEC(50),COVGHD(5
     10),GHAS(50),SEC(50)
      EQUIVALENCE(SEC(1),DAT(1,1)),(GHAS(1),DAT(1,2)),(DECS(1),DAT(1,3))
     1,(VARGHA(1),DAT(1,4)),(VARDEC(1),DAT(1,5)),(COVGHD(1),DAT(1,6))
      DIMENSION SSDC(3,4),AW(3),A(3,3),AT(3,3),DDN(3,3),W(3,3),
     1      NOBSTA(150),A1(3,3),A1T(3,3),      DDK(3),D1(3,3),AM(3,3),
     2BT(3,3),TEMP1(3,3),TEMP2(3,3),BN(3,3,6),TEMP3(3),DN(3,3,50),
     3DK(3,50),AK1(3),TA(3)
      COMMON/WPW/WPW,XPU,IDEGF,NFSTA
      DIMENSION VPVSTA(150)
      MAXSTE=50
      PI=3.14159265358979 73D0
      PI2=2.*PI
      RPD=180.0/PI
      SPR=(180.*3600.)/PI
      WPWSP=0.0
C
      REWIND 2
      REWIND 3
      WRITE(6,4397)
 4397 FORMAT(1H1)
      READ(3) TD
      WRITE(6,6004) TD
 6004 FORMAT(//20X,'TEST DISTANCE =',F20.2,'    SECONDS OF ARC')
C
C   START DATA INPUT
      KEVENT=0
      EPR=0.0
      DO 70 KSTA=1,NSTA
      NOBSTA(KSTA)=0
      VPVSTA(KSTA)=0.0
      DO 70 I=1,3
      DK(I,KSTA)=0.0
      DO 70 J=1,3
      DN(I,J,KSTA)=0.0
   70 CONTINUE
      DO 80 I=1,3
      DO 80 J=1,3
      A1(I,J)=0.D0
```

```
      A1T(I,J)=0.D0
   80 CONTINUE
      DO 314 J=1,3
      A1(J,J)=-1.
  314 A1T(J,J)=-1.
  210 CONTINUE
      READ(3) IEVENT,NSTE,EPR,
     1((IDAT(IS,J),J=1,11),MONTH(IS),(DAT(IS,J),J=1,6),GHA (IS),DEC(IS),
     2KSTATE(IS),IS=1,NSTE),CONTIN
      DO 272 IS=1,NSTE
      KSTA=KSTATE(IS)
      DO 272 M=1,3
  272 STAXYZ(M,IS)=STAUVH(M,KSTA)
      WRITE(6,6008) IEVENT
 6008 FORMAT(/ 1X,'EVENT',I6)
C
      CALL DEDIT
C
      DO 280 IS=1,NSTE
      WRITE(6,6010) ID(IS),IHR(IS),MIN(IS),SEC(IS),IDAY(IS),MONTH(IS),
     1IYR(IS),IGHH(IS),IGHM(IS),GHAS(IS),ISGND(IS),IDECD(IS),IDECM(IS),
     2DECS(IS),VARGHA(IS),VARDEC(IS),COVGHD(IS),D(IS),DELCOD(IPASS(IS))
 6010 FORMAT(I7,2I3,F9.5,3X,I3,A3,I2,2I3,F8.4,3X,A1,I2,I3,F8.4,5X,3F6.2,
     1F10.0,2X,A1)
  280 CONTINUE
      IF(ECODE.GT.1) GO TO 630
      IF(PCODE(11))  290,630,610
  610 IF(PCODE(11)-3) 611,612,611
  611 WRITE(6,6024) S
 6024 FORMAT('  SATELLITE POSITION',3F15.3)
      IF(PCODE(11)-2) 612,630,612
  612 IDTS= IDS(KSTATE(1))
      CALL UVWTG2(S,DATPRM(1,IDTS),PHI,FLAM,H)
      PHI=PHI*RPD
      FLAM=FLAM*RPD
      WRITE(6,6023) PHI,FLAM,H
 6023 FORMAT('  GEOD. COORD. OF SATELLITE',2F14.6,F14.1)
  630 CONTINUE
      WRITE(6,6012)GQI
 6012 FORMAT(10X,'GQI=',F10.5)
      IF(ECODE.GT.1) GO TO 290
      IF(NSUSED.EQ.0) GO TO 290
      RMSMC=DSQRT(EVSUM/DFLOAT(NSUSED))
      WRITE(6,6011) RMSMC
 6011 FORMAT(1H+,27X,'RMS MISCLOSURE IN METERS=',F10.1)
      GO TO 300
  290 WRITE(6,6015) ECODE
 6015 FORMAT(1H+,27X,'ENTIRE EVENT DELETED, KODE=',I4)
      GO TO 600
C
C   SET UP GENERALIZED LEAST SQUARES EQUATIONS FOR THIS EVEN AND  COMPUTE
C   CONTRIBUTIONS TO THE NORMAL EQUATIONS.
  300 CONTINUE
      IF(ECODE.GT.1) GO TO 600
      KEVENT=KEVENT+1
      DO 310 I=1,3
      DDK(I)=0.0
      DO 310 J=1,3
      DDN(I,J)=0.0
  310 CONTINUE
C
      JS=0
```

```
      DO 390 IS=1,NSTE
      IF(IPASS(IS).GT.1) GO TO 390
      JS=JS+1
C        JS IS THE COUNTER FOR NON-DELETED STATIONS IN THE EVENT
      GHA (IS)=PI2-GHA (IS)
      RSQCSD=SDC(1,IS)**2+SDC(2,IS)**2
      RSQ=RSQCSD+SDC(3,IS)**2
      RCD=DSQRT(RSQCSD)
      RANGE=DSQRT(RSQ)
      SG=DSIN(GHA (IS))
      CG=DCOS(GHA (IS))
      SD=DSIN(DEC(IS))
      CD=DCOS(DEC(IS))
      A(1,1)=SD*CG*RANGE
      A(1,2)=SG*CD*RANGE
      A(3,3)=-SD*RANGE
      A(2,1)=SD*SG*RANGE
      A(2,2)=-CG*CD*RANGE
      A(2,3)=-CD*SG*RANGE
      A(3,1)=-CD*RANGE
      A(3,2)=0.0
      A(1,3)=-CD*CG*RANGE
      AW(1)= SDC(1,IS)-RANGE*CG*CD
      AW(2)= SDC(2,IS)-RANGE*SG*CD
      AW(3)= SDC(3,IS)-RANGE*SD
C
COMPUTE WEIGHTS
      VARGHA(IS)=(VARGHA(IS)/SPR)**2
      VARDEC(IS)=(VARDEC(IS)/SPR)**2
      COVGHD(IS)=COVGHD(IS)/SPR**2
      DET=VARGHA(IS)*VARDEC(IS)-COVGHD(IS)**2
      W(1,1)=VARDEC(IS)/DET
      W(1,2)=-COVGHD(IS)/DET
      W(1,3)=0.
      W(2,1)=W(1,2)
      W(2,2)=VARGHA(IS)/DET
      W(2,3)=0.
      W(3,1)=0.
      W(3,2)=0.
      W(3,3)=0.
C
      KSTA=KSTATE(IS)
C  ELIMINATE DELETED STATIONS FROM THE LIST OF STATIONS INVOLVED IN
C        THE EVENT
      KSTATE(JS)=KSTATE(IS)
C
      CALL VERSOL(A,BT,3,3)
      DO 940 I=1,3
      DO 940 J=1,3
  940 A(I,J)=BT(I,J)
      DO 821 I=1,3
      DO 821 J=1,3
  821 AT(J,I)=A(I,J)
      CALL DGMPRD(AT,W,TEMP1,3,3,3)
      CALL DGMPRD(TEMP1,A,TEMP2,3,3,3)
      CALL DGMPRD(AIT,TEMP2,BN(1,1,JS),3,3,3)
      CALL DGMPRD(TEMP2,AW,TEMP3,3,3,1)
      DO 915 I=1,3
      DO 915 J=1,3
  915 BN(I,J,JS)=-BN(I,J,JS)
      DO 916 I=1,3
      DDK(I)=DDK(I)+TEMP3(I)
```

```
 6910 FORMAT(1H ,4D22.14)
      DO 916 J=1,3
  916 DDN(I,J)=DDN(I,J)+TEMP2(I,J)
      DO 330 I=1,3
      DO 325 J=1,3
      TERM=0.0
      DO 320 II=1,3
      DO 320 JJ=1,3
  320 TERM=TERM+A1(II,I)*TEMP2(II,JJ)*A1(JJ,J)
      DN(I,J,KSTA)=DN(I,J,KSTA)+TERM
  325 CONTINUE
      TERM=0.0
      DO 328 II=1,3
      DO 328 JJ=1,3
  328 TERM=TERM+A1(II,I)*TEMP2(II,JJ)*AW(JJ)
      DK(I,KSTA)=DK(I,KSTA)-TERM
  330 CONTINUE
      CALL DGMPRD(SDC(1,IS),TEMP2,AK1,1,3,3)
      CALL DGMPRD(AK1,SDC(1,IS),VPVTO,1,3,1)
      WRITE(6,938) VPVTO
  938 FORMAT(1H ,'NEW VPV',D20.12)
      KNO=KORDER(KSTA)
      VPVSTA(KSTA)=VPVSTA(KSTA)+VPVTO
      NOBSTA(KSTA)=NOBSTA(KSTA)+2
  390 CONTINUE
C
C        FORM REDUCED NORMAL EQUATIONS
C
C        INVERT DDN
      CALL VERSOL(DDN,BT,3,3)
      CALL DGMPRD(DDK,BT,TA,1,3,3)
      CALL DGMPRD(TA,DDK,TB,1,3,1)
      WRITE(6,939) TB
  939 FORMAT(1H ,'WPW CONTRIBUTION FROM SATELLITE POSITION',D20.12)
      WPWSP=WPWSP+TB
      NSUSED=JS
      WRITE(2) NSUSED,BT,DDK,(((BN(I,J,JS),I=1,3),J=1,3),KSTATE(JS),
     1JS=1,NSUSED),CONTIN
  600 CONTINUE
C
C     TEST FOR END OF INPUT
      IF(CONTIN.EQ.ENDSIG) GO TO 700
      GO TO 210
C
C
C
  700 CONTINUE
C
CHECK TO SEE IF END SIGNAL HAS BEEN WRITTEN ON DATA SET FT02
      IF(ECODE.EQ.1) GO TO 710
      BACKSPACE 2
C   READ AND REWRITE LAST RECORD FROM LAST GOOD EVENT
      READ(2) NSUSED,BT,DDK,(((BN(I,J,JS),I=1,3),J=1,3),KSTATE(JS),
     1JS=1,NSUSED)
      BACKSPACE 2
      WRITE(2) NSUSED,BT,DDK,(((BN(I,J,JS),I=1,3),J=1,3),KSTATE(JS),
     1JS=1,NSUSED),CONTIN
  710 CONTINUE
      WRITE(2)      ((( DN(I,J,KSTA),I=1,3),DK(J,KSTA),J=1,3),
     1KSTA=1,NSTA)
      WPW=0.0
      NOBS=0
```

```
      WRITE(6,6019)
 6019 FORMAT(1H1,8(/),10X,'ANALYSIS OF MISCLOSURES BY STATION'//
     1T10,'STATION',T20,'NUMBER OF OBSERVATIONS',T50,'RMS MISCLOSURE')
      DO 750 KSTA=1,NSTA
      NOBS=NOBS+NOBSTA(KSTA)
      WPW=WPW+VPVSTA(KSTA)
      RMSMC=0.0
      IF(NOBSTA(KSTA).GT.0) RMSMC=DSQRT(VPVSTA(KSTA)/DFLOAT(NOBSTA(KSTA)
     1))
      WRITE(6,6020) KORDER(KSTA),NOBSTA(KSTA),RMSMC
 6020 FORMAT(T10,I7,T35,I7,T50,F14.2)
  750 CONTINUE
      IDEGF=NOBS-3*KEVENT
      RMSMC=DSQRT(WPW/DFLOAT(IDEGF))
      WRITE(6,6021) NOBS,KEVENT,IDEGF,WPW,RMSMC
 6021 FORMAT(////10X,'TOTAL NUMBER OF GOOD OBSERVATIONS',T60,I8//
     110X,'TOTAL NUMBER OF GOOD EVENTS',T60,I8//
     110X,'CORRESPONDING DEGREES OF FREEDOM',T60,I8//
     110X,'TOTAL SUM OF SQUARES OF MISCLOSURES',T60,F11.2//
     110X,'CORRESPONDING STANDARD DEVIATION OF UNIT WEIGHT',T60,F11.2)
      WPW=WPW-WPWSP
      WRITE(6,6022)WPW
 6022 FORMAT(1H0,9X,'WPW INCLUDING CONTRIBUTION FROM SATELLITE POSITION'
     1/15X,'(I.E.,VPV+UX)',T60,F11.2)
      RETURN
      END
```

```
      SUBROUTINE FORMRN
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/NSTA/NSTA
      INTEGER*2 PCODE(20)
      COMMON/PCODES/PCODE
      COMMON/WPW/WPW,XPU,IDEGF,IFSTA
      DIMENSION DDN(3,3),  DDK( 3),L1(3),L2(3),BNDDNI(3,03),TN(3,3),
     1TK(3),DDL(3),DN(3,3)
      INTEGER*2 L,LSOLVE
      INTEGER CONTIN,ENDSIG/1HE/
      COMMON/STAORD/KORDER(150)
      COMMON/NORMEQ/LSOLVE
      DIMENSION REDN(3,3,1275),U(3,50),L(1275)
      DIMENSION BN(3,3,50),LG(50)
C  FORM REDUCED NORMAL EQUATIONS FOR UP TO 50 STATIONS
      DIMENSION KSTATE(50)
      LOC(K)=(K*(K+1))/2
      MAXSTA=50
      IF(NSTA.GT.MAXSTA) GO TO 901
C
C   THE REDUCED NORMAL EQUATIONS ARE STORED AS 3 X 3 BLCCKS IN THE ARRAY REDN.
C   ONLY THE UPPER TRIANGULAR PART OF THE REDUCED NORMAL EQUATIONS IS STORED.
C     THE BLOCKS OF THE REDUCED NORMAL EQUATIONS ARE NUMBERED
C       ACCORDING TO THE FOLLOWING SCHEME:
C
C        1    2    4    7   11
C             3    5    8   12
C                  6    9   13
C                      10   14
C                           15           ET CETERA
C
C  L(1275) IS THE GUIDE MATRIX
C  L=1  SIGNIFIES A NON ZERO BLOCK
C  L=0  SIGNIFIES A ZERO BLOCK
      IB=LOC(NSTA)
      DO 100 JB=1,IB
      DO 99 I=1,3
      DO 99 J=1,3
   99 REDN(I,J,JB)=0.0
  100 L(JB)=0
C
      BACKSPACE 2
      READ(2)      (((BN(I,J,KSTA),I=1,3),U(J,KSTA),J=1,3),
     XKSTA=1,NSTA)
      REWIND 2
C
C  STASH  DIAGONAL BLOCKS
      DO 110 KSTA=1,NSTA
      IB    =LOC(KSTA)
      DO 108 I=1,3
      DO 108 J=1,3
  108 REDN(I,J,IB)=BN(I,J,KSTA)
  110 CONTINUE
C
      FDEGF=IDEGF
      IF(PCODE(9).EQ.1) WRITE(7,7010) FDEGF,WPW
 7010 FORMAT(16X,2F16.6)
C   READ BLOCKS FROM EACH EVENT AND REDUCE NORMAL EQUATIONS
C
  150 READ(2) NSTE,DDN,DDK,(((BN(I,J,IS),I=1,3),J=1,3),
     1KSTATE(IS),IS=1,NSTE),CONTIN
```

```
C
      DO 180 IS=1,NSTE
      ISTA=KSTATE(IS)
      IB=ISTA
      CALL DGMPRD(BN(1,1,IS),DDN,BNDDNI,3,3,3)
      CALL DGMPRD(BNDDNI,DDK,TK,3,3,1)
      DO 155 I=1,3
  155 U(I,ISTA)=U(I,ISTA)-TK(I)
      DO 180 JS=1,NSTE
      JSTA=KSTATE(JS)
      JB=JSTA
C   SKIP IF (ISTA.GT.JSTA), SINCE ONLY THE UPPER TRIANGULAR PART OF THE
C        REDUCED NORMAL EQUATIONS IS BEING COMPUTED AND SAVED.
      IF(ISTA.GT.JSTA) GO TO 180
C   (IB,JB) GIVES THE ROW AND COLUMN NUMBER OF THE BLOCK IN THE REDUCED
C       NORMAL EQUATIONS CURRENTLY BEING PROCESSED.
C
C  SET INDICATOR
      NB=LOC(JB-1)
      NB=IB+NB
      L(NB)=L(NB)+1
C  PERFORM REDUCTION
      DO 156 I=1,3
      DO 156 J=1,3
  156 DN(J,I)=BN(I,J,JS)
      CALL DGMPRD(BNDDNI,DN,TN,3,3,3)
 6910 FORMAT(1H ,3D20.12)
      DO 130 I=1,3
      DO 130 J=1,3
  130 REDN(I,J,NB)=REDN(I,J,NB)-TN(I,J)
  180 CONTINUE
C   IF END OF DATA, GO OUT OF LOOP
      IF(CONTIN.EQ.ENDSIG) GO TO 400
C   IF NOT, RETURN TO PROCESS ANOTHER EVENT
      GO TO 150
C
C   ENTER HERE WHEN ALL EVENTS HAVE BEEN PROCESSED.
  400 CONTINUE
C
C  SIMULATE KRAKIWSKI'S GUIDE MATRIX
      IF(PCODE(6).NE.1) GO TO 441
C
      WRITE(6,6001)
 6001 FORMAT(1H1,10(/),20X,'GUIDE MATRIX')
      DO 440 ISTA=1,NSTA
      IB=0
      LG(1)=1000
      DO 435 JSTA=ISTA,NSTA
      JB=LOC(JSTA-1)+ISTA
      IF(L(JB).EQ.0) GO TO 435
      IB=IB+1
      LG(IB)=KORDER(JSTA)
  435 CONTINUE
C
      IB=IB+1
      IF(IB.GT.1) LG(IB)=999
  439 WRITE(6,6002) KORDER(ISTA),(LG(I),I=1,IB)
 6002 FORMAT(20X,I5,5X,18I5,200(/30X,18I5))
  440 CONTINUE
  441 CONTINUE
C
C  PRINT NORMALS IN ASD FORMAT,AND PUNCH IF DESIRED.
```

```
      WRITE(6,6003)
 6003 FORMAT(1H1//'               NORMAL EQUATIONS (SEE GUIDE MATRIX)'//)
      DO 450 ISTA=1,NSTA
      DO 442 I=1,3
  442 DDL(I)=-U(I,ISTA)
      IB=0
      JB=LOC(ISTA)
      IF(L(JB).GT.0) IB=1
C   PUNCH NORMALS
      IF(PCODE(9).NE.1) GO TO 443
      WRITE(7,7001) KORDER(ISTA)
 7001 FORMAT(14I5)
      WRITE(7,7006) DDL
 7006 FORMAT(3D25.16)
      WRITE(7,7008) ((REDN(I,J,JB),J=1,3),I=1,3)
 7008 FORMAT(3D25.16/3D25.16/3D25.16)
C
  443 CONTINUE
C   PRINT DIAGONAL BLOCK
      IF(PCODE(7).NE.1) GO TO 444
      WRITE(6,6004) KORDER(ISTA)
 6004 FORMAT(//I5)
      WRITE(6,6006) DDL
 6006 FORMAT(3D25.16,//)
      WRITE(6,6008) ((REDN(I,J,JB),J=1,3),I=1,3)
  444 CONTINUE
C   PRINT OFF-DIAGONAL BLOCKS
      KSTA=ISTA+1
      IF(ISTA.EQ.NSTA) GO TO 448
      DO 445 JSTA=KSTA,NSTA
      JB=LOC(JSTA-1)+ISTA
      IF(L(JB).EQ.0) GO TO 445
      IB=IB+1
      IF(PCODE(9).NE.1) GO TO 7445
      WRITE(7,7001) KORDER(JSTA)
      WRITE(7,7008) ((REDN(I,J,JB),J=1,3),I=1,3)
 7445 CONTINUE
      IF(PCODE(7).NE.1) GO TO 445
      WRITE(6,6004) KORDER(JSTA)
      WRITE(6,6008) ((REDN(I,J,JB),J=1,3),I=1,3)
  445 CONTINUE
  448 I=1000
      IF(IB.GT.0) I=999
      IF(PCODE(7).EQ.1) WRITE(6,6004) I
      IF(PCODE(9).EQ.1) WRITE(7,7001) I
  450 CONTINUE
      IF(PCODE(8).NE.1) GO TO 478
      WRITE(6,6010)
 6010 FORMAT(10(/),20X,'OBSERVATIONS ON EACH LINE')
      IB=NSTA-1
      DO 475 ISTA=1,IB
      KSTA=ISTA+1
      DO 475 JSTA=KSTA,NSTA
      WRITE(6,6011) KORDER(ISTA),KORDER(JSTA),L(LOC(JSTA-1)+ISTA)
 6011 FORMAT(8I10)
  475 CONTINUE
  478 CONTINUE
      RETURN
  901 CONTINUE
      WRITE(6,9001)  MAXSTA,NSTA
 9001 FORMAT('   FORMRN IS PRESENTLY DIMENSIONED TO HANDLE ONLY',I5,
     1'   UNKNOWN STATIONS.'/20X,' THIS PROBLEM HAS',I5,'  UNKNOWN STATI
```

```
     2IONS.'/10X,'EXECUTION IS TERMINATED BY PROGRAM.')

6008 FORMAT(3D25.16)
     STOP
     END
```

```
      SUBROUTINE DEDIT
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON/DEDITC/        ALFS(50),DEC(50),U(3,50),S(3),D(50),
     1SDC(3,50),SUM,STAXYZ(3,50),GOI,
     2TD,KSTATE(50),IPASS(50),NSTE,NSUSED,KODE
C  EDIT DATA BASED ON PRELIMINARY STATION POSITIONS AND DELETE BAD
C     OBSERVATIONS AND BAD EVENTS,BASED ON THE DISTANCE CRITERION TD
C  THIS SUBROUTINE IS DIMENSION FOR A MAXIMUM OF MAXSTE=50 STATIONS
C     PARTICIPATING IN ANY ONE EVENT. ALL AFFECTED ARRAYS ARE IN
C     COMMON BLOCK /DEDITC/.
C
C  THE NUMBER OF STATIONS PARTICIPATING IN THE EVENT IS NSTE.
C  THE NUMBER OF STATIONS NOT DELETED IS NSUSED.
C
      COMMON/STALOC/STAUVW(3,150)
      DIMENSION Q(3,3),RHS(3),QI(3,3),VI(3)
C
      PI=3.14159265358979300
      RHO=180.D0/PI
      SPR=RHO*3600.D0
      TPI=2.D0*PI
      MAXSTE=50
C  INITIALIZE
      KODE=1
      DO 110 IS=1,NSTE
  110 IPASS(IS)=1
C         IPASS=1 MEANS THIS DIRECTION OK
C         IPASS=2 MEANS THIS DIRECTION DELETED FROM EVENT
C
C  FORM UNIT VECTORS FOR ALL DIRECTIONS IN THIS EVENT
      DO 125 IS=1,NSTE
      STS=TPI-ALFS(IS)
      CA=DCOS(STS)
      SA=DSIN(STS)
      CD=DCOS(DEC(IS))
      SD=DSIN(DEC(IS))
      U(1,IS)=CA*CD
      U(2,IS)=SA*CD
      U(3,IS)=SD
  125 CONTINUE
C
C  INITIALIZE ARRAYS FOR THIS ITERATION
  130 CONTINUE
      NSUSED=0
      DO 140 I=1,3
      RHS(I)=0.0
      S(I)=0.0
      DO 140 J=1,3
      Q(I,J)=0.0
  140 CONTINUE
C
C  ACCUMULATE EQUATIONS
      DO 190 IS=1,NSTE
      IF(IPASS(IS).EQ.2) GO TO 190
      NSUSED=NSUSED+1
      DO 170 I=1,3
      DO 169 J=1,3
  169 QI(I,J)=U(I,IS)*U(J,IS)
  170 QI(I,I)=QI(I,I)-1.0
      DO 175 I=1,3
      DO 175 J=1,3
      Q(I,J)=Q(I,J)+QI(I,J)
```

```
      RHS(I)=RHS(I)+QI(I,J)*STAXYZ(J,IS)
  175 CONTINUE
  190 CONTINUE
C
C TEST FOR DELETION OF WHOLE EVENT
      IF(NSUSED.LT.2) GO TO 420
C
C  INVERT AND SOLVE
C     THE SATELLITE POSITION S IS SELECTED IN SUCH A WAY THAT THE SUM OF
C     THE SQUARES OF THE DISTANCES FROM S OF THE NON-DELETED RAYS IS MINIMIZED.
      DET=1.0
      CALLDMINV(Q,3,DET,QI(1,1),QI(1,2))
      GQI=DABS(DET/DFLOAT(NSUSED))
      IF(GQI.LT.1.0D-4) GO TO 430
      CALL DGMPRD(Q,RHS,S,3,3,1)
C
C  COMPUTE DISTANCE FROM S FOR EACH RAY
      ISMAX=0
      DMAX=0.0
      SUM=0.0
      DO 280 IS=1,NSTE
      DO 270 I=1,3
      DO 269 J=1,3
  269 QI(I,J)=U(I,IS)*U(J,IS)
      QI(I,I)=QI(I,I)-1.0
      VI(I)=S(I)-STAXYZ(I,IS)
  270 CONTINUE
      DDI=DPDOT(VI,U(1,IS),3)
      DDI=DABS(DDI)
      DI=0.0
      DO 275 I=1,3
      DI=DI+(VI(I)-DDI*U(I,IS))**2
      SDC(I,IS)=VI(I)
  275 CONTINUE
      D(IS)=DSQRT(DI)/DDI*SPR
      IF(IPASS(IS).EQ.2) GO TO 280
      SUM=SUM+DI
C  TEST D AGAINST TD AND DELETE IF NECESSARY
      IF(D(IS).LT.DMAX) GO TO 280
      DMAX=D(IS)
      ISMAX=IS
  280 CONTINUE
      IF(DMAX.LT.TD) RETURN
      IPASS(ISMAX)=2
C
C   GO BACK AND MAKE ANOTHER PASS THROUGH THE DATA
      GO TO 130
  400 CONTINUE
C  DELETE WHOLE EVENT
      DO 410 IS=1,NSTE
  410 IPASS(IS)=2
      NSUSED=0
      RETURN
  420 CONTINUE
C  DELETE FOR INSUFFICIENT GOOD OBSERVATIONS
      KODE=2
      GO TO 400
C   DELETE FOR INSUFFICIENT GEOMETRICAL SEPARATION BETWEEN OBSERVATIONS
  430 CONTINUE
      KODE=3
      GO TO 400
      END
```

```
      INTEGER FUNCTION KSTAID(ID)
      COMMON/STAORD/KORDER(150)
      COMMON/NSTA/NSTA
      KSTAID=0
C   SEARCH TABLE OF STATION IDENTIFIERS FOR THE INTERNAL NUMBER OF THIS STATION
      DO 10 I=1,NSTA
      IF(KORDER(I).NE.ID) GO TO 10
      KSTAID=I
      RETURN
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VERSOL (ORGMAT,VERMAT, I, M)
      IMPLICIT REAL*8(A-H,O-Z)
COMMENT I IS THE NUMBER OF ROWS IN ORGMAT, AND M IS I PLUS THE NUMBER OF
C     OF UNKNOWN COLUMNS. THE ORIGINAL VALUES OF ORGMAT ARE RETAINED.
      DIMENSION ORGMAT (I,M), VERMAT (I,M)
      DIMENSION P(72)
      N=I-1
      MI=M-1
      DO 1 J=1,I
      DO 1 K=1,I
    1 VERMAT(J,K)=ORGMAT(J,K)
      DO 5 K=1,I
      DO 2 J=1,MI
    2 P (J) = VERMAT (1,J+1)/VERMAT (1,1)
      P(M)=1.0D0/VERMAT(1,1)
      DO 4 L=1,N
      DO 3 J=1,MI
    3 VERMAT (L,J) = VERMAT (L+1,J+1) - VERMAT (L+1,1) * P(J)
    4 VERMAT (L,M) = - VERMAT (L+1,1) * P(M)
      DO 5 J=1,M
    5 VERMAT (I,J) = P(J)
      RETURN
      END
```

```
      SUBROUTINE UVWD(A,B,PHI,LAMDA,H,U,V,W)
      DOUBLE PRECISION PHI,LAMDA,N,E2,FAC,U,V,W,SP
      REAL*8 A,B,H
      E2=1.0-(B/A)**2
      SP=DSIN(PHI)
      N=A/DSQRT(1.0-E2*SP*SP)
      FAC=(N+H)*DCOS(PHI)
      U=FAC*DCOS(LAMDA)
      V=FAC*DSIN(LAMDA)
      W=(N*(1.0-E2)+H)*SP
      RETURN
      END
      SUBROUTINE UVWTG2(UVW,DATUM,PHI,LAM,H)
C    CONVERT RECTANGULAR TO GEODETIC COORDINATES
C    ALIAS FOR UVWTG
      IMPLICIT REAL*8(A-Z)
      DIMENSION UVW(3),DATUM(2)
      LAM=DATAN2(UVW(2),UVW(1))
      IF(LAM.LT.0.0) LAM=LAM+6.28318530717958D0
      OME2=(DATUM(2)/DATUM(1))**2
      E2=1.0-OME2
      P=DSQRT(UVW(1)**2+UVW(2)**2)
      WP=UVW(3)/P
      TP1=WP/OME2
      PHI1=DATAN(TP1)
    5 TTP=TP1*TP1
      SECP=DSQRT(1.0+TTP)
      N=DATUM(1)*SECP/DSQRT(1.0+OME2*TTP)
      H=P*SECP-N
      TP2=WP/(1.0-E2*N/(N+H))
      PHI=DATAN(TP2)
      IF(DABS(PHI-PHI1).LT.1.D-12) RETURN
      PHI1=PHI
      TP1=TP2
```

```
      GO TO 5
      END
      DOUBLE PRECISION FUNCTION ANRADD(ISGN,IDEG,MIN,SEC)
      INTEGER*2 MINUS/1H-/, PLUS/1H+/,AMPSAN/1H&/,ISGN,IDEG,MIN
      DOUBLE PRECISION SEC
      IF(IDEG.GE.0) GO TO 10
      ISGN=MINUS
      IDEG=-IDEG
   10 CONTINUE
      ANRADD=(DFLOAT((IDEG*60+MIN)*60)+SEC)/206264.80625D0
      IF(ISGN.EQ.MINUS)ANRADD=-ANRADD
      IF(ISGN.EQ.AMPSAN) ISGN=PLUS
      RETURN
      END


      FUNCTIONMJD(DATE,MONTH,YEAR)
COMPUTATION OF MODIFIED JULIAN DAY
      INTEGER*2 DATE,YEAR
      DIMENSIONMONTHS(2,12)
      DATAMONTHS/3HJAN,0,3HFEB,31,3HMAR,59,3HAPR,90,3HMAY,120,3HJUN,151,
     13HJUL,181,3HAUG,212,3HSEP,243,3HOCT,273,3HNOV,304,3HDEC,334/
      ID=365*(YEAR-50)+(YEAR-49)/4
      DO20I=1,12
      IF(MONTH.EQ.MONTHS(1,I))GOTO25
   20 CONTINUE
      IF(MONTH.LE.12) GO TO 21
      WRITE(6,6001) MONTH
 6001 FORMAT(3X,22HMONTH NAME MISPELLED  ,A3)
      STOP
   21 I=MONTH
      MONTH=MONTHS(1,I)
   25 CONTINUE
      ID=ID+MONTHS(2,I)
      IF(MOD(YEAR*1,4).EQ.0.AND.I.GT.2) ID=ID+1
      MJD=ID+DATE+33281
      RETURN
      END


      SUBROUTINE DMSTR(A,R,N,MSA,MSR)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(1),R(1)
      DO 20 I=1,N
      DO 20 J=1,N
      IF(MSR) 5,10,5
    5 IF(I-J) 10,10,20
   10 CALL LOC(I,J,IR,N,N,MSR)
      IF(IR) 20,20,15
   15 R(IR)=0.0
      CALL LOC(I,J,IA,N,N,MSA)
      IF(IA) 20,20,18
   18 R(IR)=A(IA)
   20 CONTINUE
      RETURN
      END
```