FGCC Federal Geodetic Control Committee

REPORT ON TEST AND DEMONSTRATION OF MOTOROLA MINI-RANGER DOPPLER SATELLITE SURVEY SYSTEM.

FGCC Report: FGCC-IS-83-1

BY

LARRY D. HOTHEM
JAMES MCCUNE

INSTRUMENT SUBCOMMITTEE
FEDERAL GEODETIC CONTROL COMMITTEE
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Larry D. Hothem
James McCune

Instrument Subcommittee
Federal Geodetic Control Committee
Rockville, Maryland

For further information, contact
Chairman, Federal Geodetic Control Committee
6001 Executive Boulevard
Room 305
Rockville, Maryland 20852

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Report on Test and Demonstration of Motorola Mini-Ranger Doppler Satellite Survey System

Larry D. Hothem and James McCune
Instrument Subcommittee
Federal Geodetic Control Committee
Rockville, Maryland 20852

ABSTRACT

In May 1982, the Federal Geodetic Control Committee (FGCC) conducted a test and demonstration with the Motorola Mini-Ranger Doppler Satellite Survey System. Three Mini-Rangers were deployed at separate sites of a three-station FGCC test network located in the Washington, D.C. area. The basic objectives of the test were to evaluate the operation of the hardware and field processing capabilities of the Mini-Ranger micro-processor. In addition to field processing Mini-Ranger data, the capability of field processing mixed data sets consisting of data combined with observations performed with Magnavox MX1502 and JMR-1B receivers collocated at the survey sites was also demonstrated. Differences between results of the field processed Doppler data and the terrestrial standard (Transcontinental Traverse - North American Datum 1927 system) were less than one meter in any coordinate when 12 or more simultaneous passes were processed. In general, the test objectives were successfully met.

INTRODUCTION

During the period of May 14, 1982, to May 23, 1982, a test and demonstration were conducted with the Motorola Mini-Ranger Doppler Satellite Survey System. The public demonstration (see appendix A for copy of notice), hosted by the Instrument Subcommittee of the Federal Geodetic Control Committee (FGCC), focused on the operation of the hardware and capabilities of the Motorola Mini-Ranger System's field processor. A three-station FGCC test network, located in the vicinity of Washington, D.C., was occupied simultaneously.

To demonstrate the capabilities of the Mini-Ranger's processor to handle reduction of data observed with other Doppler receivers, simultaneous observations were also carried out with three Magnavox MX1502 and two JMR-1B receivers collocated at the survey sites. During May 23 and 24, personnel from Motorola, with FGCC Instrument Subcommittee members as observers, used the Mini-Ranger processors to reduce a portion of the data. On May 25, a summary of the results was presented at an open meeting to members of the FGCC and the survey community. Aprroximately 50 people from government, industry and private survey firms attended the meeting.

Subsequent processing of the data were carried out by Motorola, the National Geodetic Survey (NGS), and the Defense Mapping Agency Topographic/Hydrographic Center (DMAHTC). These results are presented in this report along with comparisons with the terrestrial survey coordinates. The report also includes comments on problems that occurred during the observations which may have affected the quality of the data.

TEST OBJECTIVES

The objectives of the test survey were:

1. To demonstrate the field operability of the Motorola Mini-Ranger Satellite Survey System by deploying receivers on a station at each site of a three-site FGCC test network and to observe simultaneously all available Navy Navigation Satellite System or TRANSIT passes.

2. To evaluate the on-site field processing capabilities of the Motorola Mini-Ranger field processor system, including multi-master station translocation solutions.

3. To demonstrate the capability of the Mini-Ranger field processor to process mixed Doppler data sets that included data observed with MX1502 receivers made by Magnavox and JMR-1B receivers made by JMR Instruments, Inc.

TEST SURVEY NETWORK

The FGCC test survey network consists of stations located at three sites near Herndon, Va., Gaithersburg, Md., and Greenbelt, Md. as shown in Figure 1. The stations at each site have been tied to the U.S. Transcontinental Traverse (TCT) network using first order standards. Figure 2 illustrates the relationship of the sites to the TCT.

The distances between the stations at each site range from less than 30 meters at the Herndon and Gaithersburg sites to over 500 meters at the Greenbelt site. The distances for each leg of the test triangle are approximately 19, 35 and 43 km.

The estimated accuracy of the horizontal ties between the stations at each site is on the order of 1 cm (1 sigma) for distances of less than 30 meters. It may be up to 3 cm for the 500-meter line at the Greenbelt site. Since stations at each site were tied to the TCT, the estimated accuracy for the ties between the sites should approach 1 ppm. However, a more conservative estimate might be about 1:500,000 (2 sigma). This represents an uncertainty of about 8 cm for the longest line to about 4 cm for the shortest line.

The estimated accuracy of the vertical ties between the sites is on the order of 5 cm. However, the more dominant error is the uncertainty in the geoid height difference between the sites, which is estimated to be on the order of a decimeter or greater. Thus the combined uncertainty, which represents the error in the ellipsoid height difference, is approximately 12 cm (1 sigma). This may be an optimistic estimate.

OBSERVATIONS

Eight stations were occupied among the three sites. The Doppler observations were performed with three Motorola Mini-Rangers, two JMR-1B receivers and three Magnavox MX1502 receivers. Table 1 summarizes information on the station occupations. Members of the FGCC Instrument Subcommittee and personnel from Motorola carried out the task of deploying and monitoring the equipment.

Four of the eight stations were occupied beginning as early as May 14; however, simultaneous observations between all eight stations did not start until May 17. Observations were terminated at one station on May 20 and at the remaining stations on May 22. Figure 3 illustrates the period of occupation for each station.

Factors at each site which may have, or are known to have, affected the quantity and quality of the observations are the following:

1. Station 31311. The antenna cable for the Mini-Ranger at the Herndon site was damaged about a day after observations commenced, resulting in a two-day data gap. (See fig. 3).

2. Station 31312. An operator error caused a two-day gap in the middle of the observing period for the JMR-1B receiver deployed at the Herndon site. (See fig. 3).

3. Station 50279. JMR-1B receiver at Greenbelt was located between several mobile vans which obstructed the satellite signal and may have also caused reflected signal problems.

4. Station 50280. Stations at the Gaithersburg site were obstructed by trees and, to a lesser extent, by buildings. To minimize potential effects of the obstructions, station 50231 was occupied with the MX1502 antenna mounted on the top of a stand that was about 6 meters above the mark. Unfortunately, a similar stand wasn't available for elevating the Mini-Ranger antenna; therefore, the antenna mounted on the standard tripod was less than one meter above the mark for station 50280. Hence, the quantity and quality of Motorola data were not as good as the data observed with the MX1502 receiver.

5. Station 50222. The station occupied with the MX1502 receiver at the Greenbelt site was obstructed by a dome located about 5 meters south of the station.

Observations were begun immediately after the receivers were placed on power at the sites. Thus, no time was allowed for warm-up and stabilization of the receiver reference frequency standards. During the first 24-hours of observations, while the oscillator was stabilizing, the quality of the data is considered less than optimum.

DATA PROCESSING

Data processing was carried out in two phases. The first phase involved processing a portion of the data on-site using the Mini-Ranger processor. This processing began immediately after the observations were terminated

with the results presented at a meeting open to the public on May 25. The second phase, completed at a later date, involved processing the data with the Mini-Ranger processor and with versions of short-arc and point position programs available on main-frame computer systems. These reductions were carried out independently by DMAHTC, NGS, and Motorola.

On-site Processing

The on-site processing was carried out to demonstrate the near-real-time field processing capabilities of the Motorola Mini-Ranger receiver, including the ability to process various combinations of MX1502, JMR, and Mini-Ranger data sets. Using satellite Doppler data collected simultaneously from two or more stations, the Mini-Ranger processor can be used to determine the relative positions of stations. The software incorporates short arc techniques and is a version of the Motorola main-frame computer program called MOS3 (Motorola Optimal Statistical Survey Software).

The on-site processing was carried out between Sunday morning, May 23, and Monday evening, May 24. Because there was not sufficient time to process all data, processing was limited to a set of 8-station simultaneous observations that spanned a period of about 40 hours. This period is shown in figure 3. The period began about 24 hours after observations had commenced at all eight stations, thus allowing a reasonable period of time for each of the internal reference frequency standards to stabilize.

The sets included up to 30 simultaneous passes with maximum elevations above the horizon of greater than 15 degrees.

Unfortunately, a hardware problem with the JMR cassette reader prevented on-site processing of any of the JMR data. However, various combinations of of the data sets collected with the MX1502 and Mini-Ranger receivers were successfully processed. To allow sufficient time to analyze the results before presentation of results on May 25, processing consisted almost entirely of two-station solutions.

Table 2 illustrates the two-station data sets processed on-site with the Mini-Ranger. A more detailed discussion of the field procedures for the on-site processing are given in the report prepared by Motorola. (See appendix B.) Table 3 summarizes these results.

Post Processing of Data

All data were eventually processed later with the Mini-Ranger processor and with main-frame computer versions of relative and point position methods of Doppler data reduction.

Processing by Motorola. Post reductions and analyses by Motorola were carried out at their headquarters in Tempe, Az. Most of the processing was done on the Mini-Ranger processor. Various combinations of data, including the JMR-1B data, were processed in both the two and multi-master station mode of reduction. Some processing was also carried out with the main-frame

computer version of the short arc program MOS3. More details on the post processing results and an analysis by Motorola are included in the report by Motorola. (See appendix B.)

Processing by DMAHTC and NGS. Point position reductions with program DOPPLR were carried out by DMAHTC (version DOPL79) for all data sets and by the NGS (version NGS-03) for the MX1502 data sets. The data were reduced with the precise ephemerides. Each point position was determined from all data available from each station, including data where the quality may have been affected by an unstable reference frequency standard.

The results of the DMAHTC and NGS data reductions for the MX1502 data were compared to verify the compatability of their separate versions of program DOPPLR. Both versions permit determination of a parameter for tropospheric scale bias with an uncertainity of 10 percent. The data sets were reduced with a 5 degree cutoff for passes and data points. Although there are minor differences in the editing criteria incorporated in the programs, differences in the solution coordinates were insignificant. For this report, only the DMAHTC results are presented for comparisons with other Doppler and terrestrial survey coordinates. However, table 4 includes both NGS and DMAHTC point position results for the MX1502 data.

Point Position Solution Statistics

All passes, including data observed on both sides of data gaps for stations 31311 and 31312, were used in computing the point position values. The number of passes used in the solutions ranged from a low of 47 to a high of 149.

The statistical information given in table 4 for the point position results indicates possible problems with data quality for four of the eight stations. Apparently the data quality for stations 50279 and 50280 was affected by the obstructions mentioned earlier. The poor quality is indicated by the unusually high percentage of observations rejected (21% for 50279 and 12% for 50280) and the high rms values for the range residuals (20 cm for 50279 and 19 cm for 50280).

Another indicator of problems for stations 50279 and 50280 is the quantity of data available and actually used in the solutions. While the number of data points used per pass in a solution ranged from 18 to 19 for stations 50279 and 50280, respectively, data points per pass ranged from 21 to 24 for the other stations. Typically, the user should expect to see the data points per pass for a point position solution range from 22 to 25 when the cutoff angle for the observations is 5 degrees. These statistics are based on 30-second Doppler count intervals.

Stations 31311 and 50273 exhibited somewhat larger residual rms values of 15 cm as compared to the residual rms values of 10 to 12 cm for stations 30691, 31312, 50231, and 50222.

COMPARISONS OF RESULTS

The following analysis of the coordinate comparisons did not consider the possibility of scale and orientation differences between the satellite and NAD 1927 coordinate systems. Past studies have yielded estimates for the scale factor of generally less than 2 ppm for data reduced with the broadcast ephemerides and about 0.5 ppm for data reduced with the precise ephemerides, and an orientation difference about the z-axis (longitude rotation) of about 0.5 second (east) between the satellite Doppler and NAD 1927 TCT coordinates. The value 2 ppm would represent less than 10 cm for the longest base line of 43 km; hence it is not significant. The orientation factor is also not significant for this report.

The results of the point and relative position solutions were evaluated by comparisons with each other and with the terrestrial survey coordinates.

On-site Processed Data

Table 5 summarizes comparisons of the on-site processed results with the terrestrial (Transcontinental Traverse - 1982 adjustment, NAD 1927 Datum) coordinates. These comparisons are the same as those presented at the FGCC meeting on May 25, 1982. Differences between the Doppler-determined NAD 1927 and terrestrial coordinates were consistently less than 1 meter in any coordinate when 12 or more passes were processed. In the one case (solution no. 8), where a coordinate difference was greater than 1 meter, only 11 passes were processed. It did not appear that a significant difference existed between using a master station observed with a Mini-Ranger or with a MX1502 receiver. It is also interesting to note that for the single on-site multi-master station solution which included two Mini-Ranger and one MX1502 data sets, the solution converged to a maximum difference of 22 cm after only 12 passes.

Table 6 compares base lines for six two-station on-site solutions. These differences were also presented at the FGCC meeting; however, due to errors in the terrestrial base line lengths, the differences are not the same as the current values. The values presented at the FGCC meeting are shown next to the corrected values.

Additional information, including comments about on-site processed data convergence tests, is given in the Motorola report. (See appendix B.).

Post-processed Point Position Data

Analysis of the point position results involved several computational steps. In the first step, datum shifts were computed between the NSWC-9Z2 satellite datum coordinates and the NAD 1927 datum coordinates for the TCT stations. The results of these computations are summarized in table 7. As expected, when the datum shifts for stations 50279 and 50280 are excluded (part 2), the agreement is much better. The standard deviation of the mean decreased from a high of 52 cm in the x-coordinate (part 1) to less than 30 cm in any coordinate (part 2). The means and standard deviations for part 2 and part 3 (which include only stations occupied with the MX1502 receivers) do not differ significantly. Furthermore, the differences between the datum

shifts for Motorola data sets 31311 and 50273 were less than 30 cm, indicating that the unusually high rms values for the range residuals was not significant. It seems reasonable to conclude that ,with the exception where external factors contributed to data quality degradation, there was no significant differences in observational results for the systems used in the FGCC test.

The next step involved transformation of the Doppler point position coordinates by using the mean datum shifts given in part 2 of table 7. Comparisons of the transformed Doppler and NAD 1927 datum coordinates are given in table 8. Again, there are significant errors in the coordinates for 50279 and 50280.

An analysis of table 8 indicates very good agreement in the north-south direction (rms of 17 cm for all data to 11 cm when stations 50279 and 50280 are deleted). In the east-west direction the spread among the differences is significantly less when stations 50279, 51280 and 31312 are deleted. The height differences are also reasonable, particularly when the higher uncertainities are considered in the terrestrial surveyed height differences between sites. Furthermore, there appears to be a height bias for station 50222 indicating that possibly the observations were affected by the obstruction noted earlier in the report.

Finally, table 9 shows the comparisons of the terrestrial and Doppler point position derived base lines.

Post-processed Relative Position Data

Tables 6a, 6b, and 7 of the Motorola report (appendix B) compares the Motorola post-processed data with the terrestrial data.

To complete the evaluation, the baseline differences given in tables 6 and 9 of this report and table 6b of the Motorola report are summarized in table 10. Overall, there is general agreement in the differences. Problems in the data quality noted from the point position results are also apparent for the relative position results. When data of questionable quality are deleted from the comparisons, the coordinate differences are consistent with estimates for accuracies given in other reports on accuracies of Doppler relative and point position coordinates.

SUMMARY

Although site obstruction problems affected the data quality for two or three of the eight stations occupied, the very good to excellent quality for the remaining stations indicated that if appropriate measures had been taken to minimize the effects of the obstructions, there would have been a more uniform quality for all eight stations. Also, the overall quality would have been better if the receivers had been placed on power at least 24 hours before observing any data.

Except for operational problems unrelated to the receiver hardware that interrupted the data collection during a portion of the occupations, all receivers functioned normally.

Although Motorola personnel experienced a hardware problem with the JMR cassette reader, preventing on-site reduction of any of the JMR data, Motorola was successful in demonstrating that mixed data can be processed with the Mini-Ranger processor. The on-site processed data yielded results that were comparable to results determined from main-frame computer Doppler processing programs.

The data processed with the point position method using the precise ephemerides were compatible at the decimeter level with results of short arc solutions by Motorola. Poor quality data affected both modes of reduction in about the same way. Comparisons with the terrestrial standard indicated baseline agreement at the 20-cm level. The differences expressed in proportional error for the baselines between the sites ranged from about 1:20,000 to over 1 ppm, indicating the accuracy for the results was second order or better.

Finally, analysis of the transformed point position data agreed with the terrestrial coordinates at about the decimeter level in the north-south direction and, at the 2- to 3-decimeter level in the east-west direction. However, this analysis ignored any possible scale and orientation biases between the Doppler and terrestrial coordinates.

The test objectives stated on page 2 were successfully met overall.

Figure 1 - FGCC Test Network

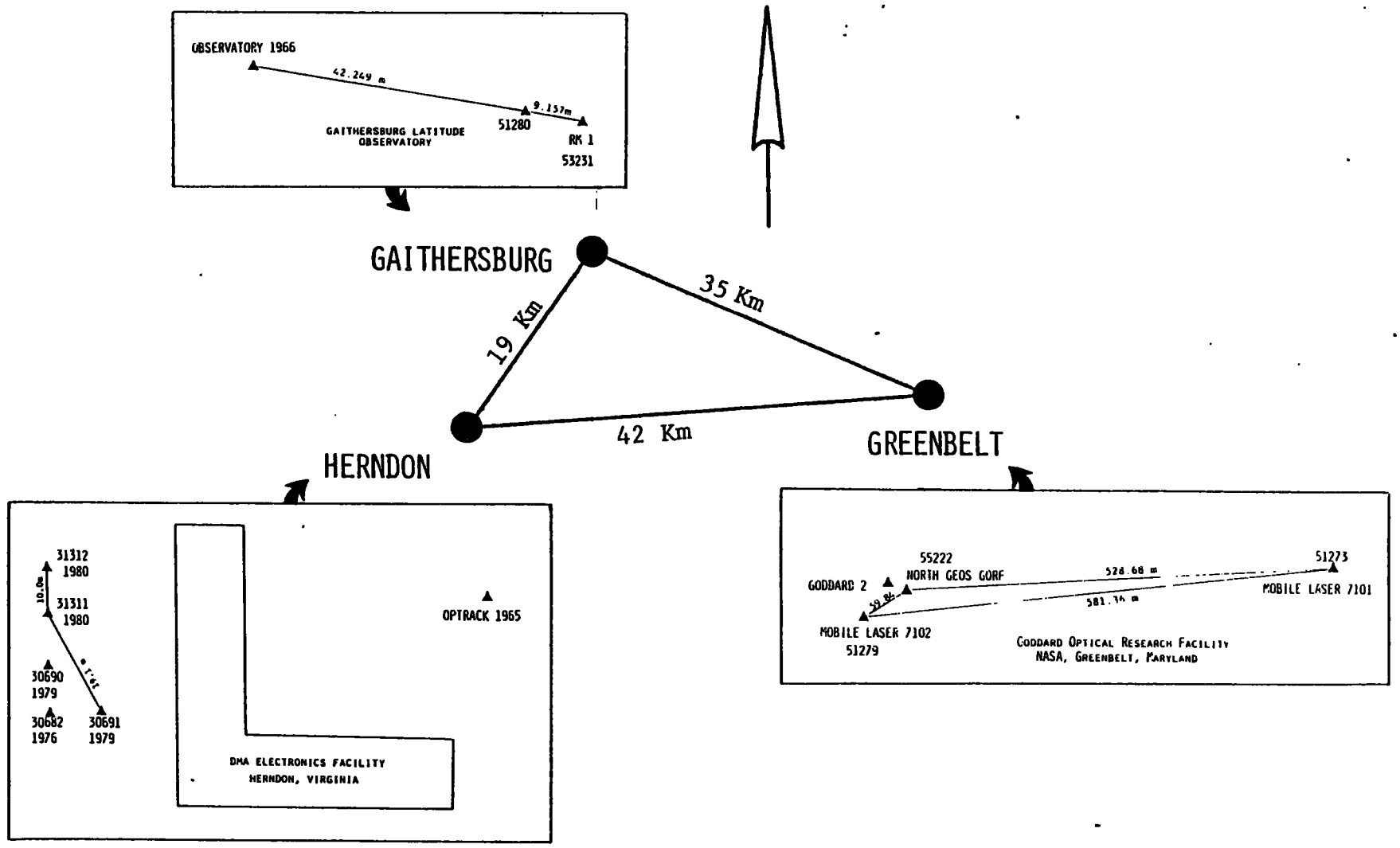


Figure 2 - Relationship of Transcontinental Traverse to FGCC Test Network

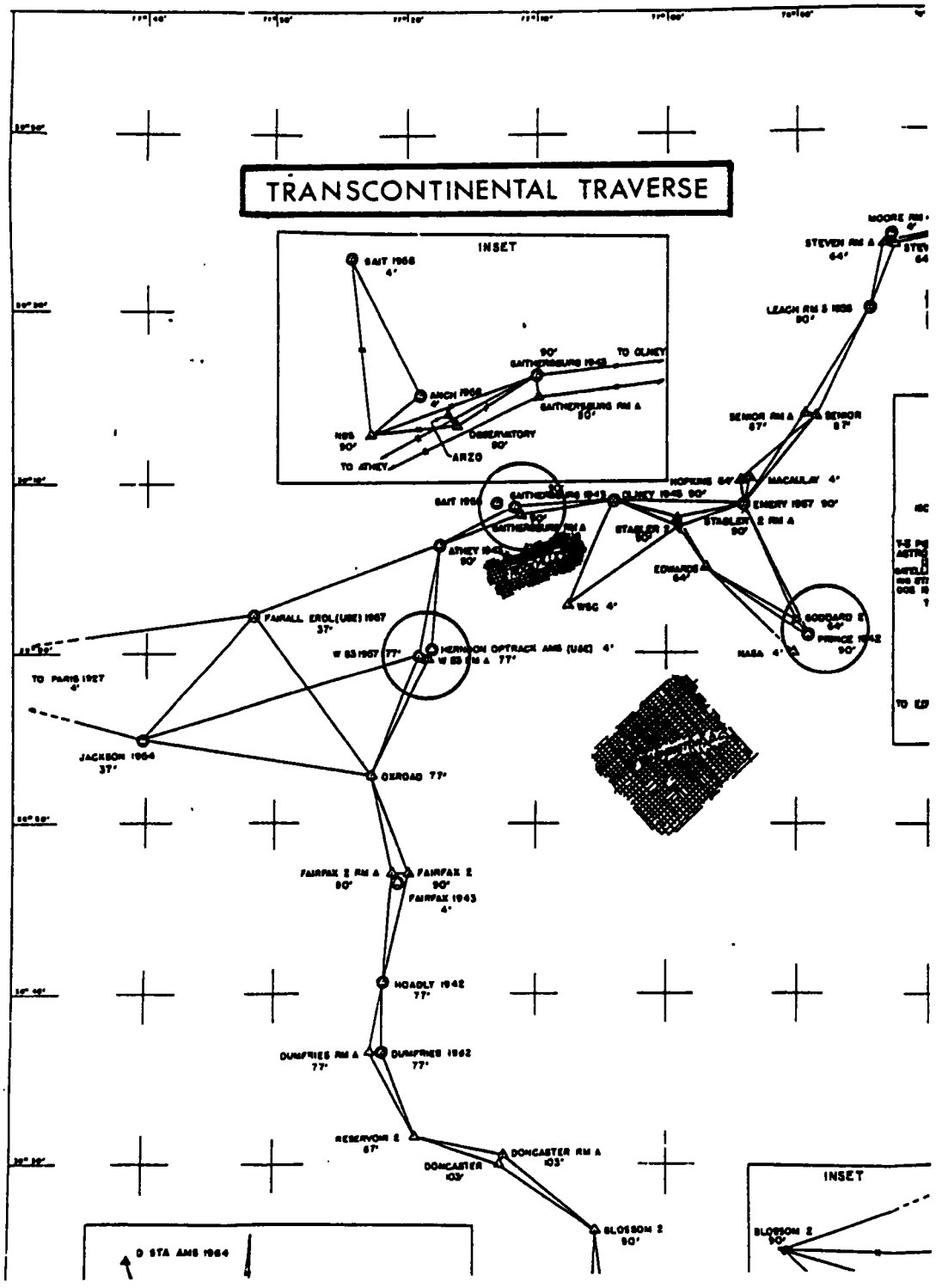


Figure 3 - Period of Occupation, FGCC Doppler Receiver Test

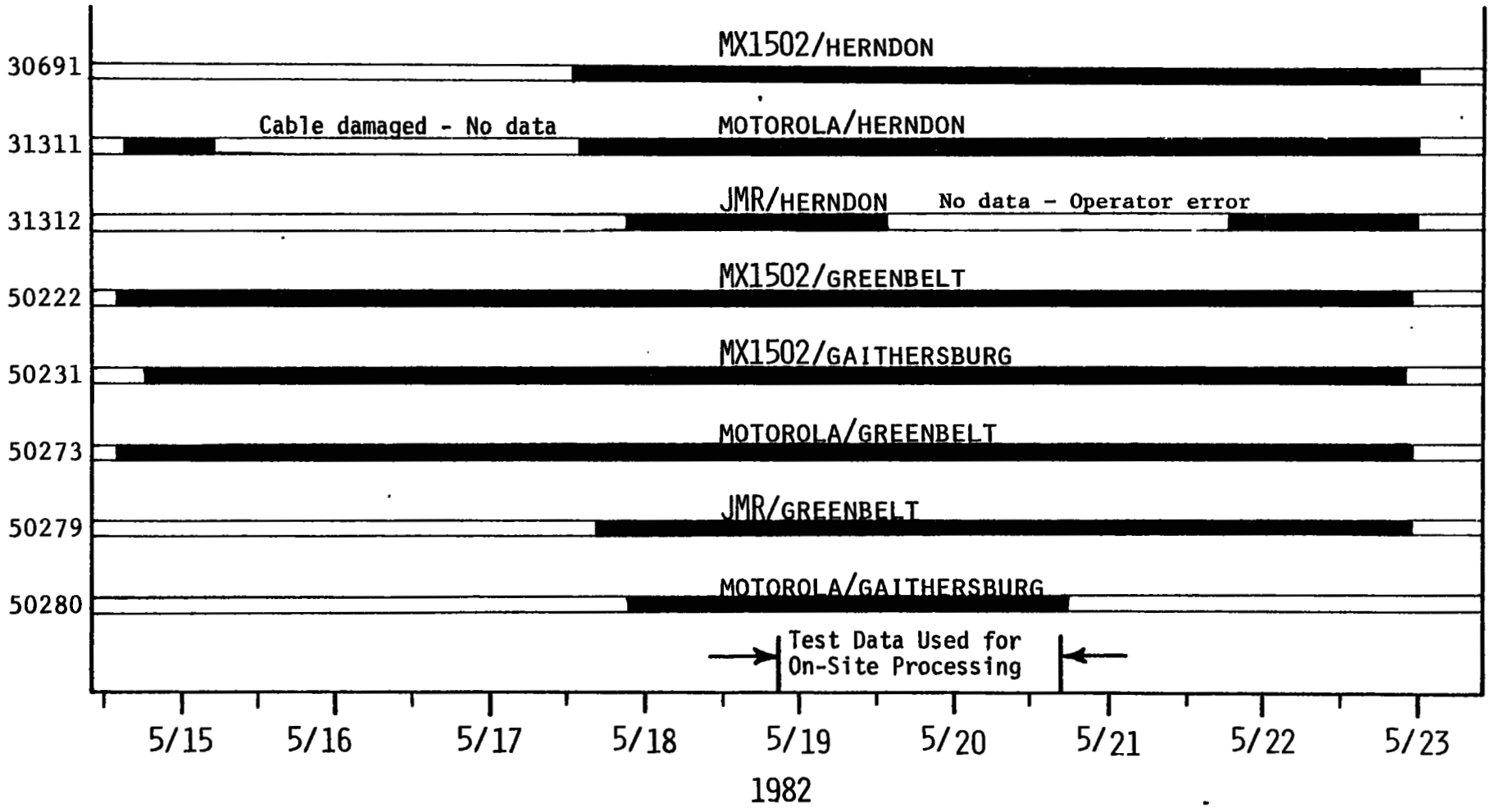


Table 1. -- Station occupation information

Station Number	Station Name	Location	Doppler Receiver			Antenna Height (m)
			Make	Model	Serial Number	
30691	30691 1979	Herndon, Va.	Magnavox	MX1502	213	1.457
31311	31311 1980	Herndon, Va.	Motorola	Mini-Ranger	10	1.092
31312	31312 1980	Herndon, Va.	JMR	JMR-1B	75-063	0.567
50231	OBSERVATORY 1966 NO. 1 1980	Gaithersburg, Md.	Magnavox	MX1502	40	5.76
50280	OBSERVATORY 1966 (TEMP. # 1)	Gaithersburg, Md.	Motorola	Mini-Ranger	9	0.995
50222	NORTH GEOS (GSFC) GORF	Greenbelt, Md.	Magnavox	MX1502	85	1.443
50273	MOBILE LASER STATION 7101	Greenbelt, Md.	Motorola	Mini-Ranger	7	1.085
50279	MOBILE LASER STATION 7102	Greenbelt, Md.	JMR	JMR-1B	75-069	0.541

Table 2. -- Possible two-station combinations for Mini-Ranger on-site processing.

Slave Stations	Master Stations							
	Motorola Stations			Magnavox Stations			JMR Stations	
	50273	31311	50280	50222	30691	50231	50279	31312
50273	-	X	XM	X	X	X		
31311		-						
50280			-					
50222	X	X	X	-	X	X		
30691			M		-			
50231						-		
50279							-	
31312								-

Notations: "X" denotes two-station combinations that were processed.
"M" denotes multi-master combination that was processed. (Master stations - 30691 and 50273; Slave station - 50280)

Table 3. -- Mini-Ranger on-site two-station solutions

Station	lat/Long (Deg-Min)	Passes/ Observations	Latitude (sec)	Longitude (sec)	Height (m)	Remarks
a) Master station: 50273, Greenbelt, Motorola Data						
50273 (Master)	N 39 01 W 76 49	26/420	16.095	18.107	40.81	(1)
31311	N 38 59 W 77 18	14/251	43.800	49.309	114.30	
50280	N 39 08 W 77 11	26/456	11.558	56.212	153.06	
50222	N 39 01 W 76 49	9/177	15.345	40.073	52.42	
50222	N 39 01 W 76 49	26/494	15.333	40.041	52.13	
30691	N 38 59 W 77 18	26/515	43.252	49.014	114.66	
50231	N 39 08 W 77 11	25/483	11.526	55.893	158.18	
b) Master station: 50222, Greenbelt, MX1502 Data						
50222 (Master)	N 39 01 W 76 49	30/560	15.345	40.073	52.42	(2)
31311	N 38 59 W 77 18	30/477	43.811	49.340	114.88	
50280	N 39 08 W 77 11	27/409	11.568	56.272	153.63	
30691	N 38 59 W 77 18	11/211	43.261	49.039	114.52	
50231	N 39 08 W 77 11	28/529	11.544	55.911	158.34	
50273	N 39 01 W 76 49	26/420	16.108	18.157	41.39	

Remarks: (1) Master station coordinates initialized to the NAD 1927 TCT MR-1982 adjustment values. (2) Master station coordinates initialized to values determined for 9-pass solution in part a, table 3, station 50222.

TABLE 4. -- SUMMARY OF POINT POSITIONING RESULTS
DATE: 10/25/82

STAT NUM	SOL CODE	SAT #	PERIOD (DAY NO) FM	TO YR	PASSES USED/IN		OBSERVATIONS USED/IN		%R	OBS RMS (M)	GEOCENTRIC COORDINATES X (M)	Y (M)	Z (M)	GEODETIC COORDINATES (WGS-66) LAT(N) D	M	S	LONG(E) D	M	S	HEIGHT (M)
30691	3004	**	137-142/82		93/	97	2193/	2344	6	.11	1090110.08	-4842536.17	3991966.86	38	59	43.2202	282	41	11.2501	75.49
30691	3094	**	137-142/82		92/	96	2152/	2349	8	.10	1090110.00	-4842536.12	3991966.70	38	59	43.2175	282	41	11.2473	75.33
31311	3004	**	137-142/82		100/	106	2191/	2333	6	.15	1090100.11	-4842527.53	3991980.30	38	59	43.7756	282	41	10.9247	75.69
31312	2004	**	137-142/82		64/	67	1373/	1484	7	.11	1090097.80	-4842521.18	3991988.40	38	59	44.1165	282	41	10.8890	75.58
50222	5004	**	134-142/82		150/	151	3494/	3646	4	.12	1130713.58	-4831331.88	3994134.26	39	1	15.2929	283	10	20.2343	13.65
50222	5094	**	134-142/82		146/	149	3399/	3597	6	.12	1130713.56	-4831331.90	3994134.20	39	1	15.2911	283	10	20.2333	13.62
50273	1004	**	134-142/82		130/	137	2884/	3018	4	.15	1131222.46	-4831188.36	3994145.58	39	1	16.0631	283	10	42.1915	2.32
50279	1004	**	137-142/82		106/	115	1868/	2350	21	.20	1130669.76	-4831362.30	3994109.03	39	1	14.2564	283	10	18.1725	13.02
50231	3004	**	134-142/82		138/	140	3150/	3322	5	.12	1097625.18	-4830740.31	4004161.60	39	8	11.4910	282	48	4.3814	114.97
50231	3094	**	134-142/82		138/	140	3145/	3336	6	.12	1097625.19	-4830740.21	4004161.49	39	8	11.4902	282	48	4.3827	114.82
50280	1004	**	137-140/82		44/	47	832/	949	12	.19	1097616.75	-4830741.15	4004162.64	39	8	11.5387	282	48	4.0313	114.81

REMARKS: WGS-66 ELLIPSOID CONSTANTS: A= 6378145.0 M., F= 1/298.25
** - COORDINATES DETERMINED FROM OBSERVATIONS ON ALL SATELLITES, INCLUDING 59, 60, 68, 77 AND 105.
DOPPLER COORDINATES DERIVED WITH PROGRAM 'DOPPLR' USING THE PRECISE EPHEMERIDES.
STATIONS 30691/3004, 50222/5004, AND 50231/3004 WERE REDUCED WITH VERSION NGS-03 BY THE NATIONAL GEODETIC SURVEY. THE REMAINING STATION COORDINATES WERE COMPUTED WITH VERSION DOPL79 BY THE DEFENSE MAPPING AGENCY HYDROGRAPHIC/TOPOGRAPHIC CENTER. BOTH VERSIONS INCORPORATE A 5 DEGREE CUTOFF AND 10% TROPO SCALE BIAS PARAMETER. COORDINATES ARE REFERRED TO STATION MARK.

Table 5. -- Coordinate differences for on-site Mini-Ranger processed data

Solution Number	Master	Slave	Passes	Obser.	Solution Differences (Doppler minus Terrestrial) North (cm)	East (cm)	Up (cm)
	(Two-station solutions)						
1	50273	50280	26	456	-42	-94	15
2	50273	50222	9	177	-36	38	86
3	50273	50222	26	494	36	-38	57
4	50273	30691	26	515	6	91	76
5	50273	50231	25	483	12	43	62
6	50222	31311	30	477	-57	22	7
7	50222	50280	27	409	-84	12	-44
8	50222	30691	11	211	-39	113	24
9	50222	50231	28	529	- 6	48	- 8
10	50222	50273	26	420	-33	82	-27
	(Multi-master solution)						
11	50273 30691	50280	12	215	- 6	-22	2

These data were presented at the FGCC meeting on May 25, 1982.

Table 6. -- Base line differences for on-site Mini-Ranger processed data

From	To	Base line Length Doppler (m)	Terrestrial (m)	Baseline Differences (cm)
50231	50222	34580.25	34579.54	71 (68)
50231	30691	18556.16	18555.75	41 (39)
50222	30691	42177.77	42176.43	134 (0)
50280	50273	35069.22	35070.20	-98 (-99)
50280	31311	18542.32	18542.03	29 (28)
50273	31311	42711.72	42711.83	-11 (-12)

Remarks: (1) The number of passes in each doppler solution ranged from 11 to 30. (2) Because of a major error in the terrestrial value for 50222-30691 baseline and minor corrections to other baselines, the baseline differences are different from values presented at the FGCC meeting on May 25, 1982. The values given in parentheses were presented at the FGCC meeting.

TABLE 7. -- SUMMARY OF DATUM SHIFTS
DATE: 09/30/82

STATION NUMBER	SOL CODE	STATION LOCATION CITY OF TOWN	COUNTRY	STATE	LATITUDE(N) D M S	LONGITUDE(W) D M S	DATUM SHIFT (LOCAL- NSWC 9Z-2) DX (M)	DY (M)	DZ (M)
30691	3094	HERNDON	US	VA	38 59 43	77 18 49	27.49	-146.57	-176.58
31311	3004	HERNDON	US	VA	38 59 44	77 18 49	27.11	-146.70	-176.53
31312	2004	HERNDON	US	VA	38 59 44	77 18 49	27.70	-146.99	-176.82
50222	5094	GREENBELT	US	MD	39 1 15	76 49 40	27.06	-146.31	-177.06
50273	1004	GREENBELT	US	MD	39 1 16	76 49 18	27.04	-146.99	-176.43
50279	1004	GREENBELT	US	MD	39 1 14	76 49 42	26.05	-146.34	-177.43
50231	3094	GAITHERSBURG	US	MD	39 8 12	77 11 56	27.00	-146.75	-176.86
50280	1004	GAITHERSBURG	US	MD	39 8 12	77 11 56	26.49	-147.18	-176.55
		(PART 1) MEAN DATUM SHIFT					26.99	-146.73	-176.78
		(PART 1) STANDARD DEVIATION OF MEAN					.52	.31	.34

REMARKS: DOPPLER COORDINATES COMPUTED WITH PROGRAM 'DOPPLR', VERSION DOPL79, 5 DEGREE CUTOFF, AND 10% TROPOSPHERIC SCALE BIAS; LOCAL COORDINATES: MEADES RANCH 1982 ADJUSTMENT (SPECIAL ADJUSTMENT OF TRANSCONTINENTAL TRAVERSE WHERE THE NAD 1927 GEODETIC POSITION FOR MEADES RANCH 1891 WAS HELD FIXED); REFERENCE ELLIPSOID: CLARKE 1866.

		(PART 2) MEAN DATUM SHIFT					27.23	-146.72	-176.71
		(PART 2) STANDARD DEVIATION OF MEAN					.29	.26	.24

REMARKS: STATIONS 50279 AND 50280 DELETED FROM GROUP.

		(PART 3) MEAN DATUM SHIFT					27.19	-146.54	-176.83
		(PART 3) STANDARD DEVIATION OF MEAN					.27	.22	.24

REMARKS: MEAN AND RMS OF MEAN DETERMINED FROM SHIFTS FOR THE THREE MAGNAVOX MX1502 DATA SETS (30691, 50222 AND 50231)

TABLE 8. -- COMPARISON OF TRANSFORMED DOPPLER POINT POSITION AND LOCAL DATUM COORDINATES
DATE: 10/25/82

STATION NUMBER	SOL CODE	STATION LOCATION LATITUDE DIR	D	M	S	LONGITUDE DIR	D	M	S	COORDINATE DIFFERENCES (LOCAL - DOPPLER) LATITUDE (SEC)	LATITUDE (CM)	LONGITUDE (SEC)	LONGITUDE (CM)	HEIGHT (CM)
30691	3094	N	38	59	43	W	77	18	49	.0052	16	-.0121	-29	1
31311	3004	N	38	59	44	W	77	18	49	.0055	17	.0047	11	7
31312	2004	N	38	59	44	W	77	18	49	-.0102	-31	-.0165	-40	22
50222	5094	N	39	1	15	W	76	49	40	.0000	0	.0029	7	-56
50273	1004	N	39	1	16	W	76	49	18	.0027	8	.0104	25	34
50279	1004	N	39	1	14	W	76	49	42	-.0051	-16	.0441	106	-95
50231	3094	N	39	8	12	W	77	11	56	-.0032	-10	.0095	23	-11
50280	1004	N	39	8	12	W	77	11	56	-.0017	-5	.0341	82	32
		ARITHMETIC MEAN (N = 8)								-.0008	-3	.0096	23	-8
		STANDARD DEVIATION (RMS)								.0054	17	.0207	50	45
	(PART 1)	SPREAD								.0157	48	.0606	146	130
		MAXIMUM								.0055	17	.0441	106	34
		MINIMUM								-.0102	-31	-.0165	-40	-95

REMARKS: DX= 27.23, DY=-146.72, DZ=-176.71, RX= .00, RY= .00, RZ= .00, K= .00PPM
DOPPLER COORDINATES: DERIVED WITH PROGRAM 'DOPPLR', VERSION - DOPL79. SHIFT DETERMINED FROM MEAN SHIFT FOR STATIONS 50231, 50222, 30691, 31311, 31312, AND 50273 (SEE TABLE 7, PART 2). LOCAL COORDINATES: NAD-1927 DATUM (MR-1982 SPECIAL TCT ADJUSTMENT).

	ARITHMETIC MEAN (N = 6)	.0000	0	-.0002	0	0
	STANDARD DEVIATION (RMS)	.0060	18	.0114	27	31
(PART 2)	SPREAD	.0157	48	.0269	65	90
	MAXIMUM	.0055	17	.0104	25	34
	MINIMUM	-.0102	-31	-.0165	-40	-56

REMARKS: STATIONS 50279 AND 50280 DELETED FROM GROUP.

	ARITHMETIC MEAN (N = 5)	.0020	6	.0031	7	-5
	STANDARD DEVIATION (RMS)	.0037	11	.0091	22	33
(PART 3)	SPREAD	.0087	27	.0225	54	90
	MAXIMUM	.0055	17	.0104	25	34
	MINIMUM	-.0032	-10	-.0121	-29	-56

REMARKS: STATIONS 50279, 50280 AND 31312 WERE DELETED FROM GROUP.

Table 9. -- Comparison of base line lengths for point position data

Stations From	Stations To	Base line Lengths Doppler (m)	Base line Lengths Terrestrial (m)	Differences (Doppler minus Terrestrial) (cm)
30691	31311	18.88	19.06	-18
"	31312	29.03	28.55	48
"	50222	42176.79	42176.42	37
"	50273	42705.43	42704.88	55
"	50279	42125.27	42123.89	138
"	50231	18556.25	18555.75	50
"	50280	18552.99	18552.22	77
31311	31312	10.55	10.03	52
"	50222	42183.33	42183.36	- 3
"	50273	42711.98	42711.83	15
"	50279	42131.82	42130.85	97
"	50231	18545.87	18545.57	30
"	50280	18542.60	18542.03	57
31312	50222	42183.46	42183.02	44
"	50273	42712.10	41711.49	61
"	50279	42131.95	42130.51	144
"	50231	18537.45	18537.29	16
"	50280	18534.18	18533.75	43
50222	50273	528.88	528.68	20
"	50279	58.96	59.88	-92
"	50231	34579.43	34579.54	-11
"	50280	34587.82	34588.50	-68
50273	50279	580.58	581.38	-80
"	50231	35061.32	35061.23	9
"	50280	35069.72	35070.20	-48
50279	50231	34545.37	34544.62	75
"	50280	34553.76	34553.58	18
50231	50280	8.57	9.17	-60

	(Part 1)	(Part 2)	(Part 3)
Arithmetic Mean	26	21	27
Standard Deviation (RMS)	58	39	25
Spread	237	145	80
Maximum	144	77	62
Minimum	- 93	- 68	- 18

Remarks: Reference Point for Comparisons: Antenna Phase Center;
Part 1: All lines. N = 28; Part 2: Station 50279 deleted. N = 21;
Part 3: Stations 50279 and 50280. N = 15

Table 10. -- Comparison of base line differences for on-site and post-processed solutions

		Base line Differences							
		(MINI-RANGER)			(MX1502)			(JMR-1B)	
From	Sol. No.	To: 50273 (cm)	31311 (cm)	50280 (cm)	50222 (cm)	30691 (cm)	50231 (cm)	50279 (cm)	31312 (cm)
31311	1	15	-						
	2	-11							
	3	-18							
50280	1	-48	57	-					
	2	-98	28						
	3	-99	28						
50222	1	20	- 3	-68	-				
	2								
	3	-38	21	-80					
30691	1	55	-18	77	37	-			
	2				134				
	3	95	-72	66	134				
50231	1	9	30	-60	-11	50	-		
	2				71	41			
	3	50	0	-88	68	39			
50279	1	-80	97	18	-92	138	75	-	
	2								
	3	-90	73	-21	-34	187	127		
31312	1	61	52	43	44	48	16	144	-
	2								
	3	111	97	32	150	59	5	202	

Remarks: Solution No. 1 - Base lines determined from point position solutions (See table 9.); Solution No. 2 - Base lines determined from on-site Mini-Ranger solutions (See table 3.); Solution No. 3 -- Base lines determined from post-processing by Motorola using Mini-Ranger, except for JMR data which were processed with main-frame version of MOS3. (Source: See Appendix B, table 6b of Motorola report)

MAY 12 1982

APPENDIX A

FGCC Federal Geodetic Control Committee

MEMBERSHIP:

Department of Agriculture

Department of Commerce

Department of Defense

Department of Energy

Department of Housing and Urban Development

Department of Interior

Department of Transportation

National Aeronautics and Space Administration

Tennessee Valley Authority

N O T I C E

DEMONSTRATION OF MOTOROLA MINI-RANGER DOPPLER SATELLITE SURVEY SYSTEM

At 9:30 a.m., Tuesday, May 25, 1982, Motorola will conduct a demonstration of the Mini-Ranger Doppler Satellite Survey System at the DMA Electronics Facility located at Herndon, Virginia.

The demonstration, hosted by the Instrumentation Subcommittee of the Federal Geodetic Control Committee (FGCC), will focus on the operation of the hardware, and the capability of the software, of the Motorola Mini-Ranger System.

Beginning on the morning of May 17, or earlier, equipment will be installed as follows: one Motorola Mini-Ranger, one Magnavox 1502, and one JMR Model 1 will be colocated at the DMA Herndon, Facility; one Motorola Mini-Ranger, and one Magnavox 1502 will be colocated at the NASA, Goddard Space Flight Center, at Beltsville, Md.; one Magnavox 1502 will be located at a station near Gaithersburg, Md. A second JMR Model 1 will be colocated at either the Beltsville or Gaithersburg sites. These sites have been used as Doppler test sites for a number of years.

It is planned to simultaneously observe, with all receivers, all available Navy Navigation Satellite passes, during the period of May 17-20, 1982. Within the time available, Motorola will attempt to reduce its own data, relative to the Broadcast Ephemeris, as well as that from other instruments, and report their results at the demonstration on May 25.

A final report will be published by the FGCC.

For additional information, you may contact:
Fred Wilson, Chairman, Instrumentation Subcommittee, FGCC
Phone: (202) 227-2213
Larry Hothem, (301) 443-8580
James McCune, (202) 227-2251

for information write:
THE CHAIRMAN
FEDERAL GEODETIC CONTROL COMMITTEE
6001 Executive Boulevard • Room 305/C1 • Rockville, Maryland 20852

APPENDIX B

FINAL REPORT

Processing and Analysis of Data Collected During the FGCC Test of the Mini-Ranger Satellite Survey System

October 21, 1982

Prepared By:

I. Newton Durboraw, III
Member Technical Staff

MOTOROLA INC.
Position Determining Systems
Government Electronics Group
Tempe, Arizona

Summary

The Instrumentation Subcommittee of the Federal Geodetic Control Committee (FGCC) conducted a field test of the Motorola Mini-Ranger Satellite Survey System during the period of 5/14/82 to 5/23/82. A part of this test included "on-site" (i.e. motel based) processing of data intended to exercise Motorola's unique capability for interfacing with existing inventories of satellite receivers. In addition, further analysis of data collected during the test period were conducted by personnel from this subcommittee. This report will deal with the processing, both on-site and off-site that was performed using the Motorola receiver/processor.

In general the test results were good and the on-site processing as well as off-site processing performed using the Motorola receiver/processor demonstrated a sub-meter accuracy capability for processing either Motorola or Magnavox data using resident software in the Mini-Ranger System. Although a malfunction of the JMR Reader prevented JMR data from being processed on-site as planned, a total of 10 2-station translocation solutions, as well as one multi-master solution, computed on the Mini-Ranger and based on various combinations of Motorola and Magnavox data sets were reported by Motorola at the conclusion of their on-site processing activities on 5/24/82. A representative from the FGCC Subcommittee compared the on-site Motorola survey results with precisely established terrestrial survey coordinates and summarized the comparison for an open presentation held at the Defense Mapping Agency Topographic/Hydrographic Center, Herndon Laboratory, on May 25, 1982.

Subsequent processing and analysis efforts by Motorola were conducted at the Motorola facility in Tempe, Arizona and the JMR reader problem was corrected to permit processing of the JMR data. Additional multi-master processing solutions as well as 2-station solutions were performed and the accuracy achieved was generally consistent with the level of quality indicated by the on-site processing activity noted above.

An exception to this accuracy level was caused by relative receiver delay when data collected from the JMR "1B" receivers was interfaced with data from either Magnavox or Motorola receivers. Detailed analysis indicated a "relative-time recovery" error that was related to certain hardware features specific to the JMR 1B receivers used for this test. An additional factor is attributed to a prior misunderstanding in the interpretation of the JMR satellite time recovery process. After correctly reckoning with these factors, good results were obtained with accuracy that appears to be consistent with the sub-meter levels obtained with other translocation combinations.

On-Site Procedure Used

A total of 8 receivers including 3 Magnavox 1502's, 3 Motorola Mini-Rangers and 2 JMR -1B's, were positioned at three sites in the regions of Herndon, VA, Gaithersburg, MD and Greenbelt, MD. (Table 1) Antennas for these receivers were carefully positioned over 1st order surveyed monuments. Receivers at each of these sites were operated simultaneously for a period of 3-8 days. Except for unexpected operational problems which prevented some data collection during the early period of site occupation, all receivers functioned without any apparent failures and data were collected and recorded on cassette tapes. A final inspection of all sites and shutdown of the receivers was completed during the evening of Saturday, May 22. All data cassettes were collected by Motorola personnel and taken along with the Mini-Ranger Receivers to a local motel room. At this point, the three Motorola receivers were set up with printer-terminals so that hard copy documentation of post processing would be available.

Except for some preliminary steps to review the data collected, actual post processing efforts were initiated on Sunday morning, May 23. In view of the limited time available to process a very large amount of data available, it was decided to limit post processing to a selected set of data collected over a period of approximatatey 39 hours, where a maximum number of common passes was likely and where all receivers were assumed to have been stabilized. This period included 31 passes with predicted elevation angles greater than 15 degrees. For demonstration of Motorola's feature that permits mixing of different data sets, all combinations of processing were considered for application of simple 2-station translocation. In addition, various combinations were also considered for exercising Motorola's unique multi-master processing feature. However, recognizing that time for completion of processing was limited, it was planned to process only those 2-station combinations indicated by X's in the receiver-site combination matrix illustrated in Table 2.

Several procedures were implemented to assist in keeping track of processing activities and were especially important with the use of multiple processors for parallel (simultaneous) reduction of data. Abbreviated notation was adopted for identification of both the site and the receiver manufacturer. By using the second letter of the site name and manufacturer (except for JMR) an easily recognized code for each data set was

defined. Each processor was identified with a tape label indicating the current processing activity on that processor. For example, "RO Master Processing" or "RA/RO" to denote that data set RA is being processed with RO as a master site. Other procedures included the use of manila folders to store hard copy result documentation for each of the sites, as well as the use of forms to record the results from each trans-location effort and a log for each of the receiver/processors. A helpful chart for guiding the processing was a detailed chart showing the overlapping passes for each of the data sets. This chart, prepared using the Mini-Ranger printed alert feature, was particularly important (and, well worth the time required to define it) for troubleshooting when anomalous behavior was observed on a data set. In addition, this chart was very useful for guiding the initialization of both master and slave station processing and in properly handling multiple tapes for a single data set. Without careful attention to overlap periods it is easy to initialize a master processing or slave processing activity for an incorrect period. Such operational errors accounted for some reprocessing of data and loss of machine time that could have been used to process more combinations of data.

Despite extensive efforts to operate a JMR cassette reader with the Motorola Processor, a failure of the reader prevented the on-site processing of JMR data. Except for combinations that included this data, all objectives for processing 2-station combinations of data were met. A preliminary 2-master station solution was also included as evidence of the Multi-Master Station processing capability. Coordinates of each of the slave stations were initially determined by simple 2-station translocation using the Motorola data set at Greenbelt as a master station data set. This procedure involves "loading" the internal master station table by processing the master station data and then processing data from each of the slave stations. A local datum shift, defined at the master station was then applied to all slave station coordinates to compare with coordinates referenced to the North America Datum (NAD) provided by FGCC. A similar procedure was used with the Magnavox data set used as a master station. In this case, since the published coordinates for the Magnavox Receiver (RA) had not been given, the coordinates that had been determined for a preliminary 9 pass solution (not shown in Table 3a) were assumed for RA. Data from Table 3a and 3b were provided to the FGCC committee on Monday evening (May 24th) for final comparison with terrestrial survey coordinates.

Reporting of On Site Processed Results

Prior to reporting the results shown in Table 3a and b to the FGCC, "known" coordinates for 3 sites had been provided to Motorola. These coordinates were based on precise terrestrial measurements on the transcontinental traverse as well as Doppler observations using the precise ephemeris. The three sites included site "RO", used as a master for results shown in Table 3a, and two sites at Herndon (EA and EO) that were planned to be used as second master sites. The coordinates for the two Herndon sites were made available for exercising the multi-master station processing capability. However, since the multi-station processing efforts were initiated prior to receipt of these coordinates, the published coordinates were not used in the processing involved for the presentation on 5/25/82. For the multi-master station solution, the second master site (EA) processing was initialized (i.e. constrained) to the 2 station solution obtained with the Herndon site (EA) used as a slave to the master at Greenbelt (RO). In effect, the solution for Herndon (EA) was permitted to "Float" relative to Greenbelt (RO).

Final comparisons between 2-station solutions as well as the multi-master station solution and the coordinates that had been previously established for the stations were performed by the FGCC and are presented in their report. In these results differences were consistently in the sub-meter range when 12 or more passes are processed. It was particularly interesting that with the multi-master processing, the solution converged to 22 cm (in the largest coordinate difference) from the terrestrial coordinates after only 12 passes.

The Kalman filter based MOS processing appears to provide excellent convergence of solutions as evidenced by a typical 2-station solution illustrated in Figure 1. In this case, the solution was within a meter of the final solution after only 6 passes.

Detailed Analysis and Further Processing Efforts at Motorola's Tempe Facility

Although results presented at DMA HTC were generally very good, it was desired to further examine solution consistency and the multi-master station potential as well as to complete the processing of JMR data sets. After the presentation of May 25, all data cassettes were copied for FGCC processing and originals taken to Motorola's facility for processing and analysis which is reported in this section.

Evaluation of the JMR reader eventually indicated that the problem was actually caused by myriad factors, among which was a connector plug that had worked loose in transit from Phoenix. In addition, several manufacturer's modifications that had not been incorporated in the reader, and a failed integrated circuit contributed to degraded performance when attempts were made to use the reader with certain of the FGCC data. A rather puzzling feature of this problem is that except for the connector plug problem, the reader seemed to function OK with JMR data sets other than those recorded by the receivers used for the FGCC test. Correction of these problems led to successful operation of the JMR reader with the FGCC data and use of the resident Mini-Ranger Receiver software for processing JMR data in conjunction with Motorola and Magnavox data collected during the test period.

Independently, efforts were applied to mainframe processing of selected data from the test. Transfer of JMR data to 9-track tapes permitted this data to be processed in combination with the Motorola and Magnavox data sets on Motorola's Honeywell 560 exercising the mainframe version of MOS-3 (Motorola Optimal Statistical Survey Software) software. This software is a more advanced version of the software resident in the receiver and allows for detailed analysis and review of intermediate as well as final results.

A detailed investigation of the interfaces between master and slave data sets indicated that a small but significant timing error existed in previous software for interpreting recovered satellite time from JMR data collected by the FGCC JMR 1B receivers. This error accounted for a small contribution to translocation position error when JMR data were used in conjunction with either Magnavox or Motorola data in a Master/Slave combination. Upon elimination of this error, performance for these combinations was generally at the sub-meter accuracy level, consistent with results from processing other combinations of data. It is significant that the receiver clock for the FGCC JMR receivers is not reset to zero for each pass but rather is allowed to run with the receiver LO for the entire occupation period.

Relative receiver delay was determined between receivers at Greenbelt by noting the differnece between translocated solutions at Greenbelt when only North or South passes are processed. While the relative time delay between the Motorola and Magnavox data set was found to be very small (less than 20 microseconds) the relative time delay between each of these data sets and the JMR data set was significant and determined to be approximately 500 microseconds. This observation was later confirmed by FGCC processing efforts using the precise ephemeris.

Final results of all Motorola processing efforts were reduced to a solution difference form using known coordinates provided by the FGCC and combined into Tables 3, 9, and 5. Two station solutions reported in Table 3 include data from on site as well as new solutions obtained by Motorola during their subsequent analysis and processing. The results are generally consistent except for the cases involving JMR data processed (in translocation) with Magnavox or Motorola datas used as a master. As mentioned above, anomalous results for these cases was found to be attributed to a feature of the receiver bit clock mechanization specific to the FGCC receivers as well as a prior misinterpretation of the JMR bit-clock mechanization. However, as indicated by mainframe solutions 4, 9, 16, and 17, precision performance was obtained using JMR data in combinations with both Magnavox and Motorola data. Furthermore, even with the current receiver software, the effects of the time recovery error can be minimized by processing balanced data sets.

Extensive use was made of the Multi-Master Station processing with various combinations of data to obtain an understanding of its performance characteristics. However, in view of the proximity (20-40 km) all of all stations, it is not surprising that a dramatic improvement was not apparent on using this feature with this data. In order for the Motorola multi-master processing capability to be most beneficial, the two master stations should be separated in an East-West direction by distance that is at least an appreciable fraction of the Satellite orbital altitude (i.e. 100-200 km). This test, involving separations of only 40 km could only provide a limited indication of the benefit of the second master. Rather than improving the slave station position through better geometry definition of the satelite orbit, the primary improvement is from redundant observations which tend to bridge any gaps in data from either receiver. However, the major benefit of this feature is expected for large scale survey projects which span distances over 100 KM. In this case, improvement is evident from geometrical factors as well as data redundancy.

Scanning the solutions comparisions of Table 4, which were all obtained using the receiver processor, it is apparent that JMR processing is degraded by the problem of time recovery as noted earlier in discussion of 2 station solutions. However, with the larger number of passes of solutions 26 and 28, the effect of this problem is minimized and errors are reduced to the 1.5 meter level. Data from all three receiver types were successfully integrated in solutions 25, 26, 27, 28, and 29.

Solution consistency for small data sets was examined briefly by considering the data set used for defining solution #11, reported in Table 3b. By splitting the 27 passes first in half, and then in 3, a set of independent solutions were obtained as illustrated in Table 5.

A baseline comparison matrix was also established for evalution of certain of the solutions reported in Tables 3 and 9. Baselines computed between various solutions were compared with terrestrially determined baselines and summarized in Tables 6a, b, and 7. In each of these tables, the solution #5 used for the comparison are identified in the vertical and horizontal axis. Differences of computed baselines between other solutions as well as between the slave and master are also included. Of course, the primary comparisons of interest are those for each of the solutions with respect to the master station. For convenience, these comparisons are aligned along the left-most column of each table. The improvement of baseline comparisons involving JMR solutions when mainframe processing is exercised is evident in Table 6b, not only in the primary baseline directions between master and slave but also in directions of other stations not used in the solutins. Note that Table 7, showing computed baseline comparisons for Magnavox master solutions, includes multi-master solutions 26 and 29 for the JMR solutions. Completion of 2-station JMR solutions with RA used as a master was inadvertently omitted in the overall Motorola data processing effort and thus the multimaster station solutions were substituted to complete the table.

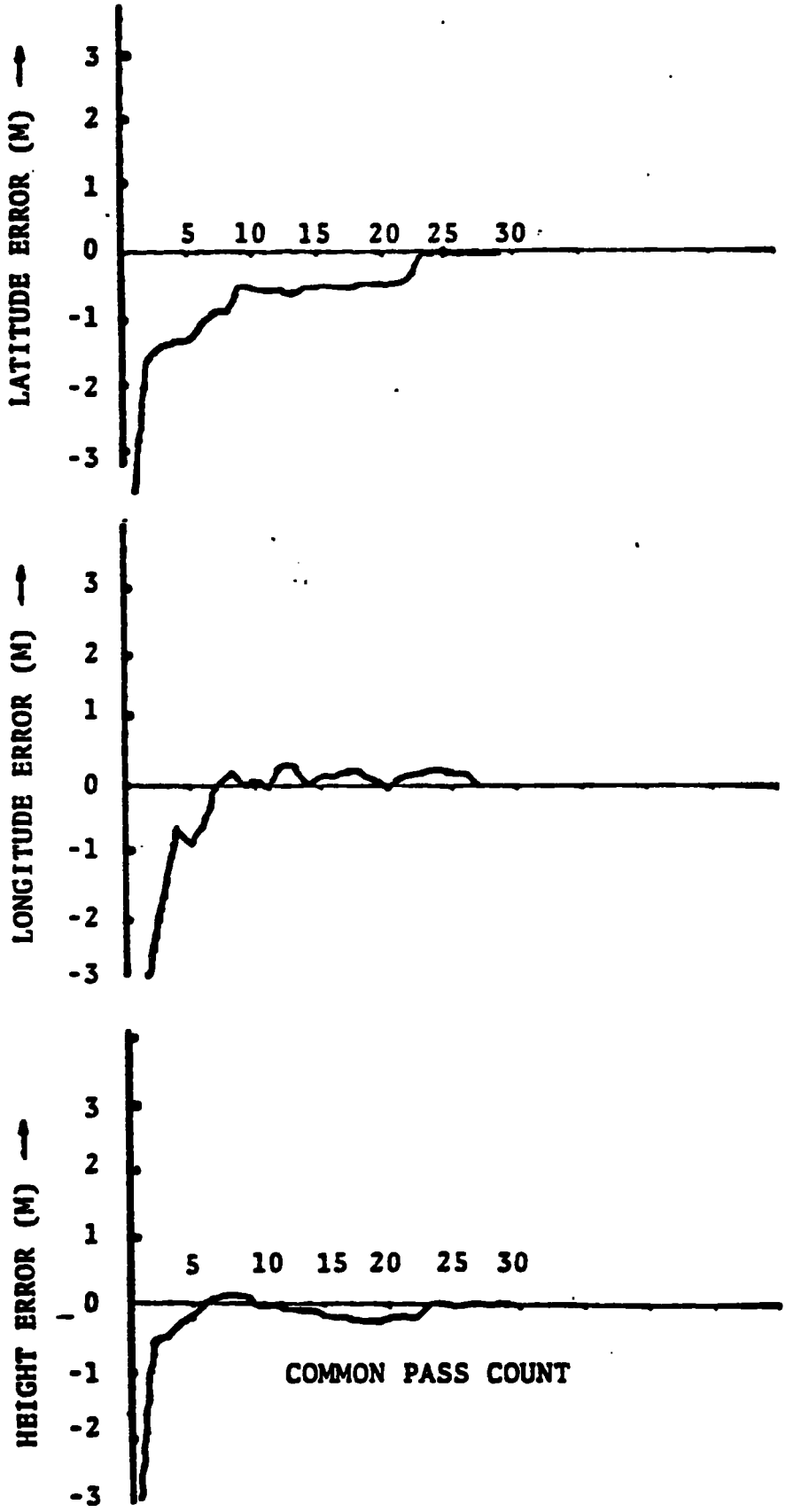
Conclusion

The results of evaluation of the data collected during the FGCC test of May 14 - May 23, 1982 indicate that the Motorola Mini-Ranger Satellite Survey System is capable of collecting and processing transit satellite data to produce a high quality (=50 cm) position in translocation over distances of 20-40 km using receiver resident software. The powerful unified processing capabilities of this receiver permit a user to interface receivers of three different manufacturers (Magnavox, JMR and Motorola) in a mixed inventory and retain a high quality of processing.

Mainframe software was also exercised and was valuable as a tool for detailed analysis for anomalous performance such as found in the case of interfacing with the FGCC JMR receivers.

The multi-master station processing capabilty was exercised for several combinations of data and improvement was found in many cases. This improvement was particularly evident in this test when combinations of Motorola and Magnavox data were used. In two cases shown here (#22 and #24) the largest coordinate difference was reduced to under 25 cm when only 13 or more common passes were used in solution.

Field processing performance when interfacing with the FGCC JMR receivers was somewhat degraded due to the fact that the current Mini-Ranger receiver software did not reckon with certain unique features of these receiver's bit clock. However, Motorola's mainframe processing program could be easily modified to correctly accommodate these features. Execellent results were then obtained for JMR receiver data interfaced with Motorola data. A relatively simple modifications of receiver software is anticipated for emulating the mainframe quality of performance achieved in this demonstration.



DATA USED FOR MOS[3] PROCESSING:

MASTER-51273 (GREENBLT) MOTOROLA

SLAVE -53231 (GAITHSBG) MAGNAVOX

FIGURE 1. Translocation Convergence For On-Site Processing of DMA Demo Data

TABLE 1

SURVEY STATIONS OPERATED DURING
FGCC DOPPLER RECEIVER TEST
May 14 through May 24, 1982

MOTOROLA IDENT CODE	STATION NUMBER	STATION NAME	LOCATION	DOPPLER RECEIVER MAKE	DOPPLER RECEIVER MODEL	DOPPLER RECEIVER S/N	ANTENNA HEIGHT (M)
EA	30691	30691 1979	Herndon, VA	Magnavox	MX1502	213	1.457
EO	31311	31311 1980	Herndon, VA	Motorola	Mini-Ranger	10	1.092
EJ	31312	31312 1980	Herndon, VA	JMR	JMR-1B	75-063	0.567
RA	55222	NORTH GEOS (GSFC) GORF	Greenbelt, MD	Magnavox	MX1502	85	1.443
AA	53231	OBSERVATORY 1966 NO. 1 1980	Gaithersburg, MD	Magnavox	MX1502	40	5.76
RO	51273	MOBILE LASER STATION 7101	Greenbelt, MD	Motorola	Mini-Ranger	7	1.085
RJ	51279	MOBILE LASER STATION 7102	Greenbelt, MD	JMR	JMR-1B	75-069	0.541
AO	51280	OBSERVATORY 1966 (TEMP. # 1)	Gaithersburg, MD	Motorola	Mini-Ranger	9	0.995

TABLE 2. 2-Station Combinations For Demonstrations of "Mixed Data Processing"

MASTER SITES \ SLAVE SITES	MOTOROLA STATIONS			MAGNAVOX STATIONS			JMR STATIONS	
	RO 273	EO 311	AO 280	RA 222	EA 691	AA 231	RJ 279	EJ 312
RO-273	-	X	X	X	X	X		
EO-311		-						
AO-280			-					
RA-222	X	X	X	-	X	X		
EA-691					-			
AA-231						-		
RJ-279							-	
EJ-312								-

X Denotes combination processed for DMA presentation

SOLUTION FILE #	SOLUTION ID	START TIME	STOP TIME	# COMMON PASSES	# DOPP OBS	SOLUTION DIFFERENCES (CM) NORTH	EAST	UP
1	EA/RO	139:0250	140:1717	26	515	6	91	76
2	EO/RO	139:0250	140:1718	26	462	-24	19	42
3	EJ/RO	138:0934	139:1318	19	344	150	21	33
4	*EJ/RO	139:0324	139:1150	8	132	48	110	-16
5	AA/RO	139:0250	140:1717	25	483	12	43	62
6	AO/RO	139:0250	140:1717	27	409	-42	-94	-15
7	RA/RO	139:0250	139:1318	9	177	-36	38	86
7A	RA/RO	139:0250	140:1717	26	494	-36	-38	-57
8	RJ/RO	138:0934	139:1318	12	224	291	156	30
9	*RJ/RO	139:0252	140:1718	24	363	-57	86	125
10	RJ/EO	139:0656	140:1534	17	279	174	189	-16
10A	AA/EO	139:0252	140:1532	24	457	39	28	11

a) Using Motorola Data For Master Station

11	EA/RA	139:0252	140:1718	27	528	- 9	-61	-15
11A	EA/RA	139:0252	139:1504	11	211	-39	113	24
12	EO/RA	139:0252	140:1718	30	477	-57	22	7
13	EJ/AA	141:2352	142:1912	11	167	93	291	-57
14	EJ/RA	139:0038	139:1318	9	158	123	131	151
15	EJ/RA	141:2002	142:2128	12	209	456	112	-45
16	*RJ/RA	138:0126	139:1150	20	343	3	0	94
17	*EJ/RA	141:2006	142:1244	10	165	6	93	33
18	AA/RA	139:0252	140:1718	28	529	- 6	48	- 8
19	AO/RA	139:0252	140:1718	27	409	-84	12	-44
20	RO/RA	139:0252	140:1718	26	420	-33	82	-27
20A	RO/EA	141:2234	142:2128	16	285	-15	19	13

b) Using Magnavox Data For Master Station

* Mainframe Solution

TABLE 3. Final 2-Station MOS[3] Solution Comparision With Terrestrial Coordinates

MULTIMASTER STATION SOLUTION

SOLUTION FILE #	SOLUTION ID	START TIME	STOP TIME	# COMMON PASSES	# DOPP OBS	SOLUTION DIFFERENCES (CM) NORTH	EAST	UP
22	AO/(RO+EA)	139:0252	139:1624	12	215	- 6	22	2
22	AA/(RO+EA)	139:0252	140:1718	26	498	- 3	70	53
23	AA/(RO+EA)	139:0252	139:2142	14	254	-33	72	4
24	EO/(RO+EA)	139:0252	139:1958	13	240	-12	9	11
25	EJ/(RO+EA)	139:0516	139:1318	9	104	123	310	212
26	EJ/(RO+AA)	138:0934	139:1318	22	389	153	-5	51
27	EJ/(RO+EA)	141:2352	142:2128	13	245	342	61	65
28	RJ/(EO+AA)	139:0036	140:1534	20	341	36	124	-14
29	RJ/(RO+AA)	138:0936	139:1316	15	256	156	133	20
30	RA/(RO+EA)	139:0252	140:1718	27	502	12	14	60
31	EJ/(EO+AA+RJ)	139:0252	140:1318	9	102	27	128	34

TABLE 4. Multi Master Station MOS[3] Solution Comparisons with Terrestrial Coordinates

# PASSES	# OBS	START TIME	STOP TIME	SOLUTION DIFFERENCE (CM) NORTH	EAST	VERT
9	167	139:0252	139:1146	-192	-135	-128
9	170	139:1318	140:0752	-102	- 58	100
9	156	140:0940	140:1718	- 93	135	205
18	354	139:0252	140:0752	- 42	- 65	- 31
18	344	139:1318	140:1718	21	- 47	- 21
27	528	139:0252	140:1718	- 9	- 61	- 15

TABLE 5. Partitiioned Solution Comparison With Terrestrial Coordinates

RO (MOTOROLA) MASTER #273
CALCULATED BASELINE DIFFERENCES FOR
2 STATION SOLUTIONS VS NGS TERRESTRIAL (PUBL) SURVEY

SOL #								
1	EA 691	42705.84						
	PUBL:	42704.89						
	SOL DIF:	.95						
2	EO 311	42711.66	18.34					
	PUBL:	42711.84	19.06					
	SOL DIF:	-.18	-.72					
4	EJ 312	42711.20	29.75	11.89				
	PUBL:	42711.49	28.55	10.05				
	SOL DIF:	-.29	1.20	1.84				
7A	RA 222	528.31	42177.77	42183.58	42183.13			
	PUBL:	528.69	42176.43	42183.37	42183.02			
	SOL DIF:	-.38	1.34	.21	.11			
9	RJ 279	579.50	42126.64	42132.46	42132.01	57.51		
	PUBL:	581.37	42123.90	42130.86	42130.52	59.90		
	SOL DIF:	-1.87	2.74	1.60	1.49	-2.39		
5	AA 231	35061.76	18556.16	18545.60	18535.77	34580.25	34545.51	
	PUBL:	35061.26	18555.77	18545.60	18537.31	34579.57	34544.65	
	SOL DIF:	.50	.39	.00	-1.54	.68	.86	
6	AO 280	35069.22	18552.88	18542.32	18532.49	34587.70	34552.95	9.26
	PUBL:	35070.21	18552.22	18542.04	18533.75	34588.50	34553.58	10.14
	SOL DIF:	-.99	.66	.28	-1.26	-.80	-.63	-.88
	BASELINE TO SOLUTION	RO 273 MASTER	EA 691 1	EO 311 2	EJ 312 4	RA 222 7	RJ 279 8	AA 231 5

FOR 7 PRIMARY BASELINES:

$\bar{x}$ = -32 CM

$\overline{x^2}$ = 92 CM

TABLE 6a. Baseline Comparison Matrix For Solutions With MOTOROLA Data At Master Site

- Receiver Processed Solutions Only

RO (MOTOROLA) MASTER #273
CALCULATED BASELINE DIFFERENCES FOR
2 STATION SOLUTIONS VS NGS TERRESTRIAL (PUBL) SURVEY

SOL #	BASELINE TO SOLUTION	RO 273 MASTER	EA 691 #1	EO 311 #2	EJ 312 #4	RA 222 #7	RJ 279* #8	AA 231 #5
1	EA 691	42705.84						
	PUBL:	42704.89						
	SOL DIF:	.95						
2	EO 311	42711.66	18.34					
	PUBL:	42711.84	19.06					
	SOL DIF:	-.18	-.72					
3	EJ 312	42712.60	29.14	11.02				
	PUBL:	42711.49	28.55	10.05				
	SOL DIF:	1.11	.59	.97				
7A	RA 222	528.31	42177.77	42183.58	42184.52			
	PUBL:	528.69	42176.43	42183.37	42183.02			
	SOL DIF:	-.38	1.34	.21	1.50			
8	RJ 279*	580.47	42125.77	42131.59	42132.54	59.56		
	PUBL:	581.37	42123.90	42130.86	42130.52	59.90		
	SOL DIF:	-.90	1.87	.73	2.02	-.34		
5	AA 231	35061.76	18556.16	18545.60	18537.36	34580.25	34545.92	
	PUBL:	35061.26	18555.77	18545.60	18537.31	34579.57	34544.65	
	SOL DIF:	.50	.39	.00	.05	.68	1.27	
6	AO 280	35069.22	18552.88	18542.32	18534.07	34587.70	34553.37	9.26
	PUBL:	35070.21	18552.22	18542.04	18533.75	34588.50	34553.58	10.14
	SOL DIF:	-.99	.66	.28	.32	-.80	-.21	-.88

FOR 7 PRIMARY BASELINES:
$\bar{x}$ = 2 CM
$\overline{x^2}$ = 78 CM

TABLE 6b. Baseline Comparison Matrix For Solutions with MOTOROLA Data Used At Master Site

*Mainframe Processing of JMR Solutions

RA (MAGNAVOX) MASTER #222
(MULTIMASTER RO(273)+EA(691) USED FOR JMR SOLUTIONS)

CALCULATED BASELINE DIFFERENCES:

SOL #	BASELINE TO SOLUTION	RA 222 MASTER	EA 691 #11	EO 311 #12	EJ 312 #26	RO 273 #20	RJ 279 #29	AA 231 #28
11	EA 691	42177.08						
	PUBL:	42176.43						
	SOL DIF:	.65						
12	EO 311	42183.64	18.32					
	PUBL:	42183.37	19.06					
	SOL DIF:	.27	-.74					
26	EJ 312	42182.64	29.15	11.58				
	PUBL:	42183.02	28.55	10.05				
	SOL DIF:	-.38	.60	1.53				
20	RO 273	527.88	42704.71	42711.28	42710.28			
	PUBL:	528.69	42704.89	42711.84	42711.49			
	SOL DIF:	-.81	-.18	-.56	-1.21			
29	RJ 279	58.00	42126.36	42132.93	42131.94	578.70		
	PUBL:	59.90	42123.90	42130.86	42130.52	581.37		
	SOL DIF:	-1.90	2.46	2.07	1.42	-2.67		
28	AA 231	34580.01	18555.84	18545.95	18536.10	35061.09	34546.42	
	PUBL:	34579.57	18555.77	18545.60	18537.31	35061.26	34544.65	
	SOL DIF:	.44	.07	.35	-1.21	-.17	1.77	
19	AO 280	34588.32	18551.83	18541.94	18532.08	35069.41	34554.72	9.90
	PUBL:	34588.50	18552.22	18542.04	18533.75	35070.21	34553.58	10.14
	SOL DIF:	-.18	-.39	-.10	-1.67	-.80	1.14	-.24

FOR 7 PRIMARY BASELINES:

$\bar{x}$ = -27 CM

$\overline{x^2}$ = 86 CM

TABLE 7. Baseline Comparison Matrix For Solutions With MAGNAVOX Data At Master Site