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WORMLEY, GODALMING, SURREY

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Magnavox 702 CA Satellite Navigation Receiver with N.I.O. Old Building as a known Base

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N. I. O. Internal Report No. A.39

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G O R R I G E N D A

1) In all cases the frequency unit of Doppler Shifts should be read as m/c (megacycles) not k/c (Kilocycles), as often printed.

2) The best known position for N.I.O. is :-

51°	08'	12".2	N	(51°	8'.203	N)
0°	38'	54".1	W	(0°	38'.902	W)

(Jan.1970)

3) Because of compilation difficulties, diagrams for appendices VII to XVIII have been separated from the text and are contained in a pocket on the inside of the back cover.

For symbols used for plotting see page 13.

4) On pages 15, 16, 18, 20, 22, 24 and 26, the last column headed "Radial distance from accepted position (n.m.)" should read "Mean of radial distances of individual fixes from accepted position (n.m.)".

1. Experimental position determination using a Magnavox 702CA satellite navigation receiver with N.I.O. old building as a known base.

In order to establish the accuracy of position determination by satellite navigation, prior to using the method at sea, several fixes were obtained from Navy Navigational Satellite System (N.N.S.S.) satellites, with the receiver aerial positioned on the roof of the N.I.O. old building. An accuracy of better than 0·05 nautical miles was achieved using the data available to its best advantage. The mean fix of this data, later referred to as the accepted position, was however nearly 0·1 n.m. from the N.I.O. position, at a bearing of 324°. Possible reasons for this departure are:-

1. Earlier values of the earth's radius and flattening were used, these have since been improved.

2. Discrepancies between satellite datum and ordnance datum may be significant.

This paper is more concerned with relative rather than absolute accuracy of fixes.

The position of the aerial on the old N.I.O. building, taken off a 6" O.S. map, was determined as Latitude 51° 8·174'N, Longitude 0° 38·817'W.

Satellite transits (passes) used

Pass No. (Local)	Day	Date Nov. '68	Time Z	Satellite No.	Elevation °	No. of 2 min. messages
1	314	9	1608	(30)180	50	9
2	316	11	1328	130	25	8
3			1430	180	50	9
4			1610	120	13	7
5	319	14	1356	180	34	6
6			1438	130	7	5
7	320	15	1638	180	25	8
8			1746	120	67	5
9	323	18	1122	130	86	9
10			1224	180	13	8
11			1310	130	22	7
12			1408	180	55	9
13	324	19	0848	130	9	5
14			1220	130	40	9
15			1320	180	30	9
16			1408	130	8	6
17			1506	180	66	9
18			1558	120	18	7
19	325	20	0944	130	25	7
20			1132	130	74	9
21			1234	180	16	8
22			1418	180	69	9
23			1508	120	7	5
24			1552	140	7	6
25			1608	180	28	8
26	326	21	1330	180	38	8
27			1744	120	82	5
28			1832	140	88	9
29	334	29	0938	130	37	9

2. Quality of information received

1. Of the 29 passes received, 21 had maximum elevations between 10° and 80°. Of the other 8, 5 were below 10° and 3 above 80°.

2. There were no cases where it was not possible to obtain fixed and variable parameters from the whole of the message received, although in some cases, recourse had to be made to some other 2 minute message where the data in the message referring to a particular 2 minute interval was mutilated.

3. In only 11 cases were there complete Doppler information; of the remaining 18, 10 had only one Doppler item missing, 8 had two or more. Pass No. 14 was the worst with six missing 2 minute Doppler counts, 2 at 400 k/c and 4 at 150 k/c. When the 4·6 second intermediate counts are available it is possible to build up the 2 minute count which is used for fix determination by a differencing method using judicious interpolation (see Appendix II). In the case of Pass No. 14 the fix obtained by this method was only 0·024 n.m. from the accepted position. If only 2 minute accumulations are available, as in the cases of Passes Nos. 1, 2 and 6, this differencing method cannot be used and an estimate of missing Doppler counts has been obtained by a ratio method (see Appendix II). For a further discussion of these two methods and a comparison of their effectiveness, see Appendix II.

4. Passes which were in the 10-80° elevation range and had full Doppler information totalled nine.

5. Pass No. 8, for which only 2 minute accumulations of Doppler counts were available, had both 400 k/c and 150 k/c data missing from the fifth message, as well as the sixth 400 k/c count. No reasonable estimate could be obtained for the missing data and the pass has not been used for statistical purposes.

6. See Appendix I for a summary of the above.

3. Treatment of data

Eight different combinations of data were used for calculating the various types of fixes detailed in paragraph 4.

A. Using all data, irrespective of quality.

A_1. As above, leaving out passes between Nos. 1 and 8 with missing doppler information.

B. Leaving out passes with elevation less than 10° and more than 80°, and pass No. 8.

B_1. As for B, but leaving out passes between Nos. 1 and 8 with missing doppler information.

C. Using passes with not more than one estimated doppler and elevation between 10 and 80°.

D. Using passes with no missing doppler data.

E. As for D, leaving out passes with elevation less than 10° and more than 80°.

F. For five passes (Nos. 3, 7, 15, 19 and 29) with no missing doppler data and elevations between 25 and 50°, an extended treatment was given to test what difference certain variations of the corrected doppler counts had on the final fix.

4. Types of fixes - Groups A to E (paragraph 3)

For each pass, fixes were determined using different combinations of data, viz:-

1. Using all available data, with estimated corrected doppler counts where necessary.

2. Using 400 kc. doppler counts instead of corrected doppler counts with estimates where necessary.

3. Similarly with 150 kc. counts.

4. Using the first four messages (three dopplers) received.

5. Similarly with the last four messages.

6. Using running four messages, i.e. messages 1, 2, 3, 4; 2, 3, 4, 5; and so on through the range of messages.

For Group F (paragraph 3)

7. Throwing the corrected doppler count to the nearest ten.

8. Similarly to the nearest hundred.

9. Adding five to the corrected doppler count.

10. Subtracting five from the corrected doppler count.

11. Adding a square wave (plus 5 to first half of corrected doppler counts, minus 5 from the remainder).

12. Adding plus 5 or minus 5 to corrected doppler counts at random.

13. Using running five messages; 1, 2, 3, 4, 5; 2, 3, 4, 5, 6 etc.

14. Using running six messages; 1, 2, 3, 4, 5, 6; etc.

5. Definitions

1. Corrected doppler counts refer to the vacuum count, i.e. that found after correcting for refraction.

2. Notation - A combination of the letters in paragraph 3 and the numbers in paragraph 4 (also referred to as elements) has been used to identify any particular mean, e.g. A1 refers to the mean position of Group A (para 3), type of fix 1 (para 4).

6. Results

1. The results obtained are tabulated and plotted in Appendices III and VII to XVIII. It will be seen that using all data available (App. III) gives good results, even for Groups A1, $A_1$1 and D1, the group means all being less than 0·02 nautical miles away from the accepted position. The accepted position has been taken as that obtained for Group B1, B_1 which is a refinement of this method, is very near (0·003 n.m.).

2. Using the 400 kc doppler data coarsens the final group mean considerably, the group means for A2, $A_1$2 and D2 being more than 0·1 nautical miles away from the accepted position; after filtering (removing passes with elevations outside the range 10-80°), B2, $B_1$2, C2 and E2 fine down to around 0·025 to 0·03 n.m.

3. The use of 150 kc doppler data seems unacceptable, the results obtained, even for the filtered methods, are all over 0·15 n.m. away from the accepted position. Surprisingly the farthest away is the fix obtained for Group E3, which is the group with most refinement, the radial distance being more than 0·5 n.m. from the reference point; this emphasises the unsatisfactoriness of the use of this data.

4. Using the first four messages received gives results around 0·1 n.m. away from the accepted position, although the scatter is considerable; the last four messages give much worse results, possibly because the satellite is tracked right down to the horizon, while acquisition of the signal can take place well after the satellite has risen. See also paragraph 6 and Appendices XIXa and XIXb.

* 5. The extended treatment given to Passes Nos. 3, 7, 15, 19 and 29 (Group F) shows that modification of the corrected doppler counts by plus or minus 5 makes little difference, nor does throwing it to the nearest 10. Adjustment to the nearest 100 gives results well under 0·1 n.m. from the original figure, which would be acceptable if circumstances warranted such an approximation. See Appendices IV and XIV - XVIII. Element Nos. in these appendices refer to sub paragraph numbers in paragraph 4.

6. The results obtained from using running five and six messages amplify the conclusion already arrived at concerning the running four messages, i.e. the messages nearest the centre of the doppler range give the best results. See Appendices IX, XIV - XVIII, XIXa and XIXb.

7. An analysis of all results for group means (for individual pass fixes see Appendices VIII to XIII) is shown in Appendix III. The radial distances from the accepted position and N.I.O. are for the group means, not individual passes.

8. Except for those with elevations over 80° and under 10°, an analysis of passes by elevations does not reveal anything exceptional. High elevations (more than 80°) give consistently poor results. (See Appendix V).

9. Analysis by satellite (Appendix VI) shows a striking result for Satellite (30) 180, compared with the other satellites. It is not thought that this is of any significance as the reception programme was not planned, to the extent that the receiver was only used when the computer was free from other work, it seems by coincidence that no high or low pass transits were received from Satellite 180.

7. Conclusions

1. The satellite navigation method of determination of position, using the Magnavox 702CA receiver, especially if the quality of the information received is good, gives results with an accuracy well within the claimed 0·05 nautical miles. This refers, of course, to determination of a fixed position.

2. The well established criteria for the maximum elevation to be between certain limits (e.g. 10° and 80° as in this paper) must be observed for good fixes.

3. If doppler information is missing (there was no experience of other information not being received) an acceptable estimate can be built up for the required 2 minute integration if sufficient 4·6 seconds summation is available. If only 2 minute integration is available, a reasonably accurate estimation can be obtained if the missing information is in the middle of the range of either 400 mc. or 150 mc. dopplers. If it is at either end, or if both 400 mc. and 150 mc. dopplers are missing for one message, no reasonable estimate is possible.

4. Using only 400 mc. doppler data gives reasonably acceptable fixes; the 150 mc. doppler data does not.

5. Doppler data between $3{\cdot}0 \times 10^6$ and $4{\cdot}5 \times 10^6$ gives the best fixes, using earlier or later data usually causes the accuracy to fall off. For justification of this claim, see Appendices IX, XIXa and XIXb. An equivalent criterion accepting doppler counts only when the satellite elevation is between certain limits could probably be used.

APPENDIX I - Analysis of quality of messages received

Pass No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
No. of messages	9	8	9	7	6	5	8	5	9	8	7	9	5	9	9	6	9	7	7	9	8	9	5	6	8	8	5	9	9
Elevation°, less than 10							7						9		8								7	7					
10 - 80	50	25	50	13	34		25	67		13	22	55		40	30		66	18	25	74	16	69		28	38			37
more than 80									86																		82	88	
400 dopplers - complete	7	7	8	6	5	3	7	4	8	7	4	7	4	6	8	5	7	6	6	6	7	4	4	6	5	4	7	8	
missing	1					1				2	1		2			1				1	1		1	1	2		1		
150 dopplers - complete	7	5	8	6	5	4	7	4	7	7	6	8	4	4	8	4	7	6	6	7	7	8	4	5	6	7	3	7	8
missing	1	2							1					4		1	1			1				1		1	1		
Corrected dopplers estimated by complete	6	5	8	6	5	3	7	4	7	7	4	7	4	3	8	4	6	6	6	7	6	7	4	4	5	5	3	7	8
ratio	2	2				1																							
differencing									1		2	1		5		1	2				1	1	1		1	2	2	1	1

APPENDIX II - Methods of estimating missing Doppler counts

1. There were 17 cases of missing doppler counts, 3 with 2 minute integration and 14 with 4·6 second integration.

2. For the first three cases a method of estimation by simple ratio was used. Take the case of Pass No. 1 for example; the fourth 150 kc. and fifth 400 kc. counts were missing. Dividing the fourth 400 kc. count by the 3rd and multiplying the result by the third 150 kc. count gives 4,000,149. Similarly a count of 4,431,357 is got for the missing 400 kc. count. Accepting these figures temporarily, the successive corrected differences (400 kc. minus 150 kc. x 9/55) are plotted and as smooth a curve as possible fitted; the two estimated points are then adjusted to the curve and these revised differences accepted for calculating the corrected doppler value. Figures of 4,000,004 and 4,431,357 were obtained for the estimated corrected doppler counts by this method, and using these for calculation of the pass fix gave a position of 51° 8·291'N, 0° 38·844'W, a radial distance of 0·056 nautical miles from the accepted position.

3. Where 4·6 second integration is available, the method used is simpler. Taking the fifth missing 400 kc. count for Pass No. 11 as an example; the run of 4·6 second information was as shown in col. (a) for each of the two doppler frequencies. Each succeeding 4·6 sec. count is differenced as shown under cols. $(b)_{400}$ and $(b)_{150}$ down to the 295 .... count, after which only 150 kc. differencing is possible. Note that the difference between the last two counts is approximately twice that of the others, this is caused by format considerations. If corresponding terms for $(b)_{400}$ and $(b)_{150}$ are then differenced as shown under col. (c), the sequence of numbers appears smooth enough to warrant extrapolation as shown, and once this accepted, backward building up is possible. In this connection the degree of accuracy found for Group F (see para. 6.5) justifies this method of estimation.

400 kc.		150 kc.			
Data available down to					
(a)	$(b)_{400}$	(a)	$(b)_{150}$	$(b)_{400}$ - (c)	$(b)_{150}$
2119163		2119050			
	165989		165979	10	
2285152		2285029			
	166375		166366	9	
2451527		2451395			
	166763		166755	8	
2618290		2618150			
	167131		167124	7	
2785421		2785274			
	167501		167494	7	
2952922		2952768			
	(167866)		167859	(7)	
(3120788)		3120627			
	(168227)		168220	(7)	
(3289015)		3288847			
	(168570)		168564	(6)	
(3457585)		3457411			

(3626491)	(168906)	168900	(6)
(3795735)	(169244)	169238	(6)
(3965303)	(169568)	169563	(6)
(4319229)	(353926)	353916	(10)
	3626311		
	3795549		
	3965112		
	4319028		

The bracketed figures are the estimated values from the above considerations.

4. As a test of the efficacy of these two methods, each was used to determine a position for the following passes which had missing doppler data:-

Pass No.	Missing data	Total no. of dopps.	(a) Differencing		(b) Ratio		Radial dist. (b) from (a)
			51°N	0°W	51°N	0°W	
11	5th and 6th 400	6	8·249	38·905	8·286	38·515	0·248
12	4th 400	8	8·251	38·885	8·307	38·768	0·092
17	4th 150 5th 400	8	8·251	38·968	8·256	38·950	0·012
20	5th 150	8	8·230	39·025	8·224	39·011	0·011
21	7th 400	7	8·249	38·843	9·088	39·060	0·867
22	4th 400	8	8·249	38·894	8·256	38·880	0·011
25	4th 400 7th 150	7	8·315	38·908	8·339	38·716	0·122
26	2nd and 3rd 400	7	8·230	39·000	8·216	38·866	0·085

5. It will be seen that when the missing data is near the middle of the range (Nos. 12, 17, 20, 22, 26) the two methods give at least a fair comparison, i.e. within 0·1 n.m.; when they are at either end, the comparison is bad (No. 25 is a mixture, having one missing in the middle and one at the declining end). It is for this reason that further groups A_1 and B_1 were summarised and plotted, leaving out passes between Nos. 1 and 8 which had missing doppler data.

Note: See Appendices XX, 1-29, for details of Doppler counts received for each pass.

APPENDIX III - Summary of all group means

Group	No. of passes	Lat. N. 51°	Long. W. 0°	Radial distance Accepted posn.		(n.m.) from N.I.O.	
1. Using all data							
A	29	8·246'	38·887'	0·012		0·084	·044 012
A_1	24	8·255'	38·877'	0·018		0·089	·054 017°
*B	20	8·250' 8.23	38·904' 38·89	·0	·02 @ 158°	0·094	·047 357½°
B_1	18	8·247' 8 22	38·904' 38 91	0·003	·03 @ 172½°	0·091	·044 °
C	13	8·244' 8 23	38·889' 38·40	0·011	·02 @ 169°	0·083	·042 011°
D	11	8·262'	38·903'	0·012		0·103	·059 354°
E	9	8·243' 8 23	38·879' 38.88	0·017	·025 @ 43°	0·079	·042 019°
2. Using 400 kc. doppler counts							
A	29	8·246'	39·076'	0·108		0·178	·117 291½°
A_1	27	8·253'	39·075'	0·107		0·180	·120 295°
B	20	8·271'	38·924'	0·025		0·118	·069 348½°
B_1	19	8·269'	38·935'	0·027		0·120	·069 342½°
C	13	8·267'	38·975'	0·048		0·136	·079 324°
D	16	8·275'	39·192'	0·183		0·256	·139 301°
E	11	8·276'	38·884'	0·029		0·110	·074 008½°
3. Using 150 kc. doppler counts							
A	28	8·146'	38·634'	0·198		0·118	·177 104°
A_1	26	8·118'	38·699'	0·185		0·093	·153 134°
B	20	8·371'	39·124'	0·184		0·276	·218 320½°
B_1	18	8·356'	39·272'	0·254		0·339	·278 308½°
C	13	8·410'	39·500'	0·407		0·490	·428 299°
D	18	8·140'	39·340'	0·295		0·330	·252 257°
E	14	8·396'	39·784'	0·571		0·647	·586 284°
4. Using first four messages							
A, A_1	27	8·230'	39·052'	0·095		0·157	·098 286°
B, B_1	20	8·170'	38·842'	0·089		0·016	·050 131°
C	13	8·165'	38·802'	0·106		0·013	·074 121°
D	23	8·236'	38·759'	0·092		0·072	·096 070°
E	18	8·191'	38·772'	0·102		0·033	·083 098½°
5. Using last four messages							
A	28	8·102'	39·403'	0·346		0·375	·329 252°
A_1	26	8·073'	39·186'	0·250		0·253	·220 234°
B	20	8·133'	39·266'	0·255		0·285	·239 253°
B_1	19	8·048'	39·023'	0·215		0·180	·173 306°
C	13	8·206'	39·729'	0·520		0·573	·519 270°
D	19	8·120'	39·508'	0·401		0·437	·390 258°
E	15	8·100'	39·317'	0·299		0·323	·280 248½°

* Taken as accepted position, i.e. reference point for all other data.

APPENDIX IV - Summary of results obtained for extended treatment to Passes Nos. 3, 7, 15, 19 and 29

Pass No.	Type of adjustment used	Lat. N 51°	Long. W 0°	Radial distance from 1. (n.m.)
3	1. Using all data as received	8·262'	38·874'	-
	7. Throwing corr. dopp to nearest ten	8·258'	38·887'	0·009
	8. Throwing corr. dopp to nearest hundred	8·263'	38·891'	0·011
	9. Adding 5 to corr. dopp.	8·262'	38·874'	0
	10. Subtracting 5 from corr. dopp	8·262'	38·874'	0
	11. Adding square wave to corr.dopp	8·255'	38·903'	0·019
	12. Adding plus 5 or minus 5 at random to corr. dopp.	8·263'	38·868'	0·004
7	1. As above	8·197'	38·931'	-
	7. -do-	8·203'	38·919'	0·010
	8. -do-	8·155'	38·898'	0·047
	9. 10.)-do-	8·197'	38·927'	0·003
	11. -do-	8·184'	38·918'	0·015
	12. -do-	8·188'	38·936'	0·009
15	1. As above	8·216'	38·856'	-
	7. -do-	8·217'	38·865'	0·006
	8. -do-	8·221'	38·765'	0·057
	9. 10.)-do-	8·216'	38·860'	0·003
	11. -do-	8·210'	38·886'	0·020
	12. -do-	8·212'	38·843'	0·009
19	1. As above	8·211'	38·874'	-
	7. -do-	8·205'	38·876'	0·006
	8. -do-	8·280'	38·798'	0·084
	9. 10.)-do-	8·211'	38·880'	0·004
	11. -do-	8·213'	38·903'	0·018
	12. -do-	8·218'	38·880'	0·008
29	1. As above	8·202'	38·838'	-
	7. -do-	8·205'	38·837'	0·003
	8. -do-	8·196'	38·836'	0·006
	9. 10.)-do-	8·203'	38·839'	0·001
	11. -do-	8·202'	38·862'	0·015
	12. -do-	8·203'	38·836'	0·001

See Appendices XIV to XVIII for detail and plot.

APPENDIX V - Analysis of passes by elevation and radial distance from accepted position

Elevation (degs.)	Less than 10		11 - 20		21 - 30		31 - 40		41 - 50		51 - 60		61 - 70		71 - 80		More than 80	
	No.	rd.	No.	rd.	No.	rd.	No.	rd.	No.	rd.	No.	rd.	No.	rd.	No.	rd.	No.	rd.
	6	.460	4	.057	2	.030	5	.038	1	.056	12	.012	8	.162	20	.079	9	.443
	13	.048	10	.074	7	.056	14	.024	3	.022			17	.041			27	1.017
	16	.138	18	.016	11	.001	26	.063					22	.006			28	1.527
	23	.188	21	.038	15	.045	29	.063										
	24	.077			19	.043												
					25	.065												
n =	5		4		6		4		2		1		3		1		3	
Mean		.182		.046		.040		.047		.039		.012		.069		.079		.996

APPENDIX VI - Analysis of radial distances from accepted position by Satellite

Satellite No.:-	120		130		140		180	
	No.	rd.	No.	rd.	No.	rd.	No.	rd.
	4	·057	2	·030	24	·077	1	·056
	8	·162	6	·460	28	1·527	3	·022
	18	·016	9	·443			5	·038
	23	·188	11	·001			7	·056
	27	1·017	13	·048			10	·074
			14	·024			12	·012
			16	·138			15	·045
			19	·043			17	·040
			20	·079			21	·038
			29	·063			22	·006
							25	·065
							26	·063
n =	5		10		2		12	
Mean		·288		·133		·802		·043

SYMBOLS USED FOR PLOTTING POSNS.

APP. VII

- MEAN POSITION FOR GROUP, IDENTIFIED BY LETTERS (A, A_1, B, B_1 etc.) and number (1, 2, 3, 4, 8) as on opposite page.

  ○·1 n.m. radius circle

APP. VIII to XII

- ACTUAL FIX

⊗ ACCEPTED POSITION

\+ MEAN POSITION OF METHOD (TAKEN AS MEAN FOR GROUP B)

Circle for above drawn with ○·1 m.m. radius

APP. XIV to XVII

- ACTUAL FIX IDENTIFIED BY LETTERS AND NOS. AS FOLLOWS:-

  A 1 - 4, 5, or 6 Running 4 messages

  B 1 - 3, 4, 5 Running 5 messages

  C 1 - 2, 3, 4 Running 6 messages

  D 1 Throwing corr. dopp. to nearest 10

  D 2 Throwing corr. dopp. to nearest 100

  E 1 Corrected dopp. + 5 } always same

  E 2 Corrected dopp. - 5 } position

  E 3 Corrected dopp. + sq. wave

  E 4 Corrected dopp. ± 5 at random

Circles for above drawn with ○·05 n.m. and ○·1 n.m. radius.

APPENDIX VII - Mean positions found by various methods

Types of fixes 1 to 5 - see paragraph 4

Groups A, A_1, B, B_1, C, D, E; - see paragraph 3.

Group	No. of passes	Lat. N. 51°	s.d.	Long. W. 0°	s.d.	Mean Radial distance from accepted posn. (n.m.)
1. Using all data						
A	29	8·246'	± ·067'	38·887'	± ·575'	0·169
A_1	24	8·255'	± ·054'	38·877'	± ·599'	0·156
* B	20	8·250'	± ·031'	38·904'	± ·057'	0·041
B_1	18	8·247'	± ·031'	38·904'	± ·050'	0·041
C	13	8·244'	± ·030'	38·889'	± ·057'	0·042
D	11	8·262'	± ·057'	38·903'	± ·072'	0·059
E	9	8·243'	± ·036'	38·879'	± ·047'	0·046
2. Using 400 kc. doppler						
A	29	8·246'	± ·108'	39·076'	± ·753'	0·292
A_1	27	8·253'	± ·100'	39·075'	± ·773'	0·292
B	20	8·271'	± ·060'	38·924'	± ·205'	0·125
B_1	19	8·269'	± ·051'	38·935'	± ·204'	0·124
C	13	8·267'	± ·056'	38·975'	± ·190'	0·122
D	16	8·275'	± ·098'	39·192'	± ·902'	0·327
E	11	8·276'	± ·071'	38·884'	± ·191'	0·119
3. Using 150 kc. doppler						
A	28	8·146'	± ·695'	38·634'	± 3·161'	1·342
A_1	26	8·118'	± ·711'	38·699'	± 3·271'	1·387
B	20	8·371'	± ·266'	39·124'	± 1·449'	0·830
B_1	18	8·356'	± ·268'	39·272'	± 1·453'	0·838
C	13	8·410'	± ·293'	39·500'	± 1·498'	0·900
D	18	8·140'	± ·740'	39·340'	± 1·514'	0·984
E	14	8·396'	± ·287'	39·784'	± ·953'	0·771
4. Using first four messages						
A,A_1	27	8·230'	± ·165'	39·052'	± 1·081'	0·375
B,B_1	20	8·170'	± ·130'	38·842'	± ·569'	0·248
C	13	8·165'	± ·128'	38·802'	± ·283'	0·179
D	23	8·236'	± ·143'	38·759'	± ·302'	0·189
E	18	8·191'	± ·118'	38·772'	± ·280'	0·168
5. Using last four messages						
A	28	8·102'	± ·632'	39·403'	± 2·383'	1·058
A_1	26	8·073'	± ·539'	39·186'	± 2·302'	0·963
B	20	8·133'	± ·708'	39·266'	± 2·253'	1·054
B_1	19	8·048'	± ·616'	39·023'	± 1·752'	0·926
C	13	8·206'	± ·538'	39·729'	± 1·537'	0·781
D	19	8·120'	± ·561'	39·508'	± 2·437'	0·986
E	15	8·100'	± ·629'	39·317'	± 1·950'	0·918

APPENDIX VIII - Fixes obtained by using original data (estimated values for corrected doppler counts where necessary)

Using SAT C1 for computation

Group means

Group	No. of passes	Lat. N. 51°	s.d.	Long. W. 0°	s.d.	Radial distances from accepted position (n.m.)
A 1	29	8·246'	± ·067'	38·887'	± ·575'	0·169
A_1 1	24	8·255'	± ·054'	38·877'	± ·599'	0·156
* B 1	20	8·250'	± ·031'	38·904'	± ·057'	0·041
		8·23	± ·05'	38·89	± ·07'	
B_1 1	18	8·247'	± ·031'	38·904'	± ·050'	0·041
		8·22	± ·045'	38·91	± ·05	
C 1	13	8·244'	± ·030'	38·889'	± ·057'	0·042
		8.23	± ·055'	38·90	± ·05	
D 1	11	8·262'	± ·057'	38·903'	± ·072'	0·059
E 1	9	8·243'	± ·036'	38·879'	± ·047'	0·046
		8.23	± ·04	38.88	± ·045'	

* Plotted on chart as ⊠ and used as accepted position (reference point) for all other fixes.

RD @ bearing SAT C1 from SAT

			RD (n.m.)	Bearing
B1	−·020	+·014 ·009	·022	156°
$B_1$1	−·027	−·006 ·004	·027	188½°
C1	−·014	−·011 −·007	·016	206½°
E1	−·013	−·001 ✓	·013	184½°

APPENDIX VIII - contd.

Pass No.	Lat. N. 51°	Long. W. 0°	Acc. posn.	Radial distance (n.m.) from: Group means: A1	$A_1$1	B1	$B_1$1	C1	D1	E1
1	8·291'	38·844'	·056	·052	-	·056	-	-	-	-
2	8·257'	38·950'	·030	·041	-	·030	-	-	-	-
3	8·262'	38·874'	·022	·018	·007	·022	·024	·022	·018	·019
4	8·306'	38·886'	·057	·060	·051	·057	·060	·057	·045	·063
5	8·265'	38·960'	·038	·050	·053	·038	·039	·038	·036	·056
6	8·010'	39·531'	·460	·468	-	-	-	-	-	-
7	8·197'	38·931'	·056	·056	·067	·056	·053	·056	·067	·057
8	8·253'	39·162'	·162	·173	-	-	-	-	-	-
9	8·215'	38·200'	·443	·432	-	-	-	-	-	-
10	8·266'	38·790'	·074	·064	·056	·074	·074	·074	·071	·061
11	8·249'	38·905'	·001	·011	·019	·001	·002	-	-	-
12	8·251'	38·885'	·012	·005	·006	·012	·013	·012	-	-
13	8·292'	38·943'	·048	·058	·055	-	-	-	·039	-
14	8·238'	38·938'	·024	·033	·042	·024	·023	-	-	-
15	8·216'	38·856'	·045	·036	·041	·045	·043	·045	·060	·030
16	8·385'	38·951'	·138	·145	·138	-	-	-	-	-
17	8·251'	38·968'	·040	·051	·051	·040	·040	-	-	-
18	8·266'	38·905'	·016	·023	·021	·016	·019	·016	·004	·028
19	8·211'	38·874'	·043	·036	·044	·043	·041	·043	·054	·032
20	8·230'	39·025'	·079	·088	·096	·079	·078	·079	-	-
21	8·249'	38·843'	·038	·028	·022	·038	·038	·038	-	-
22	8·249'	38·894'	·006	·005	·013	·006	·006	·006	-	-
23	8·403'	39·078'	·188	·198	·194	-	-	-	·179	-
24	8·214'	38·795'	·077	·066	·065	-	-	-	-	-
25	8·315'	38·908'	·065	·070	·063	·065	·068	-	-	-
26	8·230'	39·000'	·063	·073	·082	·063	·062	-	-	-
27	8·191'	40·522'	1·017	1·027	1·034	-	-	-	-	-
28	8·171'	36·474'	1·527	1·516	1·513	-	-	-	-	-
29	8·202'	38·838'	·063	·054	·058	·063	·061	·063	·073	·049

APPENDIX IX - Using only corrected doppler counts between c. 3 x 10^6 and c. 4·5 x 10^6 for passes in Group B_1

Group means and s.d's

Group	No. of passes	Lat. N. 51°		Long. W. 0°		Radial distance from accepted position (n.m.)
			s.d.		s.d.	
B_1	19	8·247'	± ·019'	38·924'	± ·050'	0·031
C1	13	8·25[illegible]'	± ·022'	38·893'	± ·048'	0·031
E1	9	8·252'	± ·024'	38·879'	± ·035'	0·029

Pass No.	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.)				
			Acc. posn.	Group means			Original B_1 position
				$B_1$1	C1	E1	
3	8·243'	38·914'	0·009	0·007	0·015	0·024	0·031
4	8·306'	38·886'	0·057	0·060	0·056	0·054	0
5	8·225'	38·876'	0·031	0·028	0·027	0·027	0·066
7	8·259'	38·904'	0·009	0·012	0·011	0·017	0·064
10	8·266'	38·790'	0·074	0·074	0·067	0·069	0
11	8·249'	38·905'	0·001	0·002	-	-	0
12	8·259'	38·902'	0·009	0·012	0·011	-	0·014
14	8·237'	38·870'	0·025	0·023	-	-	0·043
15	8·235'	38·857'	0·033	0·031	0·027	0·022	0·019
17	8·256'	38·941'	0·024	0·025	-	-	0·018
18	8·266'	38·905'	0·016	0·019	0·018	0·021	0
19	8·229'	38·890'	0·023	0·020	0·021	0·024	0·021
20	8·221'	38·984'	0·058	0·056	0·064	-	0·028
21	8·247'	38·843'	0·038	0·038	0·031	-	0·002
22	8·247'	38·974'	0·044	0·044	0·051	-	0·050
25	8·239'	38·935'	0·022	0·021	-	-	0·078
26	8·228'	39·001'	0·065	0·064	-	-	0·002
29	8·241'	38·889'	0·013	0·011	0·009	0·013	0·050

APPENDIX X - Fixes obtained by using 400 kc. doppler counts (with estimated counts where data missing)

Group means and s.d.'s

Group	No. of passes	Lat. N. 51°		Long. W. 0°		Radial distance from approved position (n.m.)
			s.d.		s.d.	
A2	29	8·246'	± ·108'	39·076'	± ·753'	0·292
$A_1$2	27	8·253'	± ·100'	39·075'	± ·773'	0·292
B2	20	8·271'	± ·060'	38·924'	± ·205'	0·125
$B_1$2	19	8·269'	± ·051'	38·935'	± ·204'	0·124
C2	13	8·267'	± ·056'	38·975'	± ·190'	0·122
D2	16	8·275'	± ·098'	39·192'	± ·902'	0·327
E2	11	8·276'	± ·071'	38·884'	± ·191'	0·119

Pass No.	Lat.N. 51°	Long.W. 0°	Acc. posn.	Radial distance from (n.m.) Group means						
				A2	$A_1$2	B2	$B_1$2	C2	D2	E2
1	8·303'	38·703'	·137	·241	-	·143	-	-	-	-
2	8·421'	38·552'	·279	·373	·369	·277	·284	-	·428	·254
3	8·277'	39·092'	·121	·033	·026	·105	·099	·073	·063	·131
4	8·377'	38·931'	·128	·160	·153	·106	·108	·114	·193	·105
5	8·230'	39·057'	·098	·020	·025	·093	·086	·063	·096	·118
6	7·987'	39·472'	·442	·359	-	-	-	-	-	-
7	8·249'	38·815'	·056	·164	·163	·071	·078	·102	·238	·051
8	8·207'	39·657'	·475	·367	·367	-	-	-	-	-
9	8·236'	41·980'	1·931	1·824	1·824	-	-	-	1·750	-
10	8·344'	38·867'	·096	·164	·160	·081	·086	·103	·215	·069
11	8·245'	38·823'	·051	·159	·159	·068	·074	-	-	-
12	8·254'	39·136'	·146	·039	·038	·134	·127	·102	-	-
13	8·352'	39·089'	·154	·106	·099	-	-	-	·101	-
14	8·240'	38·777'	·081	·188	·187	·097	·103	-	-	-
15	8·217'	38·989'	·062	·062	·065	·068	·062	·051	·140	·089
16	8·458'	38·843'	·211	·257	·252	-	-	-	·285	-
17	8·266'	38·737'	·106	·214	·212	·117	·124	-	-	-
18	8·288'	38·923'	·040	·105	·102	·017	·021	·039	·169	·027
19	8·231'	39·058'	·099	·019	·025	·093	·086	·063	·095	·118
20	8·206'	38·481'	·269	·375	·377	·285	·292	·316	·451	·263
21	8·354'	39·052'	·140	·109	·102	·115	·112	·099	-	-
22	8·254'	39·324'	·264	·156	·156	·252	·244	·219	-	-
23	8·067'	38·475'	·325	·417	·420	-	-	-	·496	-
24	7·954'	38·573'	·361	·430	·434	-	-	-	-	-
25	8·260'	38·997'	·059	·052	·049	·047	·040	-	-	-
26	8·207'	39·205'	·194	·090	·094	·187	·180	-	-	-
27	8·171'	40·968'	1·297	1·189	1·191	-	-	-	1·119	-
28	8·195'	37·682'	·769	·876	·876	-	-	-	-	-
29	8·193'	38·955'	·065	·093	·096	·080	·077	·075	·170	·094

APPENDIX XI - Fixes obtained by using 150 kc. doppler counts (with estimated counts where data missing)

Group means and s.d.'s

Group	No. of passes	Lat. N. 51°		Long. W. 0°		Radial distance from appd. posn. (n.m.)
			s.d.		s.d.	
A3	28	8·146'	± ·695'	38·634'	± 3·161'	1·342
$A_1$3	26	8·118'	± ·711'	38·699'	± 3·271'	1·387
B3	20	8·371'	± ·266'	39·124'	± 1·449'	0·830
$B_1$3	18	8·356'	± ·268'	39·272'	± 1·453'	0·838
C3	13	8·410'	± ·293'	39·500'	± 1·498'	0·900
D3	18	8·140'	± ·740'	39·340'	± 1·514'	0·984
E3	14	8·396'	± ·287'	39·784'	± 0·953'	0·771

Pass No.	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.)							
			Acc. posn.	Group means						
				A3	$A_1$3	B3	$B_1$3	C3	D3	E3
1	8·307'	37·927'	·616	·473	-	·754	-	-	-	-
2	8·700'	37·649'	·907	·830	-	·983	-	-	-	-
3	8·367'	40·422'	·960	1·144	1·109	·814	·722	·581	·716	·401
4	8·801'	39·201'	·582	·746	·752	·433	·447	·434	·667	·546
5	8·019'	39·635'	·514	·641	·595	·476	·407	·400	·221	·388
6	7·806'	39·188'	·478	·487	·438	-	-	-	·347	-
7	8·561'	38·132'	·575	·521	·568	·650	·744	·871	·867	1·050
8	8·192'	41·587'	1·685	1·854	1·814	-	-	-	-	-
9	6·512'	25·093'	8·839	8·653	8·688	-	-	-	-	-
10	8·825'	39·321'	·632	·804	·807	·471	·470	·430	·685	·518
11	8·226'	38·302'	·379	·223	·271	·536	·623	-	·657	·945
12	8·275'	40·668'	1·107	1·283	1·246	·974	·880	·745	·844	·568
13	8·710'	39·963'	·808	1·006	·990	-	-	-	·691	-
14	8·260'	37·803'	·691	·533	·580	·836	·927	-	-	-
15	8·221'	39·773'	·546	·719	·682	·434	·342	·255	·284	·175
16	8·906'	38·180'	·798	·817	·853	-	-	-	-	-
17	8·356'	37·377'	·964	·816	·863	1·096	1·189	-	-	-
18	8·416'	39·030'	·184	·367	·356	·074	·163	·295	·338	·473
19	8·351'	40·138'	·781	1·015	·933	·636	·543	·404	·544	·227
20	8·065'	35·292'	2·275	2·099	2·139	2·424	2·514	2·663	-	-
21	9·000'	40·288'	1·147	1·344	1·331	·964	·907	·770	1·046	·682
22	8·289'	41·930'	1·899	2·073	2·034	1·763	1·669	1·530	1·632	1·351
23	6·398'	34·765'	3·190	2·992	3·009	-	-	-	3·358	-
24	6·060'	37·227'	2·430	2·265	2·256	-	-	-	2·467	-
25	8·184'	39·450'	·349	·513	·476	·277	·205	-	-	-
26	8·064'	40·463'	·996	1·151	1·108	·894	·802	-	·709	·540
27	8·080'	43·282'	2·752	2·918	2·876	-	-	-	-	-
28	No reasonable answer.									
29	8·134'	39·670'	·495	·650	·609	·417	·334	·296	·207	·272

APPENDIX XII - Fixes obtained by using first four messages (with estimated counts for corrected doppler data where necessary

Group means and s.d.'s

Group	No. of passes	Lat. N. 51°		Long. W. 0°		Radial distance from accepted position (n.m.)
			s.d.		s.d.	
A4,$A_1$4	27	8·230'	± ·165'	39·052'	± 1·081'	0·375
B4,$B_1$4	20	8·170'	± ·130'	38·842'	± ·569'	0·247
C4	13	8·165'	± ·128'	38·802'	± ·283'	0·179
D4	23	8·236'	± ·143'	38·759'	± ·302'	0·214
E4	18	8·191'	± ·118'	38·772'	± ·280'	0·168

Pass No.	Lat. N. 51°	Long. W. 0°	Acc. posn.	Radial distance from (n.m.) Group means				
				$A_4, A_1 4$	$B_4, B_1 4$	C_4	D_4	E_4
1	8·222'	38·831'	·053	·139	·052	–	·047	·048
2	8·242'	38·802'	·064	·157	·076	–	·028	·054
3	8·210'	39·079'	·117	·026	·154	·180	·203	·194
4	8·197'	38·883'	·055	·111	·037	·060	·087	·070
5	8·225'	38·876'	·031	·110	·059	·076	·074	·073
6	8·474'	38·700'	·258	·329	–	–	·241	–
7	8·162'	38·759'	·127	·196	·053	·027	·074	·030
8	8·586'	43·754'	3·061	2·972	–	–	–	–
9	No reasonable answer							
10	7·748'	39·323'	·567	·511	·519	·530	·603	·562
11	8·274'	38·708'	·125	·220	·134	–	·050	·092
12	8·204'	38·617'	·186	·274	·145	·122	·095	·098
13	8·232'	38·679'	·142	·234	–	–	·050	–
14	7·934'	38·026'	·635	·709	·564	–	–	–
15	8·209'	38·707'	·131	·217	·094	·074	·043	·045
16	8·510'	38·067'	·586	·678	–	–	·513	–
17	8·321'	38·204'	·445	·540	·428	–	·358	·379
18	8·216'	38·953'	·046	·064	·084	·108	·124	·117
19	8·235'	38·876'	·023	·110	·068	·084	·073	·078
20	8·198'	38·610'	·191	·279	·149	·124	·100	·102
21	8·068'	38·987'	·189	·167	·137	·151	·217	·183
22	8·203'	38·078'	·520	·612	·480	·456	·428	·435
23	8·452'	39·157'	·257	·232	–	–	·330	–
24	8·309'	39·947'	·657	·568	–	–	·139	–
25	8·248'	38·932'	·018	·077	·096	–	·110	·115
26	8·018'	40·917'	1·284	1·189	1·311	–	–	–
27	8·244'	39·250'	·217	·125	–	–	–	–
28	No reasonable answer							
29	8·264'	38·679'	·142	·236	·139	·125	·057	·093

APPENDIX XIII - Fixes obtained by using last four messages (with estimated counts for corrected doppler data where necessary

Group means and s.d.'s

Group	No. of passes	Lat. N. 51°		Long. W. 0°		Radial distance from accepted position (n.m.)
			s.d.		s.d.	
A5	28	8·102'	± ·632'	39·403'	± 2·383'	1·058
$A_1 5$	26	8·073'	± ·539'	39·186'	± 2·302'	0·963
B5	20	8·133'	± ·708'	39·266'	± 2·253'	1·062
$B_1 5$	19	8·048'	± ·616'	39·023'	± 1·752'	0·936
C5	13	8·206'	± ·538'	39·729'	± 1·537'	0·781
D5	19	8·120'	± ·561	39·508'	± 2·437'	1·074
E5	15	8·100'	± ·629'	39·317'	± 1·950'	0·930

Pass No.	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.)						
			Acc. posn.	Group means					
				A5	$A_1$5	B5	$B_1$5	C5	D5	E5
1	6·678'	34·458'	3·379	3·414	3·279	3·350	3·176	-	3·482	3·364
2	9·766'	43·873'	3·467	3·261	-	3·320	-	-	-	-
3	6·667'	42·959'	2·997	2·653	2·754	2·742	2·830	2·545	2·608	2·697
4	8·137'	40·321'	·896	·577	·715	·662	·819	·377	·510	·631
5	8·285'	38·990'	·064	·317	·245	·230	·238	·471	·364	·276
6	7·204'	39·599'	1·133	·906	-	-	-	-	-	-
7	9·326'	42·817'	2·680	2·467	2·600	2·527	2·702	2·238	2·401	2·515
8	8·238'	38·525'	·238	·568	·447	-	-	-	-	-
9	No reasonable answer									
10	8·244'	39·269'	·229	·165	·179	·111	·249	·291	·195	·147
11	8·027'	38·639'	·278	·485	·346	·407	·242	-	-	-
12	8·028'	39·758'	·580	·235	·362	·326	·461	·179	·182	·286
13	8·423'	39·038'	·192	·394	·362	-	-	-	·423	-
14	8·192'	39·662'	·480	·186	·322	·255	·426	-	-	-
15	8·440'	38·058'	·564	·909	·797	·818	·722	1·075	·965	·860
16	8·059'	39·040'	·209	·232	·093	-	-	-	-	-
17	8·193'	38·488'	·267	·581	·454	·492	·366	-	·644	·528
18	8·267'	38·994'	·059	·305	·228	·217	·220	·465	·355	·263
19	8·147'	39·044'	·135	·229	·116	·140	·100	·434	·292	·177
20	8·251'	38·109'	·499	·826	·699	·736	·609	1·018	·888	·773
21	8·232'	38·862'	·032	·363	·258	·273	·210	·545	-	-
22	8·351'	38·543'	·248	·595	·490	·504	·427	·758	·649	·547
23	8·404'	38·921'	·154	·427	·370	-	-	-	·465	-
24	7·901'	38·928'	·349	·359	·236	-	-	-	-	-
25	6·958'	34·523'	3·037	3·269	3·131	3·200	3·027	-	-	-
26	8·171'	39·187'	·192	·155	·104	·067	·165	-	·209	·112
27	7·793'	46·318'	4·674	4·350	4·484	-	-	-	4·285	-
28	8·168'	36·619'	1·436	1·748	1·614	-	-	-	1·814	-
29	8·304'	40·757'	1·164	·874	·968	·951	1·118	·652	·805	·927

APPENDIX XIV

Pass No. 3 - Group F (paragraph 3)
Elements 1, 7 to 14 (paragraph 4)

Pass No. 3 Elevation 50°

Element Para. 4	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.)	
			Acc. posn.	All data posn. (Elem. 1)
1	8·262'	38·874'	·022	-
6 1-4	8·210'	39·079'	·117	·139
2-5	8·217'	38·999'	·068	·090
3-6	8·260'	38·931'	·020	·036
4-7	8·259'	38·928'	·017	·034
5-8	8·231'	38·544'	·231	·215
6-9	6·667'	42·959'	2·997	2·847
7	8·258'	38·887'	·014	·009
8	8·263'	38·891'	·015	·011
9, 10	8·262'	38·874'	·022	0
11	8·255'	38·903'	·005	·019
12	8·263'	38·868'	·026	·004
13 1-5	8·212'	39·011'	·077	·099
2-6	8·243'	38·914'	·009	·031
3-7	8·260'	38·931'	·020	·036
4-8	8·252'	38·857'	·029	·015
5-9	8·144'	39·474'	·373	·395
14 1-6	8·232'	38·916'	·020	·040
2-7	8·252'	38·901'	·003	·020
3-8	8·248'	38·920'	·010	·032
4-9	8·261'	39·027'	·078	·096

APPENDIX XV

Pass No. 7 - Group F (paragraph 3)
Elements 1, 7 to 14 (paragraph 4)

Pass No. 7 Elevation 25°

Element Para. 4	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.) Acc. posn.	All data posn. (Elem. 1)
1	8·197'	38·931'	·056	-
6 1-4	8·162'	38·759'	·127	·114
2-5	8·385'	38·865'	·137	·192
3-6	8·207'	39·129'	·147	·124
4-7	8·231'	38·460'	·280	·298
5-8	9·327'	42·817'	2·680	2·687
7	8·203'	38·919'	·048	·010
8	8·155'	38·898'	·095	·047
9,10	8·197'	38·927'	·055	·003
11	8·184'	38·918	·067	·015
12	8·188'	38·936'	·065	·009
13 1-5	8·288'	38·920'	·039	·091
2-6	8·269'	38·886'	·022	·078
3-7	8·277'	38·947'	·038	·081
4-8	8·282'	39·751'	·532	·522
14 1-6	8·259'	38·904'	·009	·064
2-7	8·283'	38·875'	·038	·093
3-8	8·195'	39·277'	·240	·217

APPENDIX XVI

Pass No. 15 - Group F (paragraph 3)

Elements 1, 7 to 14 (paragraph 4)

Pass No. 15 Elevation 30°

Element para. 4	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.) Acc. posn.	All data posn. (Elem. 1)
1	8·216'	38·856'	·045	-
6 1-4	8·209'	38·707'	·131	·093
2-5	8·169'	38·970'	·091	·086
3-6	8·192'	38·931'	·060	·053
4-7	8·299'	38·992'	·074	·119
5-8	8·278'	38·637'	·170	·150
6-9	8·440'	38·058'	·564	·549
7	8·217'	38·865'	·041	·006
8	8·221'	38·765'	·092	·057
9,10	8·216'	38·860'	·044	·003
11	8·210'	38·886'	·041	·020
12	8·212'	38·843'	·054	·009
13 1-5	8·193'	38·917'	·058	·044
2-6	8·182'	38·933'	·070	·059
3-7	8·261'	38·888'	·015	·049
4-8	8·252'	38·916'	·008	·052
5-9	8·282'	38·484'	·266	·242
14 1-6	8·190'	38·928'	·062	·052
2-7	8·235'	38·857'	·033	·019
3-8	8·249'	38·886'	·011	·038
4-9	8·219'	38·824'	·059	·020

APPENDIX XVII

Pass No. 19 - Group F (paragraph 3)

Elements 1, 7 to 14 (paragraph 4)

Pass No. 19 Elevation 25°

Element para. 4	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.) Acc. posn.	All data posn. (Elem. 1)
1	8·211'	38·874'	·043	-
6 1-4	8·235'	38·876'	·023	·024
2-5	8·265'	38·919'	·017	·061
3-6	8·161'	38·995'	·106	·091
4-7	8·147'	39·044'	·135	·125
7	8·205'	38·876'	·048	·006
8	8·280'	38·798'	·073	·084
9,10	8·211'	38·880'	·042	·004
11	8·213'	38·903'	·037	·018
12	8·218'	38·880'	·035	·008
13 1-5	8·245'	38·918'	·010	·044
2-6	8·219'	38·897'	·031	·016
3-7	8·153'	39·005'	·116	·100
14 1-6	8·229'	38·890'	·023	·021
2-7	8·193'	38·899'	·057	·024

APPENDIX XVIII

Pass No. 29 - Group F (paragraph 3)

Elements 1, 7 to 14 (paragraph 4)

Pass No. 29 Elevation 37°

Element para. 4	Lat. N. 51°	Long. W. 0°	Radial distance from (n.m.) Acc. posn.	All data posn. (Elem. 1)
1	8·202'	38·838'	·063	-
6 1-4	8·264'	38·679'	·142	·118
2-5	8·244'	38·913'	·008	·063
3-6	8·232'	38·886'	·021	·042
4-7	8·249'	38·867'	·023	·050
5-8	8·169'	39·489'	·376	·410
6-9	8·304'	40·757'	1·164	1·208
7	8·205'	38·837'	·062	·003
8	8·196'	38·836'	·069	·006
9,10	8·203'	38·839'	·062	·001
11	8·202'	38·862'	·055	·015
12	8·203'	38·836'	·064	·001
13 1-5	8·232'	38·866'	·030	·035
2-6	8·240'	38·886'	·015	·052
3-7	8·240'	38·891'	·013	·055
4-8	8·191'	38·971'	·072	·084
5-9	8·147'	39·755'	·544	·578
14 1-6	8·232'	38·881'	·023	·040
2-7	8·241'	38·889'	·013	·050
3-8	8·210'	38·894'	·040	·036
4-9	8·140'	39·089'	·160	·170

APPENDIX XIX - Analysis of mid-doppler count in running four message fixes against radial distance of fix from accepted position

Corr. doppler count x 10^6 between:	Radial distance from accepted position (n.m.) between:								
	0 - 0·05	0·05 - 0·10	0·10 - 0·15	0·15 - 0·20	0·20 - 0·25	0·25 - 0·50	0·50 - 0·75	0·75 - 1·00	more than 1·00
2·85-2·94				1		1			1
2·95-3·04				1	2	1	1		
3·05-3·14	2	2	3						1
3·15-3·24		1			1				
3·25-3·34		2	1				1		
3·35-3·44	2	1		1					
3·45-3·54	6	2	2						
3·55-3·64		2		1					
3·65-3·74	1	2							
3·75·3·84	3	1	1	1					
3·85-3·94	3								
3·95-4·04	2		1	1					
4·05-4·14	4	2	1	1					
4·15-4·24		1	1						
4·25-4·34	1	3	1		1	1			
4·35-4·44	1	1		1	1	2	1	1	
4·45-4·54	1	2	2	1					1
4·55-4·64		1	1	1		1	1		2
4·65-4·74		1			1	2	1	1	3
4·75-4·84		1			1	1			1

APPENDIX XIXa - Analysis of mid-doppler count in running five message fixes against radial distance of fix from accepted position

Corr. doppler count x 10^6 between	Radial distance from accepted position (n.m.) between: 0· – 0·05	0·05 – 0·10	0·10 – 0·15	0·15 – 0·20	0·20 – 0·25	0·25 – 0·50	0·50 – 0·75
3·15-3·24	1	2					
3·25-3·34							
3·35-3·44							
3·45-3·54		1					
3·55-3·64	2						
3·65-3·74	2						
3·75-3·84							
3·85-3·94	1						
3·95-4·04	1						
4·05-4·14	3						
4·15-4·24	1						
4·25-4·34	1						
4·35-4·44							
4·45-4·54	1	1				1	1
4·55-4·64			1				
4·65-4·74						1	1

APPENDIX XIXb - Analysis of mid-doppler count in running six message fixes against radial distance of fix from accepted position

Corr. doppler count x 10^6 between:	Radial distance from accepted position (n.m.) between: 0· – 0·05	0·05 – 0·10	0·10 – 0·15	0·15 – 0·20	0·20 – 0·25
3·25-3·34	1	1			
3·35-3·44	1				
3·45-3·54					
3·55-3·64	1				
3·65-3·74					
3·75-3·84	2				
3·85-3·94	2				
3·95-4·04					
4·05-4·14	1				
4·15-4·24	1				
4·25-4·34	1	1			
4·35-4·44	1	1			1
4·45-4·54					
4·55-4·64				1	
4·65-4·74		1			

APPENDIX XX

Pass No. 1 | Day 314 (Date) (9.11.68) | Time 1608 Z

Sat. No. 180 | Elevation 50° | No. of messages 9

Fixed Parameters

t_p	598·0879
$\dot{M}$	3·3660861
ωp	225·3262
$\lvert\dot{\omega}_p\rvert$	0·0020352
E	0·006895
A_o	7463·55
Ω_N	279·6745
$\dot{\Omega}_N$	0·0000012
cos i	0·000103
Ω_G	198·1593
sin i	1·0

Variable Parameters

t_k	ΔE_k	ΔAk	Δn_k
968·	0·0041	2·22	0·09
970·	0·0049	1·92	0·11
972·	0·0054	1·59	0·12
974·	0·0057	1·25	0·13
976·	0·0056	0·92	0·15
978·	0·0052	0·61	0·16
980·	0·0046	0·34	0·17
982·	0·0038	0·13	0·18
984·	0·0028	-0·02	0·18

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp = 400 + converson)

figures in brackets show estimated values

400 kc.	2985015	3138916	3476829	3999938	(4431357)	4647551	4739541	4776444	
150 kc.	2985527	3139286	3477012	(4000004)	4431369	4647539	4739863	4776404	
Diff.	-512	-370	-183	(-66)	(-12)	12	-322	40	
Conversion	-84	-61	-30	(-11)	(-2)	2	-53	7	
Corr. Dopp.	2984931	3138855	3476799	(3999927)	(4431355)	4647553	4739488	4776451	

Pass No. 2 | Day 316 (Date) (11.11.68) | Time 1328 Z

Sat. No. 130 | Elevation 25° | No. of messages 8

Fixed Parameters

t_p	375•1029
$\dot{M}$	3•3651746
ωp	87•9114
$\lvert\dot{\omega}_p\rvert$	0•0019784
E	0•003265
A_o	7464•90
Ω_N	50•2151
$\dot{\Omega}_N$	-0•0000294
oos i	0•006959
Ω_G	144•2317
sin i	0•999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
808•	-0•0015	0•14	0•25
810•	-0•0026	0•33	0•24
812•	-0•0035	0•58	0•23
814•	-0•0041	0•88	0•22
816•	-0•0044	1•20	0•21
818•	-0•0044	1•53	0•19
820•	-0•0040	1•85	0•17
822• 824	-0•0034 -0•0024	2•14 2•40	0•15 0•15 13

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp = 400 + conversion

figures in brackets show estimated values

400 kc.	3058326	3233434	3534169	3934507	4298276	4534215	4662094		
150 kc.	3058040	3233680	3534389	3934496	(4298080)	4533941	(4661788)		
Diff.	286	-246	-220	11	(196)	274	(306)		
Conversion	47	-40	-36	2	(32)	45	(50)		
Corr. Dopp.	3058373	3233394	3534133	3934509	(4298308)	4534260	(4662144)		

Pass No. 3 | Day 316 (Date) (11.11.68) | Time 1430 Z

Sat. No. 180 | Elevation 50° | No. of messages 9

Fixed Parameters

t_p	605•5448
$\dot{M}$	3•3660842
ωp	218•8847
$\lvert\dot{\omega}_p\rvert$	0•0020333
E	0•0016983
A_o	7463•55
Ω_N	279•6733
$\dot{\Omega}_N$	0•0000013
cos i	0•0001102
Ω_G	201•9999
sin i	1•0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
870•	0•0019	2•25	0•11
872•	0•0028	1•96	0•12
874•	0•0034	1•63	0•12
876•	0•0037	1•29	0•13
878•	0•0037	0•96	0•13
880•	0•0034	0•65	0•14
882•	0•0027	0•38	0•14
884•	0•0019	0•16	0•15
886•	0•0008	0•01	0•16

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion

figures in brackets show estimated value

400 kc.	2932889	3047874	3328815	3857199	4376385	4646601	4757070	4800343	
150 kc.	2933373	3048220	3329048	3857223	4376210	4646404	4757150	4800706	
Diff.	-484	-346	-233	-24	175	197	-80	-363	
Conversion	-79	-57	-38	-4	29	32	-13	-59	
Corr. Dopp.	2932810	3047817	3328777	3857195	4376414	4646633	4757057	4800284	

Pass No. 4 | Day 316 (Date) (11.11.68) | Time 1610 Z

Sat. No. 120 | Elevation 13° | No. of messages 7

Fixed Parameters

t_p	801•7998
$\dot{M}$	3•3802822
ωp	190•8582
$\lvert\dot{\omega}_p\rvert$	0•0020221
E	0•001354
A_o	7442•64
Ω_N	327•5366
$\dot{\Omega}_N$	0•0000175
cos i	-0•003967
Ω_G	251•198
sin i	0•999992

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
970•	0•0027	1•72	0•08
972•	0•0030	1•38	0•07
974•	0•0029	1•05	0•07
976•	0•0025	0•74	0•07
978•	0•0018	0•46	0•07
980•	0•0009	0•25	0•06
982•	-0•0003	0•10	0•06

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion

figures in brackets show estimated values

400 kc.	3268899	3496102	3796951	4110243	4363568	4533471			
150 kc.	3268981	3496138	3796930	4110223	4363694	4533683			
Diff.	-82	-36	21	20	-126	-212			
Conversion	-13	-6	3	3	-21	-35			
Corr. Dopp.	3268886	3496096	3796954	4110246	4363547	4533436			

Pass No. 5	Day 319 (Date) (14.11.68)	Time 1356 Z
Sat. No. 180	Elevation 34°	No. of messages 6

Fixed Parameters

t_p	670•2657
$\dot{M}$	3•3660903
ωp	209•3230
$\lvert\dot{\omega}_p\rvert$	0•0020304
E	0•007130
A_o	7463•55
Ω_N	279•6719
$\dot{\Omega}_N$	0•0000011
oos i	0•000098
Ω_G	221•1814
sin i	1•0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
836•	0•0051	1•38	0•08
838•	0•0051	1•04	0•08
840•	0•0048	0•71	0•08
842•	0•0042	0•43	0•08
844•	0•0033	0•19	0•09
846•	0•0022	0•02	0•09

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3640954	4114348	4467350	4653350	4740530				
150 kc.	3641075	4114336	4467213	4653167	4740433				
Diff.	-121	12	137	183	97				
Conversion	-20	2	22	30	16				
Corr. Dopp.	3640934	4114350	4467372	4653380	4740546				

Pass No. 6 | Day 319 (Date) (14.4.68) | Time 1438 Z

Sat. No. 130 | Elevation 7° | No. of messages 5

Fixed Parameters

t_p	442•1136
$\dot{M}$	3•3651782
ωp	82•2968
$\lvert\dot{\omega}_p\rvert$	0•0019780
E	0•003241
A_o	7464•90
Ω_N	50•0931
$\dot{\Omega}_N$	−0•0000292
cos i	0•006955
Ω_G	163•9872
sin i	0•999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
878•	−0•0000	0•22	0•10
880•	−0•0009	0•44	0•09
882•	−0•0015	0•71	0•09
884•	−0•0018	1•02	0•08
886•	−0•0018	1•34	0•08

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3555766	3799867	4049555	(4264217)					
150 kc.	3555753	3799831	4049456	4264113					
Diff.	13	36	99	(104)					
Conversion	2	6	16	(17)					
Corr. Dopp.	3555768	3799873	4049571	(4264234)					

Pass No. 7 | Day 320 (Date) (15.11.68) | Time 1638 Z

Sat. No. 180 | Elevation 25° | No. of messages 8

Fixed Parameters

t_p	620·5446
$\dot{M}$	3·3660801
ωp	206·3028
$\lvert\dot{\omega}_p\rvert$	0·0020254
E	0·007184
A_o	7463·54
Ω_N	279·6714
$\dot{\Omega}_N$	0·0000013
oos i	0·000109
Ω_G	209·7028
sin i	1·0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
998·	0·0071	1·94	0·08
1000·	0·0076	1·59	0·09
1002·	0·0079	1·23	0·10
1004·	0·0078	0·88	0·12
1006·	0·0074	0·55	0·12
1008·	0·0067	0·27	0·13
1010·	0·0058	0·04	0·13
1012·	0·0047	-0·12	0·14

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3241490	3481425	3814268	4155111	4409845	4564507	4649609		
150 kc.	3241655	3481528	3814293	4155027	4409723	4564503	4649973		
Diff.	-165	-103	-25	84	122	4	-364		
Conversion	-27	-17	-4	14	20	1	-60		
Corr. Dopp.	3241463	3481408	3814264	4155125	4409865	4564508	4649549		

Pass No. 8 | Day 320 (Date) (15.11.68) | Time 1746 Z

Sat. No. 120 | Elevation 67° | No. of messages 5 usable

Fixed Parameters

t_p	792•6048
$\dot{M}$	3•3802861
ωp	178•5992
$\lvert\dot{\omega}_p\rvert$	0•0020225
E	0•001598
A_o	7442•64
Ω_N	327•6283
$\dot{\Omega}_N$	0•0000176
cos i	-0•003963
Ω_G	252•8356
sin i	0•999992

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k	
1066•	0•0019	2•45	0•09	
1068•	0•0029	2•18	0•11	Used for fix determinatio
1070•	0•0037	1•87	0•12	
1072•	0•0041	1•54	0•14	
1074•	0•0043	1•19	0•15	
1076•	0•0041	0•86	0•16	
1078•	0•0036	0•56	0•17	
1080•	0•0028	0•30	0•18	
1082•	0•0019	0•10	0•18	

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

							Not used		
400 kc.	2852293	2888429	2997409	3317671	Both	(4528600)	4744288	4816826	4839521
150 kc.	2852362	2888573	2997557	3317770	missing	4528469	4744156	4816741	4839572
Diff.	-69	-144	-148	-99		(131)	132	85	-51
Conversion	-11	-24	-24	-16		(22)	22	14	-8
Corr. Dopp.	2852282	2888405	2997385	3317655		(4528622)	4744310	4816840	4839513

Pass No. 9	Day 323 (Date) (18.11.68)	Time 1122 Z
Sat. No. 130	Elevation 86°	No. of messages 9

Fixed Parameters

t_p	353•1489
$\dot{M}$	0•3651822
ωp	75•1260
$\lvert\dot{\omega}_p\rvert$	0•0[illegible]1981
E	0•003186
A_o	7464•89
Ω_N	49•9362
$\dot{\Omega}_N$	-0•0000292
cos i	0•006936
Ω_G	145•6277
sin i	0•999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
682•	-0•[illegible]035	0•07	0•18
684•	-0•[illegible]046	0•24	0•18
686•	-0•[illegible]56	0•48	0•17
688•	-0•0064	0•77	0•17
690•	-0•0068	1•09	0•15
692•	-0•0070	1•44	0•14
694•	-0•0069	1•78	0•12
696•	-0•[illegible]065	2•10	0•10
698•	-0•0058	2•38	0•08

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2846904	2889057	3019551	3411904	4127062	4603440	4769208	4823010	
150 kc.	2846817	2889164	3019770	3412032	(4126915)	4603049	4768788	4822570	
Diff.	87	-107	-219	-128	(147)	391	420	440	
Conversion	14	-18	-36	-21	(24)	64	69	72	
Corr. Dopp.	2846918	2889039	3019515	3411883	(4127086)	4603504	4769277	4823082	

Pass No. 10 Day 323 Time 1224 Z

Date) (18.11.68)

Sat. No. 180 Elevation 13° No. of messages 8

Fixed Parameters

t_p	578·3932
$\dot{M}$	3·3660804
ωp	197·2297
$\lvert\dot{\omega}_p\rvert$	0·0020253
E	0·007348
Λ_o	7463·56
Ω_N	279·6693
$\dot{\Omega}_N$	0·0000011
cos i	0·000104
Ω_G	202·0929
sin i	1·0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
744·	0·0028	1·97	0·07
746·	0·0034	1·64	0·07
748·	0·0038	1·30	0·06
750·	0·0037	0·95	0·05
752·	0·0032	0·63	0·04
754·	0·0025	0·35	0·04
756·	0·0015	0·13	0·04
758·	0·0002	-0·03	0·04

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3172847	3327393	3555673	3842161	4129925	4361220	4519228		
150 kc.	3173045	3327605	3555737	3842182	4129948	4361348	4519542		
Diff.	-198	-212	-64	-21	-23	-128	-314		
Conversion	-32	-35	-10	-3	-4	-21	-51		
Corr. Dopp.	3172815	3327358	3555663	3842158	4129921	4361199	4519177		

Pass No. 11 | Day 323 (Date) (18.11.68) | Time 1310Z

Sat. No. 130 | Elevation 22° | No. of messages 7

Fixed Parameters

t_p	353·1489
$\dot{M}$	3·3651822
ωp	75·126
$\lvert\dot{\omega}_p\rvert$	0·001981
E	0·003186
Λ_o	7464·89
Ω_N	49·9362
$\dot{\Omega}_N$	−0·0000292
cos i	0·006936
Ω_G	145·6277
sin i	0·999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
790·	−0·0013	0·15	0·24
792·	−0·0024	0·35	0·23
794·	−0·0032	0·60	0·22
796·	−0·0038	0·89	0·21
798·	−0·0041	1·22	0·19
800·	−0·0040	1·54	0·18
802·	−0·0037	1·86	0·16

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3113307	3308912	3617840	3994060	(4319222)	(4531281)			
150 kc.	3113289	3308935	3617818	3993990	4319028	4531072			
Diff.	18	−23	22	70	(194)	(209)			
Conversion	3	−4	4	11	(32)	(33)			
Corr. dopp.	3113310	3308908	3617844	3994071	(4319254)	(4531314)			

Pass No. 12	Day 323 (Date) (18.11.68)	Time 1408 Z
Sat. No. 180	Elevation 55°	No. of messages 9

Fixed Parameters

t_p	578·3932
$\dot{M}$	3·3660804
ωp	197·2297
$\lvert\dot{\omega}_p\rvert$	0·0020253
E	0·007348
A_o	7463·56
Ω_N	279·6693
$\dot{\Omega}_N$	0·0000011
cos i	0·000104
Ω_G	202·0929
sin i	1·0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
848·	0·0019	2·42	0·09
850·	0·0031	2·14	0·11
852·	0·0039	1·82	0·12
854·	0·0044	1·47	0·12
856·	0·0045	1·11	0·13
858·	0·0043	0·77	0·13
860·	0·0037	0·46	0·14
862·	0·0029	0·20	0·14
864·	0·0018	0·00	0·15

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2888962	2945888	3095978	(3465858)	4065509	4517054	4713485	4789106
150 kc.	2889366	2946387	3096269	3465968	4065446	4516875	4713319	4789154
Diff.	-404	-499	-291	(-110)	63	179	166	-48
Conversion	-66	-82	-48	(-18)	10	29	27	-8
Corr. Dopp.	2888896	2945806	3095930	(3465840)	4065519	4517083	4713512	4789098

Pass No. 13 | Day 324 (Date) (19.11.68) | Time 0848 Z

Sat. No. 130 | Elevation 9° | No. of messages 5

Fixed Parameters

t_p	411·1337
$\dot{M}$	3·3651828
ωp	73·1515
$\lvert\dot{\omega}_p\rvert$	0·0019798
E	0·003166
A_o	7464·89
Ω_N	48·895
$\dot{\Omega}_N$	−0·0000290
oos i	0·006929
Ω_G	161·1492
sin i	0·999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
528·	−0·0044	0·20	−0·04
530·	−0·0054	0·43	−0·03
532·	−0·0063	0·72	−0·02
534·	−0·0069	1·05	−0·02
536·	−0·0073	1·40	−0·01

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3386435	3593322	3843030	4092710					
150 kc.	3386258	3593206	3842895	4092480					
Diff.	177	116	135	230					
Conversion	29	19	22	38					
Corr. Dopp.	3386464	3593341	3843052	4092748					

Pass No. 14 | Day 324 (Date) (19.11.68) | Time 1220 Z

Sat. No. 130 | Elevation 40° | No. of messages 9

Fixed Parameters

t_p	411•1337
$\dot{M}$	3•3651828
ωp	73•1515
$\lvert\dot{\omega}_p\rvert$	0•0019798
E	0•003166
A_o	7464•89
Ω_N	49•8950
$\dot{\Omega}_N$	-0•0000290
cos i	0•006929
Ω_G	161•1492
sin i	0•999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
740•	-0•0011	0•05	0•19
742•	-0•0023	0•20	0•19
744•	-0•0034	0•41	0•18
746•	-0•0042	0•68	0•16
748•	-0•0048	0•99	0•15
750•	-0•0050	•132	0•14
752•	-0•0049	1•66	0•12
754•	-0•0046	1•98	0•10
756•	-0•0038	2•26	0•08

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2903552	2976042	3142423	3490297	(4004834)	(4429319)	4650264	4747780
150 kc.	(2903417)	2976128	3142602	3490393	4004755	(4429094)	(4649918)	(4747443)
Diff.	(135)	-86	-179	-96	(79)	(225)	(346)	(337)
Conversion	(22)	-14	-29	-16	(13)	(37)	(57)	(55)
Corr. dopp.	(2903574)	2976028	3142394	3490281	(4004847)	(4429356)	(4650321)	(4747835)

Pass No. 15 | Day 324 (Date) (19.11.68) | Time 1320 Z

Sat. No. 180 | Elevation 30° | No. of messages 9

Fixed Parameters

t_p	528•7094
$\dot{M}$	3•3660805
ωp	194•3329
$\lvert\dot{\omega}_p\rvert$	0•0020206
E	0•007407
A_o	7463•56
Ω_N	279•6683
$\dot{\Omega}_N$	0•0000013
cos i	0•000089
Ω_G	190•6236
sin i	1•0

Variable Parameters

t_k	ΔE_k	$\Delta\Lambda_k$	Δn_k
800•	0•0029	2•27	0•08
802•	0•0040	1•98	0•08
804•	0•0046	1•65	0•08
806•	0•0050	1•30	0•08
808•	0•0050	0•95	0•09
810•	0•0046	0•63	0•09
812•	0•0039	0•34	0•10
814•	0•0029	0•11	0•10
816•	0•0016	−0•06	0•10

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2975836	3074888	3275473	3628319	4070067	4420177	4619060	4718030	
150 kc.	2976067	3075189	3275672	3628423	4070038	4420034	4618942	4718190	
Diff.	-231	-301	-199	-104	29	143	118	-160	
Conversion	-38	-49	-33	-17	5	23	19	-26	
Corr. Dopp.	2975798	3074839	3275440	3628302	4070072	4420200	4619079	4718004	

Pass No. 16 | Day 324 (Date) (19.11.68) | Time 1408 Z

Sat. No. 130 | Elevation 8° | No. of messages 6

Fixed Parameters

t_p	411•1337
$\dot{M}$	3•3651828
ωp	73•1515
$\lvert\dot{\omega}_p\rvert$	0•0019798
E	0•003166
A_o	7464•89
Ω_N	49•8950
$\dot{\Omega}_N$	−0•0000290
cos i	0•006929
Ω_G	161•1492
sin i	0•999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
848•	0•0008	0•09	0•11
850•	−0•0003	0•26	0•10
852•	−0•0012	0•48	0•10
854•	−0•0018	0•76	0•10
856•	−0•0021	1•07	0•09
858•	−0•0021	1•40	0•09

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3343455	3550962	3804029	4062272	4281486				
150 kc.	3343252	3550838	3803971	4062124	(4281286)				
Diff.	203	124	58	148	(200)				
Conversion	33	20	9	24	(33)				
Corr. dopp.	3343488	3550982	3804038	4062296	(4281519)				

Pass No. 17 | Day 324 (Date) (19.11.68) | Time 1506Z

Sat. No. 180 | Elevation 66° | No. of messages 9

Fixed Parameters

t_p	528•7094
$\dot{M}$	3•3660805
ωp	194•3329
$\lvert\dot{\omega}_p\rvert$	0•0020206
E	0•007407
A_o	7463•56
Ω_N	279•6683
$\dot{\Omega}_N$	0•0000013
cos i	0•000089
Ω_G	190•6236
sin i	1•0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
906•	0•0042	2•44	0•05
908•	0•0054	2•17	0•07
910•	0•0062	1•84	0•08
912•	0•0067	1•49	0•10
914•	0•0068	1•13	0•12
916•	0•0066	0•79	0•13
918•	0•0061	0•47	0•14
920•	0•0053	0•19	0•16
922•	0•0042	-0•02	0•17

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2888884	2942166	3085228	3449770	(4060603)	4519169	4712396	4784521	
150 kc.	2889320	2942540	3085488	(3449896)	4060570	4519027	4712245	4784512	
Diff.	-436	-374	-260	(-126)	(33)	142	151	9	
Conversion	-71	-61	-43	(-21)	(5)	23	25	1	
Corr. dopp.	2888813	2942105	3085185	(3449749)	(4060609)	4519192	4712421	4784522	

Pass No. 18 | Day 324 (Date) (19.11.68) | Time 1558 Z

Sat. No. 120 | Elevation 18° | No. of messages 7

Fixed Parameters

t_p	677•4253
$\dot{M}$	3•3802876
ωp	168•3148
$\lvert\dot{\omega}_p\rvert$	0•0020197
E	0•001837
A_o	7442•63
Ω_N	327•7173
$\dot{\Omega}_N$	0•0000173
cos i	-0•003937
Ω_G	227•9044
sin i	0•999992

Variable Parameters

t_k	ΔE_k	$\Delta\Lambda_k$	Δn_k
958•	0•0029	1•83	0•10
960•	0•0034	1•50	0•10
962•	0•0035	1•16	0•10
964•	0•0033	0•84	0•10
966•	0•0027	0•55	0•10
968•	0•0019	0•31	0•10
970•	0•0009	0•13	0•10

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3176410	3391331	3708943	4067650	4362861	4553908			
150 kc.	3176453	3391429	3709000	4067656	4362866	4554073			
Diff.	-43	-98	-57	-6	-5	-165			
Conversion	-7	-16	-9	-1	-1	-27			
Corr. dopp.	3176403	3391315	3708934	4067649	4362860	4553881			

Pass No. 19 | Day 325 (Date) (20.11.68) | Time 0948 Z

Sat. No. 130 | Elevation 25° | No. of messages 7

Fixed Parameters

t_p	362·1494
$\dot{M}$	3·365185
ωp	71·4189
$\lvert\dot{\omega}_p\rvert$	0·0019824
E	0·003147
A_o	7464·88
Ω_N	49·8566
$\dot{\Omega}_N$	-0·0000292
cos i	0·006933
Ω_G	149·8553
sin i	0·999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
588·	-0·0062	0·36	0·10
590·	-0·0071	0·63	0·10
592·	-0·0078	0·95	0·10
594·	-0·0082	1·29	0·10
596·	-0·0083	1·65	0·10
598·	-0·0081	1·99	0·09
600·	-0·0077	2·31	0·08

Doppler Shifts (conversion factor 9/55 (Diff); corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3218545	3495448	3884864	4257125	4504939	4640419			
150 kc.	3218727	3495568	3884862	4256892	4504671	4639906			
Diff.	-182	-120	2	233	268	513			
Conversion	-30	-20	0	38	44	84			
Corr. dopp.	3218515	3495428	3884864	4257163	4504983	4640503			

Pass No. 20	Day 325 (Date) (20.11.68)	Time 1132 Z
Sat. No. 130	Elevation 74°	No. of messages 9

Fixed Parameters

t_p	362•1494
$\dot{M}$	3•365185
ωp	71•4189
$\lvert\dot{\omega}_p\rvert$	0•0019824
E	0•003147
A_o	7464•88
Ω_N	49•8566
$\dot{\Omega}_N$	-0•0000292
cos i	0•006933
Ω_G	149•8553
sin i	0•999976

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
692•	-0•0030	0•07	0•20
694•	-0•0041	0•24	0•20
696•	-0•0051	0•48	0•19
698•	-0•0059	0•76	0•18
700•	-0•0064	1•09	0•16
702•	-0•0066	1•43	0•14
704•	-0•0065	1•77	0•13
706•	-0•0061	2•09	0•11
708•	-0•0054	2•37	0•09

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2850075	2895325	3029665	3414374	4102083	4580672	4757197	4816714	
150 kc.	2850150	2895663	3030001	3414543	(4101968)	4580344	4756676	4816385	
Diff.	-75	-338	-336	-169	(115)	328	521	329	
Conversion	-12	-56	-55	-28	(19)	54	85	54	
Corr. Dopp.	2850063	2895269	3029610	3414346	(4102102)	4580726	4757282	4816768	

Pass No. 21 | Day 325 (Date) (20.11.68) | Time 1234 Z

Sat. No. 180 | Elevation 16° | No. of messages 8

Fixed Parameters

t_p	585·9757
$\dot{M}$	3·3660759
ωp	191·2273
$\lvert\dot{\omega}_p\rvert$	0·0020195
E	0·0017464
A_o	7463·57
Ω_N	279·6677
$\dot{\Omega}_N$	0·0000012
cos i	0·000085
Ω_G	205·9651
sin i	1·0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
754·	0·0033	1·83	0·08
756·	0·0038	1·49	0·07
758·	0·0040	1·14	0·07
760·	0·0038	0·80	0·07
762·	0·0033	0·49	0·07
764·	0·0024	0·22	0·07
766·	0·0013	0·02	0·07
768·	0·0000	-0·11	0·06

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3198934	3396182	3681105	4008773	4294901	4494074	(4615694)		
150 kc.	3199150	3396404	3681136	4008649	4294704	4493980	4616314		
Diff.	-216	-222	-31	124	197	94	(-620)		
Conversion	-35	-36	-5	20	32	15	(-101)		
Corr. dopp.	3198899	3396146	3681100	4008793	4294933	4494089	(4615593)		

Pass No. 22 | Day 325 (Date) (20.11.68) | Time 1418 Z

Sat. No. 180 | Elevation 69° | No. of messages 9

Fixed Parameters

t_p	585·9757
$\dot{M}$	3·3660759
ωp	191·2273
$\lvert\dot{\omega}_p\rvert$	0·0020195
E	0·0007464
A_o	7463·57
Ω_N	279·6677
$\dot{\Omega}_N$	0·0000012
cos i	0·000085
Ω_G	205·9651
sin i	1·0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
858·	0·0029	2·32	0·08
860·	0·0039	2·01	0·10
862·	0·0046	1·68	0·11
864·	0·0050	1·32	0·12
866·	0·0050	0·96	0·13
868·	0·0047	0·63	0·15
870·	0·0040	0·33	0·15
872·	0·0030	0·08	0·16
874·	0·0019	-0·10	0·17

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2885060	2955375	3155065	(3652930)	4296680	4645404	4772229	4816954	
150 kc.	2885396	2955729	3155399	3653019	4296466	4645135	4772355	4817297	
Diff.	-336	-354	-334	(-89)	214	269	-126	-343	
Conversion	-55	-58	-55	(-15)	35	44	-21	-56	
Corr. dopp.	2885005	2955317	3155010	(3652915)	4296715	4645448	4772208	4816898	

Pass No. 23 | Day 325 (Date) (20.11.68) | Time 1508 Z

Sat. No. 120 | Elevation 7° | No. of messages 5

Fixed Parameters

t_p	728·562
$\dot{M}$	3·3802886
ωp	165·7755
$\lvert\dot{\omega}_p\rvert$	0·0020198
E	0·001893
A_o	7442·63
Ω_N	327·7407
$\dot{\Omega}_N$	0·0000171
cos i	-0·003937
Ω_G	241·7092
sin i	0·999992

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
908·	0·0032	1·09	0·02
910·	0·0027	0·78	0·02
912·	0·0020	0·51	0·01
914·	0·0010	0·28	0·01
916·	-0·0002	0·13	0·00

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	(3666191)	3934647	4186627	4384550					
150 kc.	3666407	3935084	4186774	4384297					
Diff.	-216	-437	-147	253					
Conversion	-35	-71	-24	41					
Corr. dopp.	3666156	3934576	4186603	4384591					

Pass No. 24	Day 325 (Date) (20.11.68)	Time 1552 Z
Sat. No. 140	Elevation 7°	No. of messages 6

Fixed Parameters

t_p	832•5311
$\dot{M}$	3•3716413
ωp	64•8836
$\lvert\dot{\omega}_p\rvert$	0•0019762
E	0•006024
A_o	7455•36
Ω_N	160•8067
$\dot{\Omega}_N$	-0•0000514
cos i	0•012551
Ω_G	267•7727
sin i	0•999921

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
952•	-0•0042	0•16	-0•06
954•	-0•0052	0•40	-0•05
956•	-0•0061	0•69	-0•04
958•	-0•0067	1•02	-0•03
960•	-0•0070	1•38	-0•02
962•	-0•0071	1•73	-0•01

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion

figures in brackets show estimated values

400 kc.	3506268	3723733	3962148	4181867	(4355410)				
150 kc.	3506261	3723387	3961874	4181787	4355494				
Diff.	7	346	274	80	(-84)				
Conversion	1	57	45	13	(-14)				
Corr. dopp.	3506269	3723790	3962193	4181880	(4355396)				

Pass No. 25 | Day 325 (Date) (20.11.68) | Time 1608 Z

Sat. No. 180 | Elevation 28° | No. of messages 8

Fixed Parameters

t_p	585·9757
$\dot{M}$	3·3660759
ωp	191·2273
$\lvert\dot{\omega}_p\rvert$	0·0020195
E	0·007464
A_o	7463·57
Ω_N	279·6677
$\dot{\Omega}_N$	0·0000012
cos i	0·000085
Ω_G	205·9651
sin i	1·0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
968·	0·0069	1·88	0·07
970·	0·0074	1·53	0·08
972·	0·0076	1·16	0·10
974·	0·0074	0·80	0·11
976·	0·0069	0·47	0·12
978·	0·0061	0·18	0·13
980·	0·0051	-0·04	0·14
982·	0·0039	-0·20	0·14

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	3221607	3479446	3844933	(4208971)	4463924	4608504	4683571		
150 kc.	3221749	3479629	3845003	4209149	4464542	4608768	(4683858)		
Diff.	-142	-183	-70	(-178)	-618	-264	(-287)		
Conversion	-23	-30	-11	(-29)	-101	-43	(-47)		
Corr. dopp.	3221584	3479416	3844922	(4208942)	4463823	4608461	(4683524)		

Pass No. 26 | Day 326 (Date) (21.11.68) | Time 1330 Z

Sat. No. 180 | Elevation 38° | No. of messages 8

Fixed Parameters

t_p	536•3076
$\dot{M}$	3•3660797
ωp	188•3849
$\lvert\dot{\omega}_p\rvert$	0•0020217
E	0•007521
A_o	7463•56
Ω_N	279•6672
$\dot{\Omega}_N$	0•0000012
cos i	0•000074
Ω_G	194•4997
sin i	1•0

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
810•	0•0024	2•20	0•11
812•	0•0033	1•88	0•12
814•	0•0039	1•54	0•12
816•	0•0040	1•18	0•13
818•	0•0039	0•83	0•13
820•	0•0033	0•51	0•14
822•	0•0025	0•24	0•14
824•	0•0014	0•02	0•14

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2966375	(3088476)	(3352909)	3809395	4284607	4575859	4713281		
150 kc.	2966732	3088712	3353117	3809365	4284421	4575578	4713022		
Diff.	-357	(-236)	(-208)	30	186	281	259		
Conversion	-58	(-39)	(-34)	5	30	46	42		
Corr. dopp.	2966317	(3088437)	(3352875)	3809400	4284637	4575905	4713323		

Pass No. 27 | Day 326 (Date) (21.11.68) | Time 1746 Z

Sat. No. 120 | Elevation 82° | No. of messages 5

Fixed Parameters

t_p	673•2059
$\dot{M}$	3•3802868
ωp	163•4779
$\lvert\dot{\omega}_p\rvert$	0•0020176
E	0•001953
A_o	7442•63
Ω_N	327•7621
$\dot{\Omega}_N$	0•0000173
cos i	−0•003938
Ω_G	228•818
sin i	0•999992

Variable Parameters

t_k	ΔE_k	$\Delta\Lambda_k$	Δn_k
1066•	0•0050	1•12	0•14
1068•	0•0047	0•80	0•15
1070•	0•0042	0•50	0•17
1072•	0•0034	0•25	0•18
1074•	0•0023	0•07	0•18

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	4128538	4608142	4774949	4828902					
150 kc.	(4128526)	4608104	4774968	4828901					
Diff.	(+12)	38	−19	1					
Conversion	(+2)	6	−3	0					
Corr. dopp.	(4128540)	4608148	4774946	4828902					

Pass No. 28 | Day 326 (Date) (21.11.68) | Time 1832 Z

Sat. No. 140 | Elevation 88° | No. of messages 9

Fixed Parameters

t_p	780•7257
$\dot{M}$	3•3716435
ωp	62•6345
$\lvert\dot{\omega}_p\rvert$	0•0019793
E	0•005978
A_o	7455•35
Ω_N	160•7375
$\dot{\Omega}_N$	-0•0000515
cos i	0•012555
Ω_G	255•7716
sin i	0•999921

Variable Parameters

t_k	ΔE_k	ΔA_k	Δn_k
1112•	-0•0028	-0•04	0•19
1114•	-0•0040	0•10	0•19
1116•	-0•0050	0•32	0•18
1118•	-0•0059	0•59	0•17
1120•	-0•0065	0•90	0•16
1122•	-0•0069	1•23	0•15
1124•	-0•0069	1•58	0•13
1126•	-0•0066	1•90	0•11
1128•	-0•0061	2•20	0•09

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

figures in brackets show estimated values

400 kc.	2845113	2875173	2970969	3269497	(3945636)	4532320	4753873	4824474	
150 kc.	2845352	2875209	2970968	3269520	(3945613)	4532264	4753794	4824331	
Diff.	-239	-36	1	-23	(23)	56	79	143	
Conversion	-39	-6	0	-4	(4)	9	13	23	
Corr. dopp.	2845074	2875167	2970969	3269493	(3945640)	4532329	4753886	4824497	

Pass No. 29 | Day 334 (Date) (29.11.68) | Time 0938 Z

Sat. No. 130 | Elevation 37° | No. of messages 9

Fixed Parameters

t_p	349•0065
$\dot{M}$	3•3651957
ω_p	54•3765
$\lvert\dot{\omega}_p\rvert$	0•0019852
E	0•002886
Λ_o	7464•87
Ω_N	49•4972
$\dot{\Omega}_N$	-0•0000292
cos i	0•006946
Ω_G	155•4316
sin i	0•999976

Variable Parameters

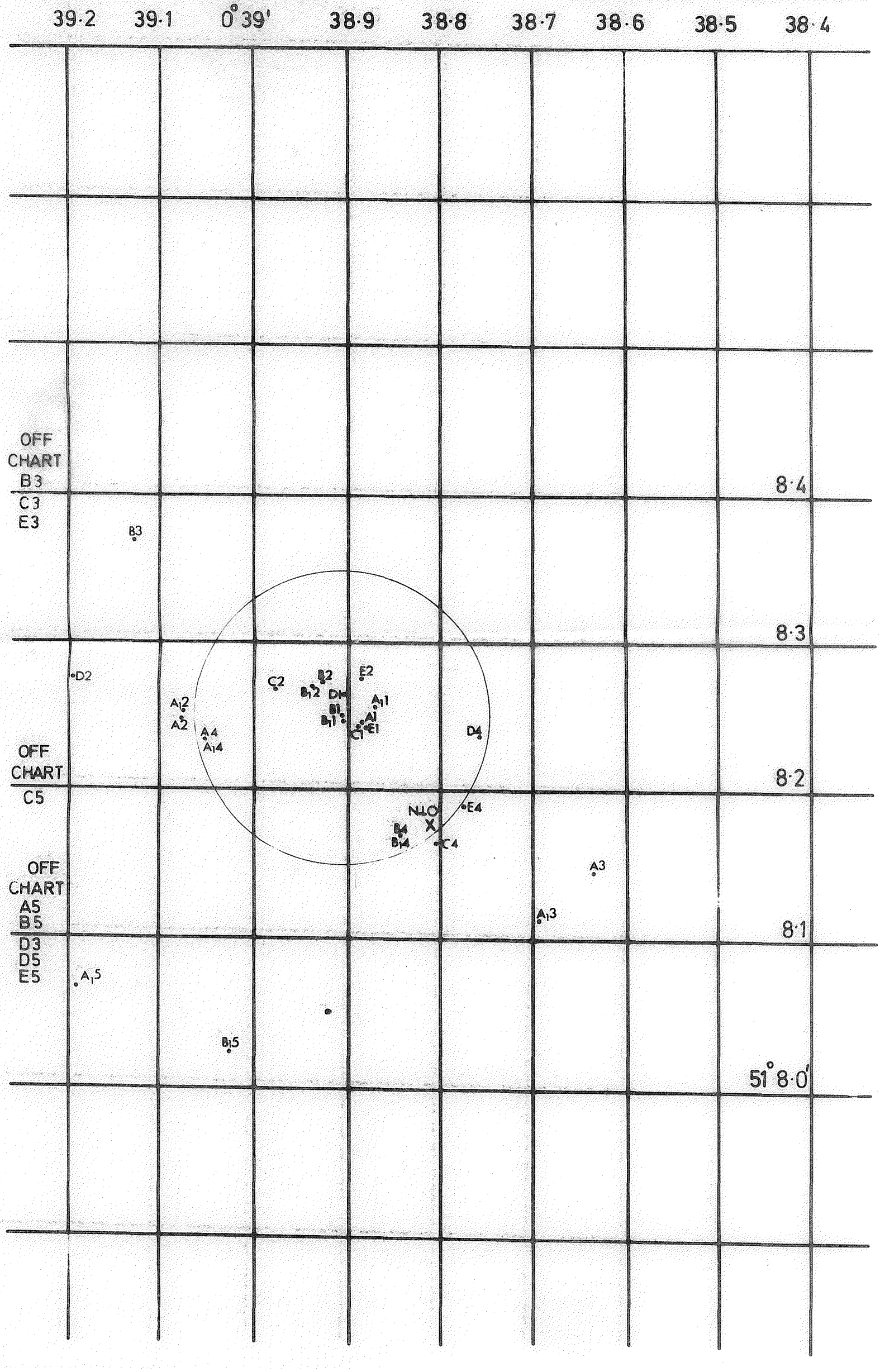
t_k	ΔE_k	$\Delta\Lambda_k$	Δn_k
578•	-0•0040	0•16	0•07
580•	-0•0050	0•37	0•08
582•	-0•0060	0•64	0•08
584•	-0•0066	0•96	0•08
586•	-0•0070	1•30	0•08
588•	-0•0071	1•65	0•07
590•	-0•0068	1•99	0•06
592•	-0•0064	2•30	0•05
594•	-0•0056	2•56	0•04

Doppler Shifts (conversion factor 9/55 (Diff): corr. dopp. = 400 + conversion)

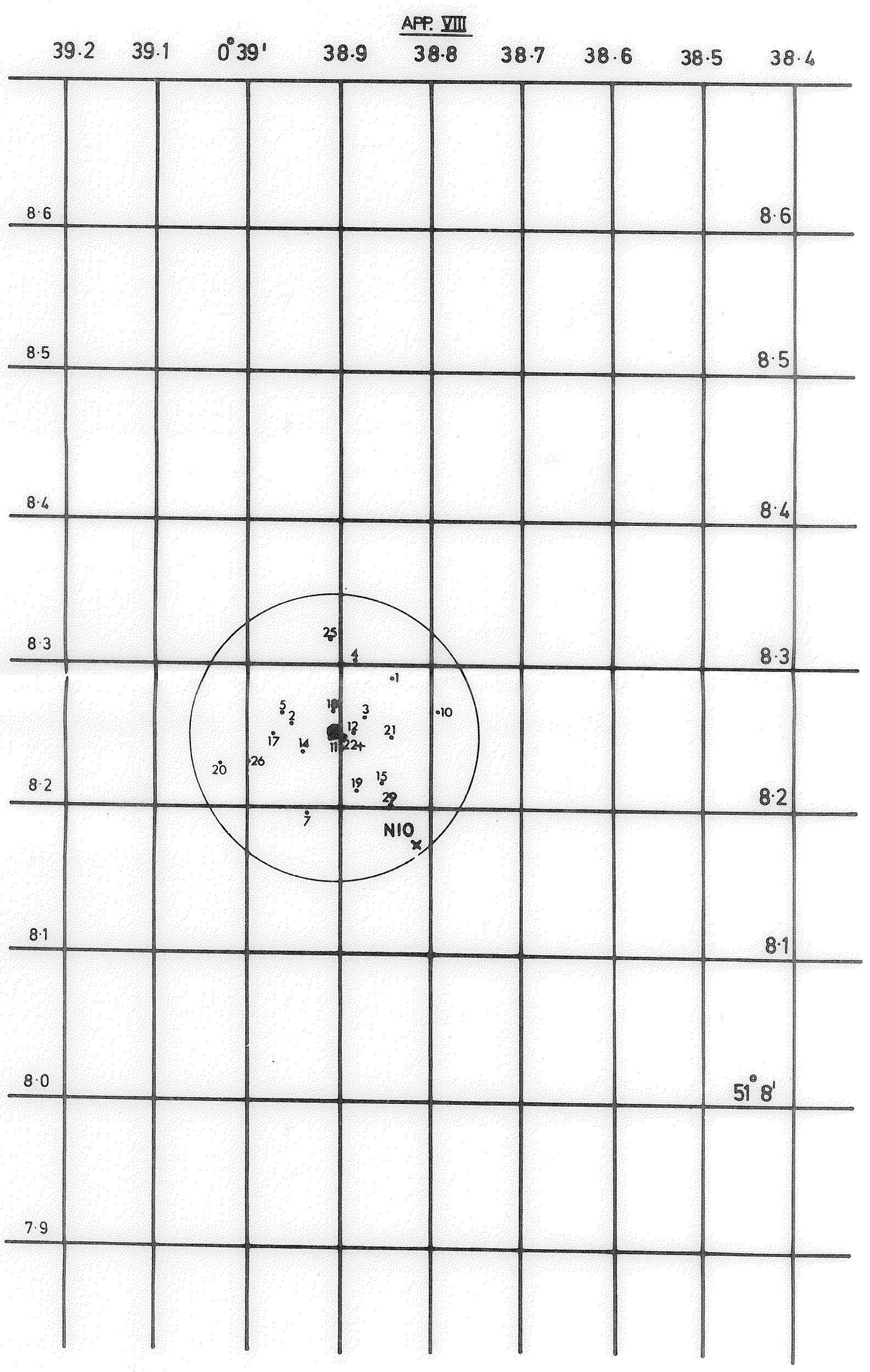
figures in brackets show estimated values

400 kc.	2968617	3093943	3368506	3838227	4308372	4583980	4710533	4765411	
150 kc.	2968655	3094080	3368610	3838218	4308192	4583700	4710186	4765465	
Diff.	-38	-137	-104	9	180	280	347	-54	
Conversion	-6	-22	-17	1	29	46	57	-9	
Corr. dopp.	2968611	3093921	3368489	3838228	4308401	4584026	4710590	4765402	

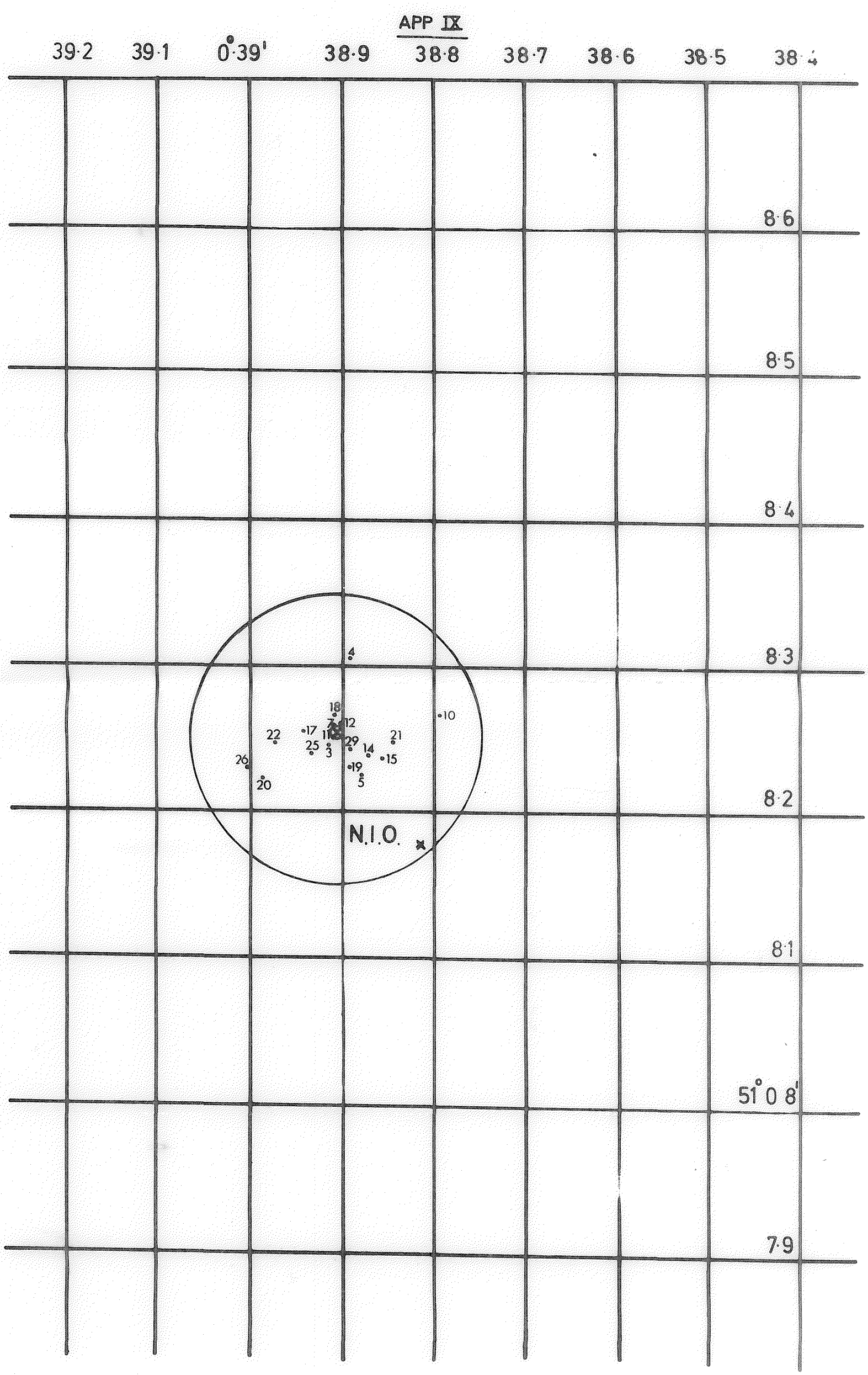
MEAN POSITIONS APP. VII. VARIOUS METHODS



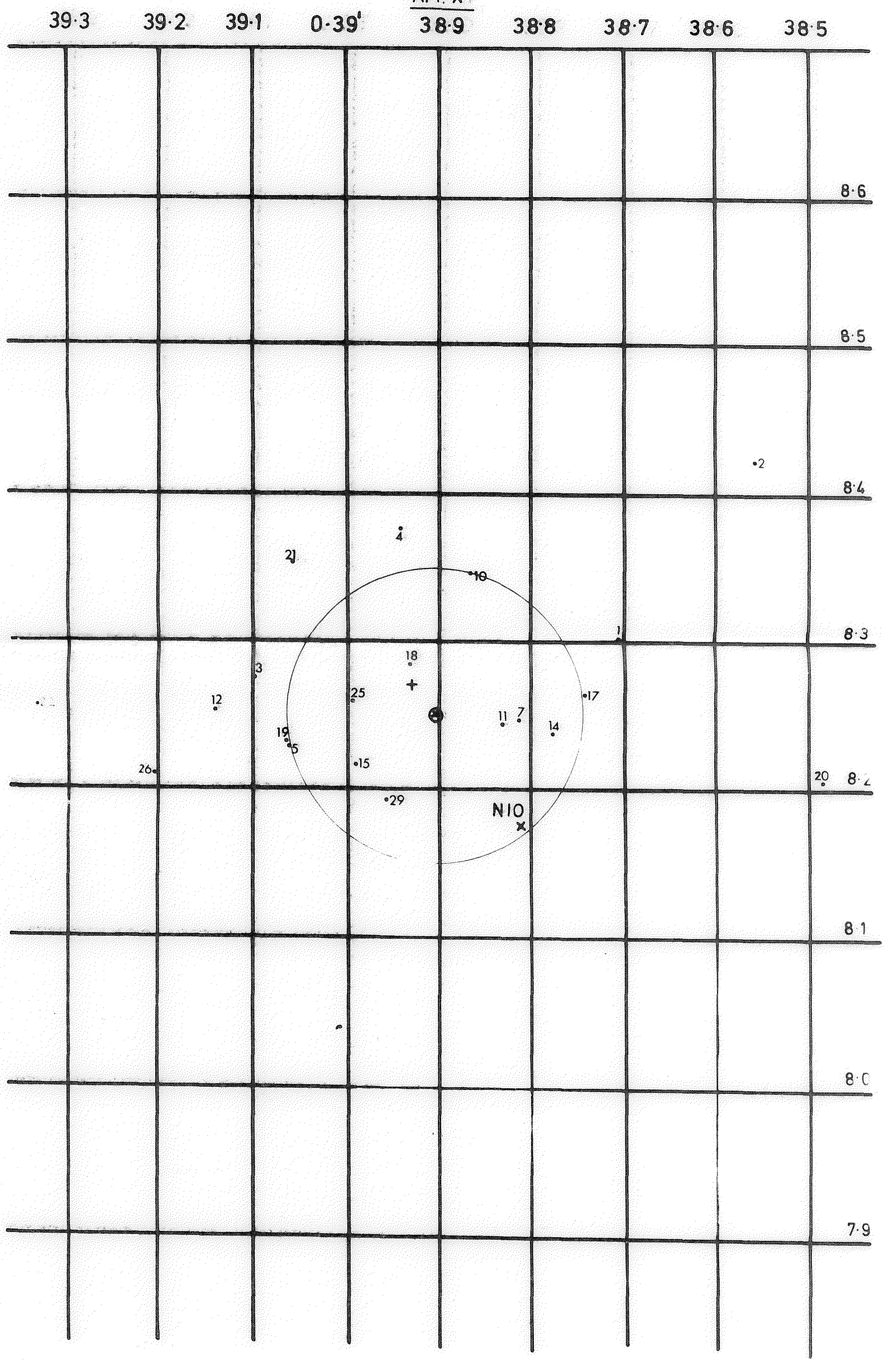
APP. VIII


39·2
39·1
0° 39'
38·9
38·8
38·7
38·6
38·5
38·4
8·6
8·5
8·4
8·3
8·2
8·1
8·0
7·9
51° 8'
25
4
1
5
2
18
3
10
12
21
17
14
11
22
26
20
19
15
29
7
N10

APP IX

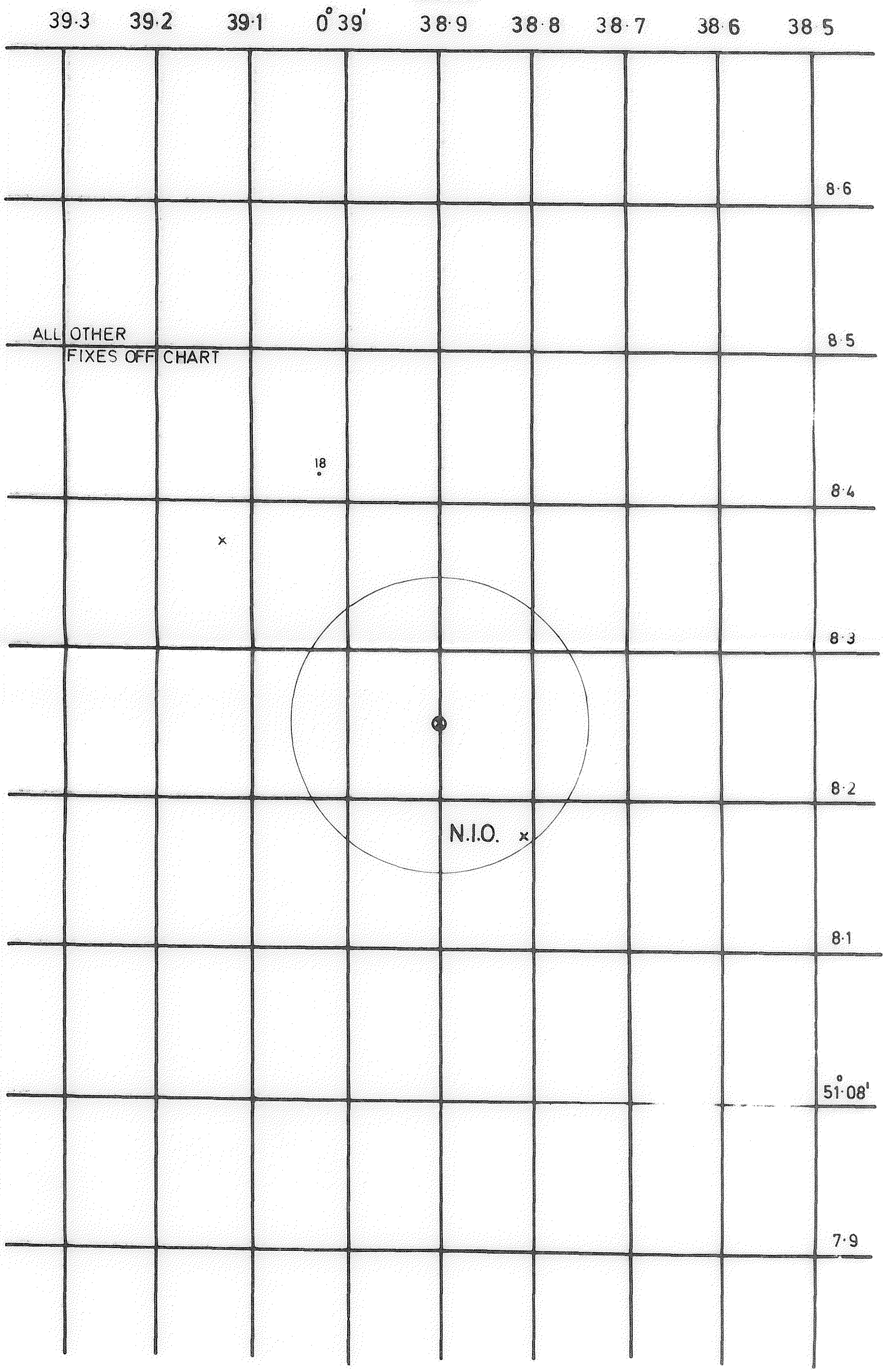

39·2
39·1
0°39'
38·9
38·8
38·7
38·6
38·5
38·4
8·6
8·5
8·4
8·3
8·2
8·1
51°08'
7·9
4
18
12
10
22
17
1
29
21
25
3
14
15
26
19
20
5
N.I.O.

APP. X



39·3
39·2
39·1
0·39'
38·9
38·8
38·7
38·6
38·5
8·6
8·5
8·4
8·3
8·2
8·1
8·0
7·9
2
4
21
10
1
18
3
25
17
12
11
7
14
19
5
15
26
20
29
N10

APP XI


39·3
39·2
39·1
0° 39'
38·9
38·8
38·7
38·6
38·5
8·6
8·5
8·4
8·3
8·2
8·1
51° 08'
7·9
ALL OTHER
FIXES OFF CHART
18
N.I.O.

APP. XII

39·2 39·1 0° 39' 38·9 38·8 38·7 38·6 38·5 38·4

8·6

8·5

8·4

OFF CHART

10
26

OFF CHART

14
17
22

8·3

11
29
25
19
2
5
1
3
18
15
12
4
20
N10
7

8·2

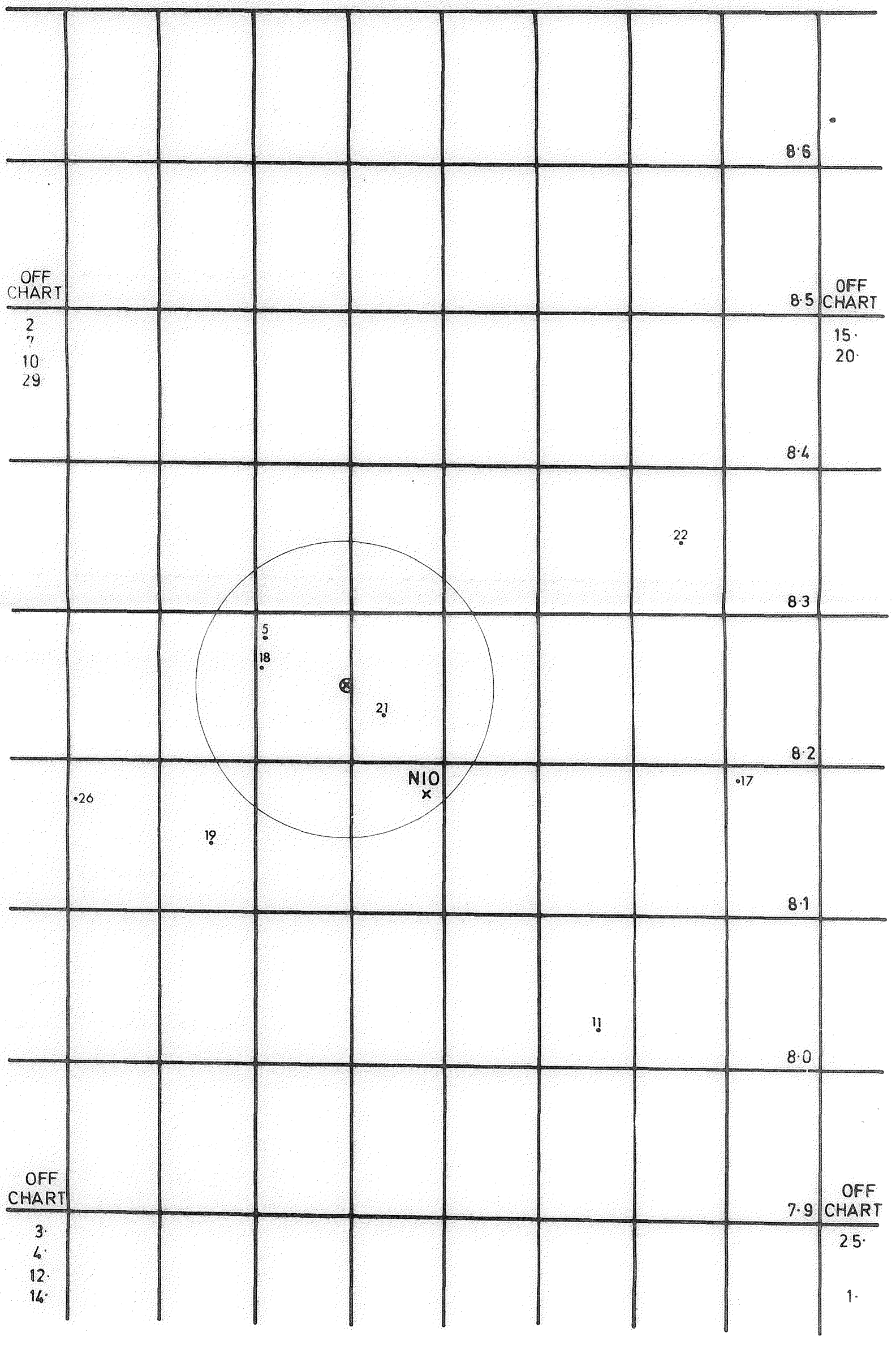
8·1

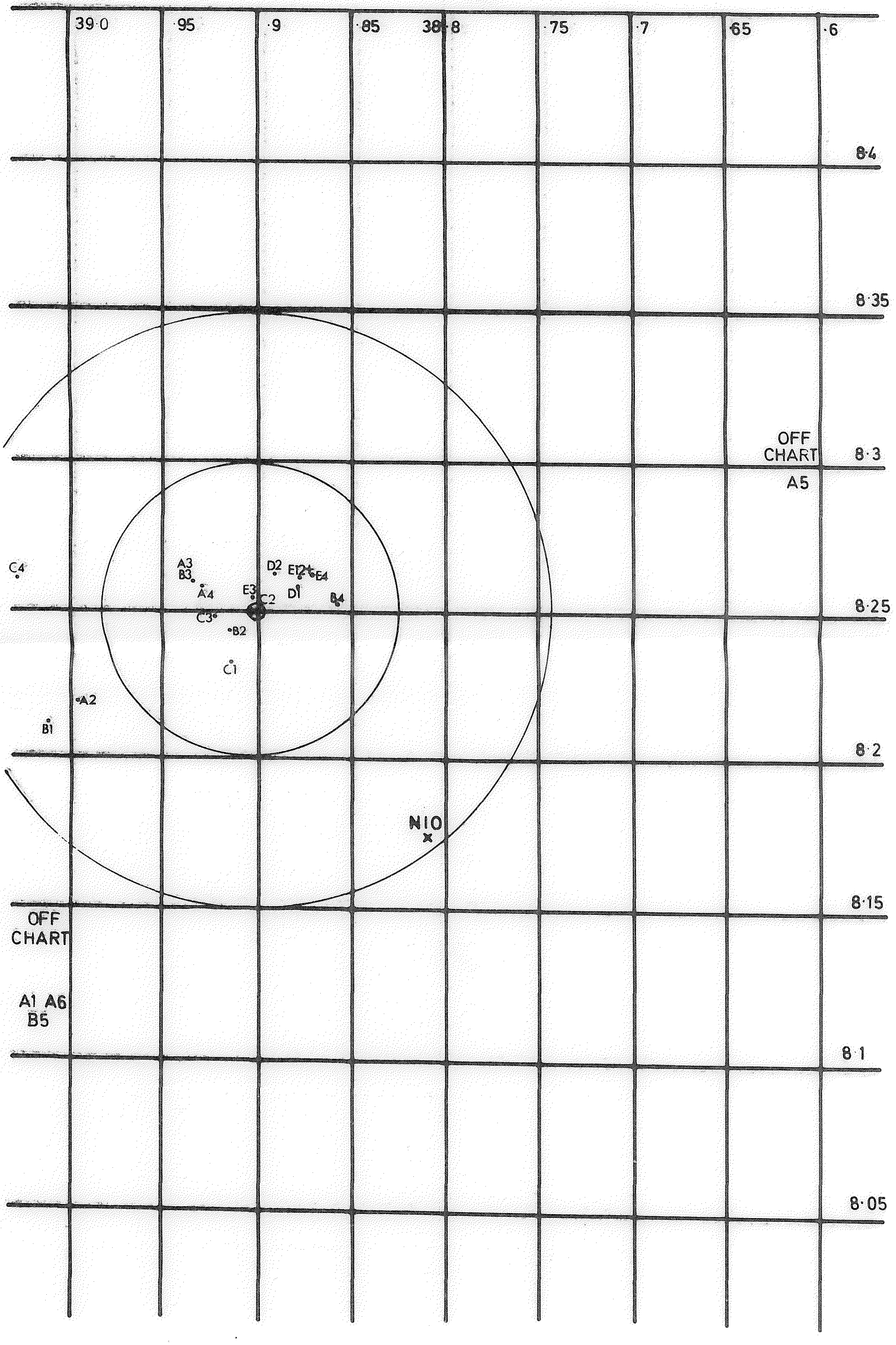
21

51° 08'

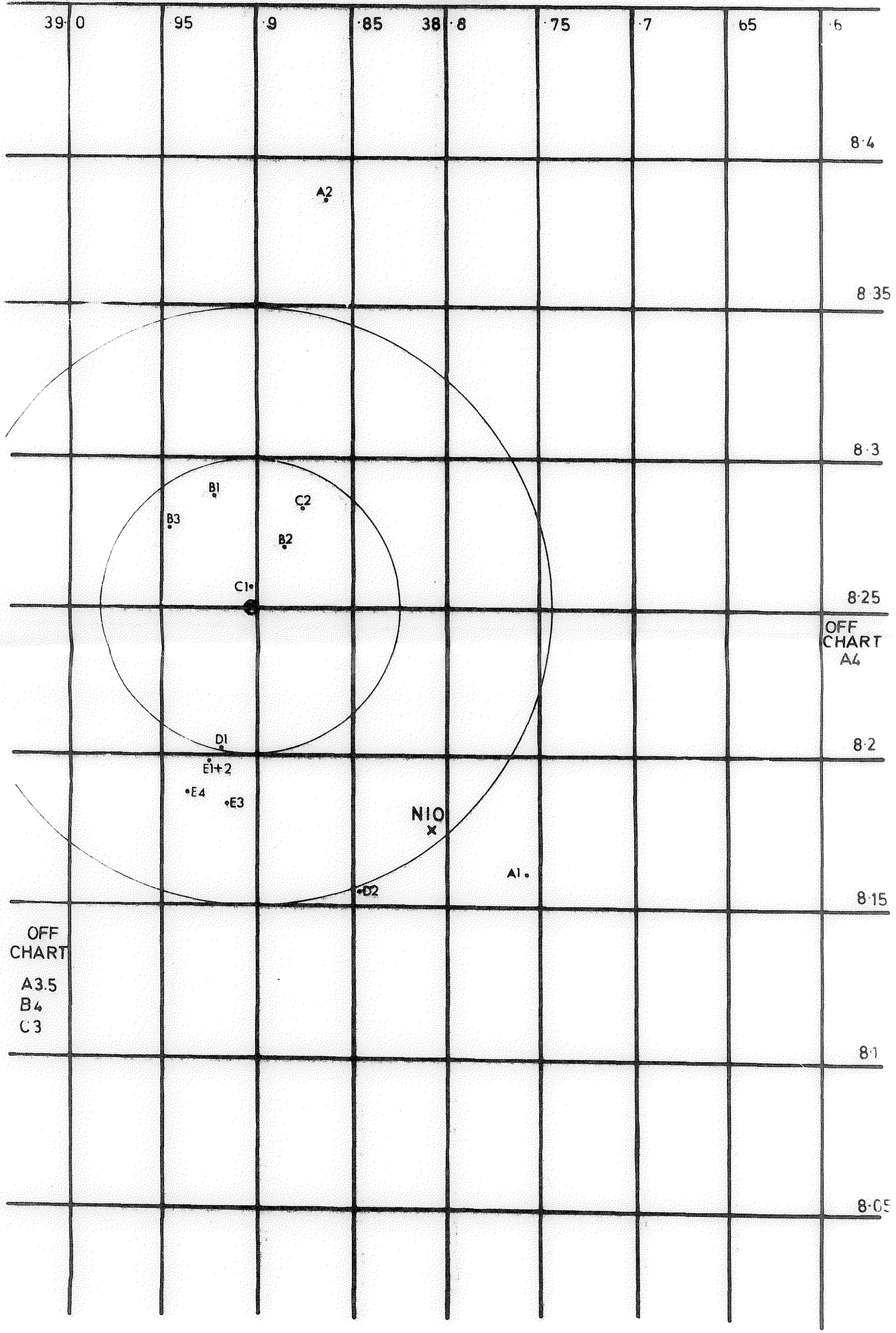
7·9

APP XIII

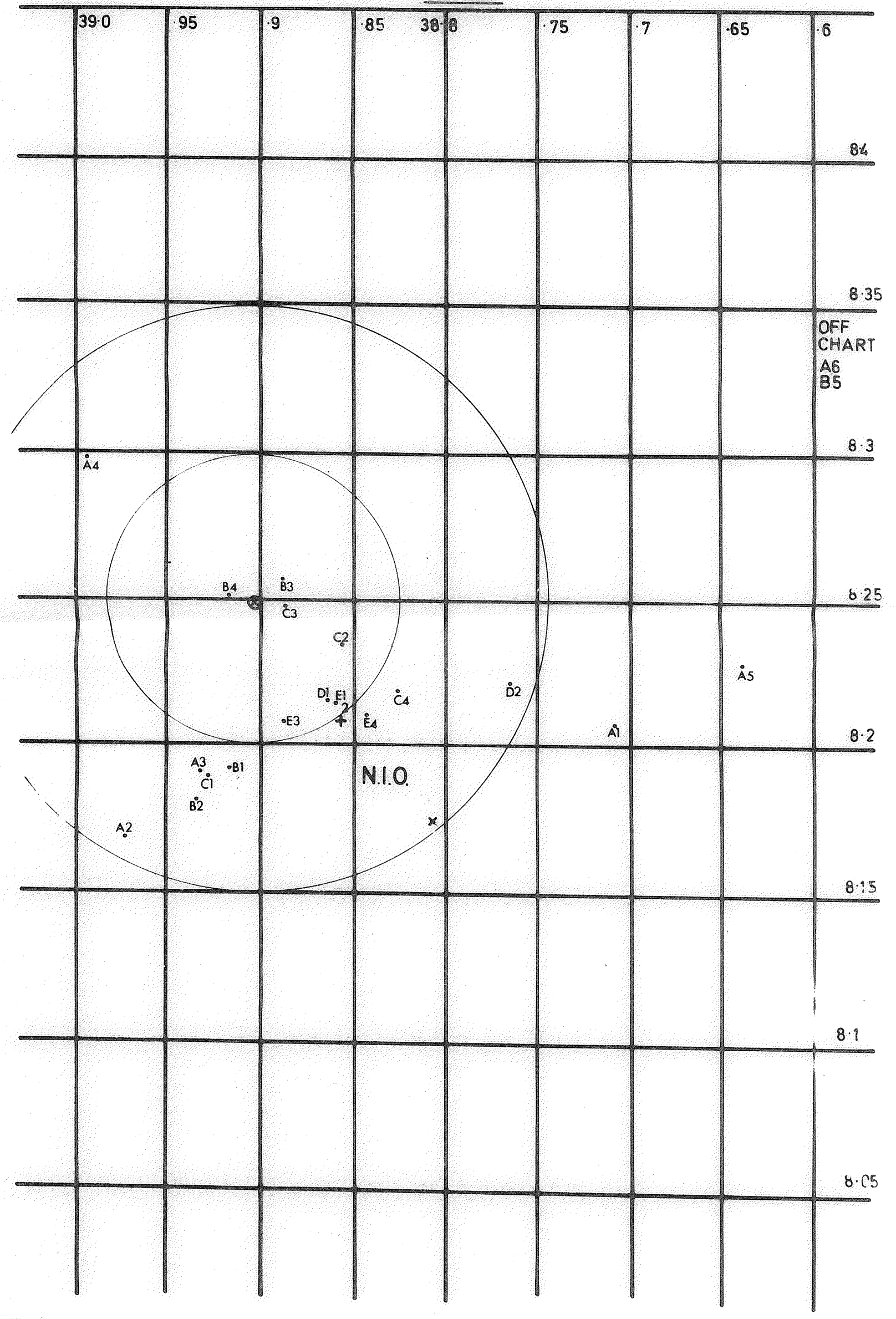

39·2
39 1
0 39'
38·9
38·8
38·7
38·6
38·5
38·4
8·6
8·5
8·4
8·3
8·2
8·1
8·0
7·9
OFF CHART
2
7
10
29
15·
20·
22
5
18
21
NIO
·26
19
·17
11
3·
4·
12·
14·
25·
1·


39·0
·95
·9
·85
38·8
·75
·7
·65
·6
8·4
8·35
OFF CHART
8·3
A5
C4
A3
B3
A4
E3
C2
D2
E1
E2
E4
D1
B4
8·25
C3
B2
C1
A2
B1
8·2
N10
8·15
OFF CHART
A1 A6 B5
8·1
8·05

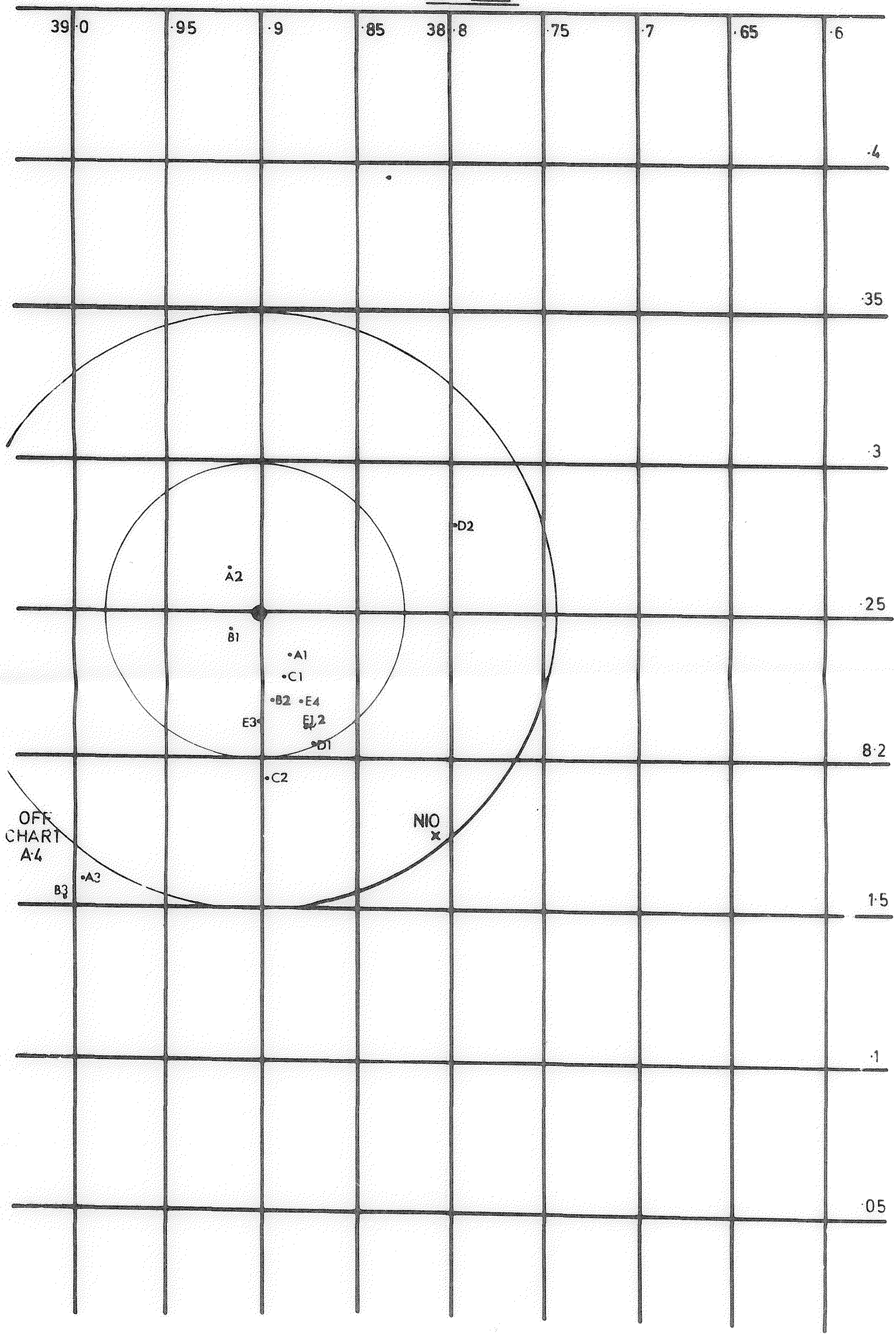
APP XV

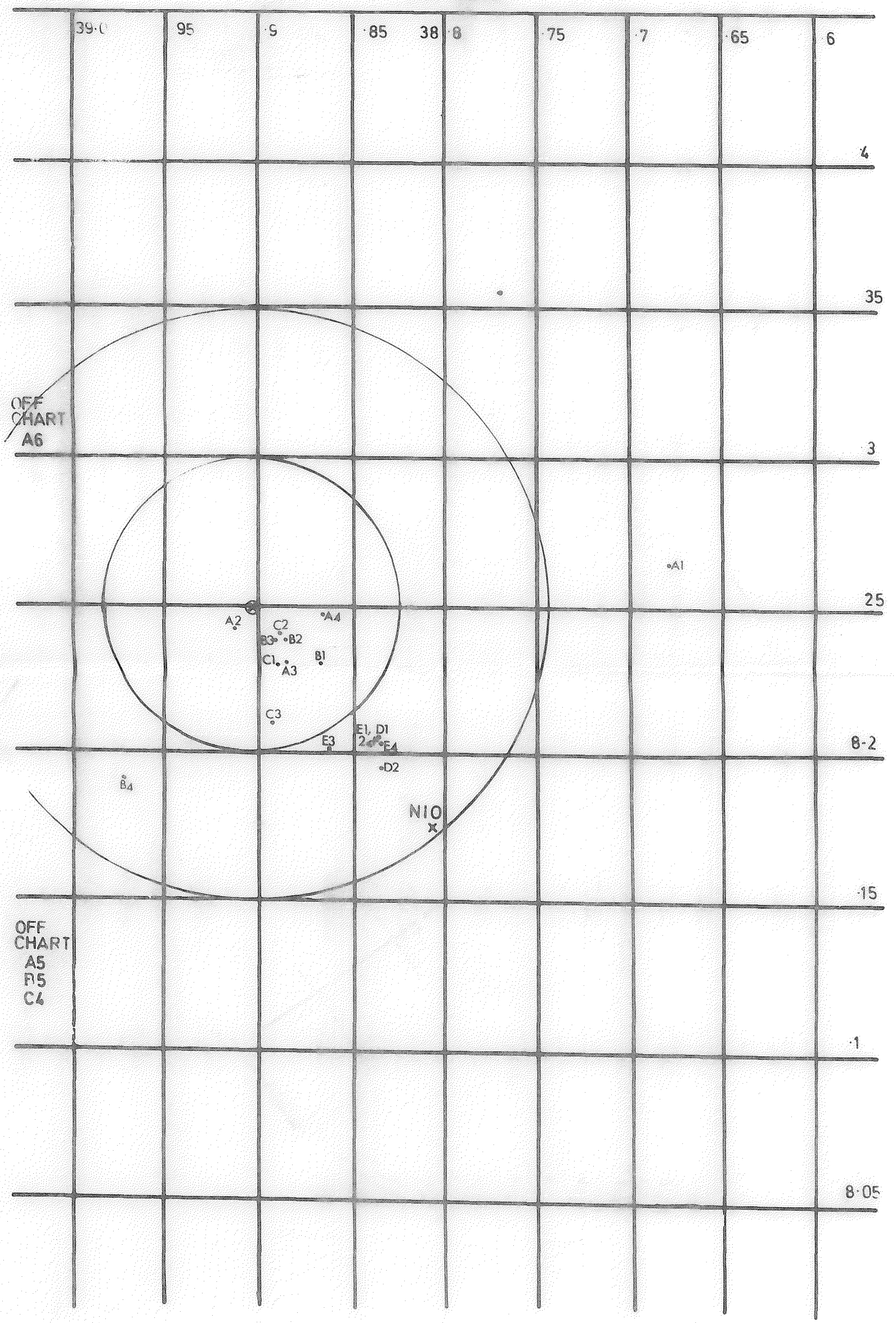

39·0
95
·9
·85
38
·8
·75
·7
65
·6
8·4
8·35
8·3
8·25
8·2
8·15
8·1
8·05
A2
B1
C2
B3
B2
C1
D1
E1+2
E4
E3
NIO
A1
D2
OFF CHART A4
OFF CHART A3.5 B4 C3

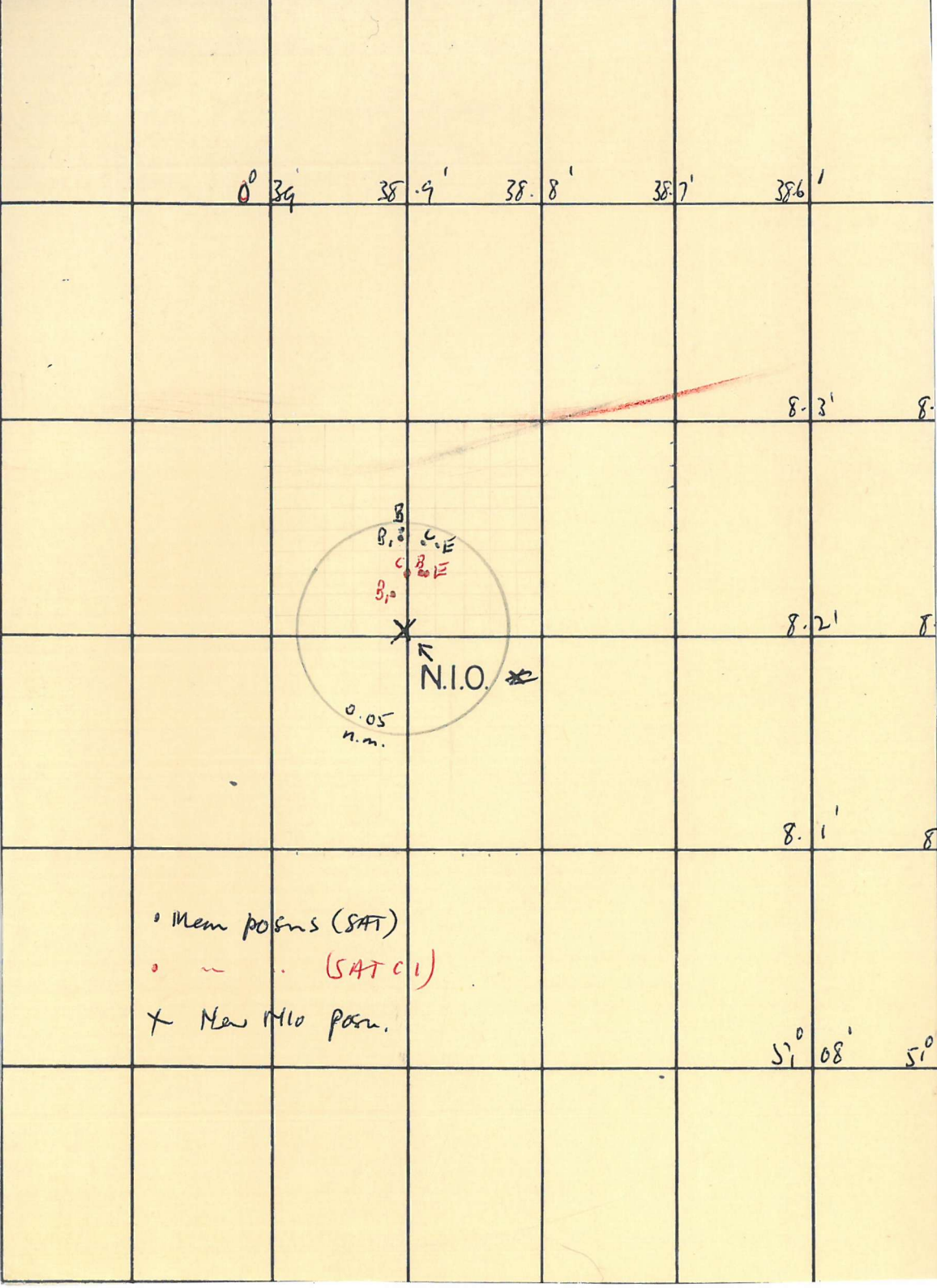
APP XVI


39·0
·95
·9
·85
38·8
·75
·7
·65
·6
84
8·35
OFF CHART
A6
B5
8·3
A4
B4
B3
C3
C2
6·25
A5
D1
E1
2
C4
D2
E3
E4
A1
8·2
A3
B1
C1
B2
N.I.O.
A2
8·15
8·1
8·05

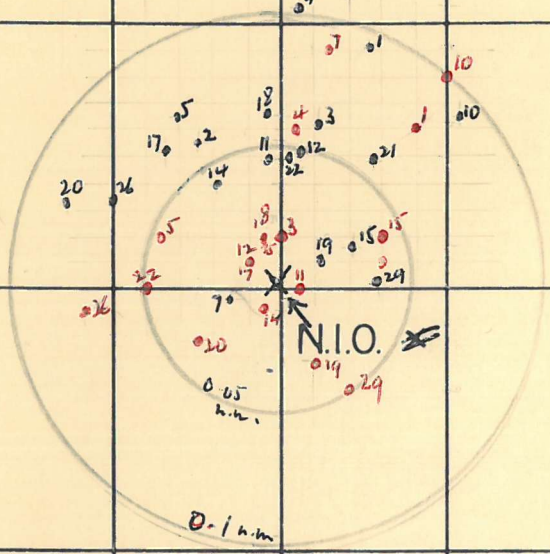
APP XVII


39·0
·95
·9
·85
38·8
·75
·7
·65
·6
·4
·35
·3
·25
8·2
1·5
·1
·05
D2
A2
B1
A1
C1
B2
E4
E3
E1,2
D1
C2
OFF CHART A4
A3
B3
NIO


39·0
95
9
·85
38
8
·75
7
·65
6
4
35
3
25
8·2
·15
·1
8·05
OFF CHART A6
OFF CHART A5 F5 C4
A1
A2
A4
C2
B3
B2
C1
A3
B1
C3
E3
E1, D1
F2
F4
D2
B4
N10



0° 39'
38.9'
38.8'
38.7'
38.6'
8.3'
8.2'
8.1'
51° 08'
B
B1
C
E
N.I.O.
0.05 n.m.
• Mean posns (SAT)
• ~ . (SAT C1)
X New NIO posn.



35.1' 0° 35' 38.9' 38.8' 38.7' 38.6'

8.3'

8.2'

8.1'

51° 08'

• IBI fixes (SAT)

• " (SAT cl)

x Mean MIO posn.