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INITIAL FLIGHT TEST OF A LORAN-C RECEIVER/DATA COLLECTION SYSTEM

Described are the flight test results of a Loran-C navigation receiver/data collection system designed at Ohio University.

by

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I. INTRODUCTION

The Avionics Engineering Center has been conducting research in developing a low-cost Loran-C receiver for general aviation use. During this time there have been several improvements made to the initial low-cost receiver design produced at Ohio University. The most recent improvement involves the use of a phase-locked loop oscillator to track the Loran-C signals.[1] At the present time this receiver appears to be a promising candidate for a low-cost Loran-C system.

The purpose of this paper is to describe the preparation and procedure of a flight test conducted with this receiver and also to show that such a receiver is a viable alternative for future work in developing a low-cost Loran-C navigat r.

II. OBJECTIVES

The first objective of this flight test is to navigate along a line of constant time difference using the output LOP deviation indication of the Mini-L PLL receiver. The results of this test could then be compared to the theoretical path that was chosen. In this way it could be shown that the Mini-L PLL receiver is capable of providing guidance information along a predetermined path. Also, the results could demonstrate the possible path deviation that would occur with the position information provided by the Mini-L PLL receiver.

The second objective is to determine the general flyability of the receiver/data collection package. This would involve the evaluation of the method with which the LOP data is displayed to the pilot.

III. FLIGHT TEST PROCEDURE

The flight test was conducted in a Piper Cherokee 180. The pilot was R.W. Lilley, J.P. Fischer was the navigator and J.D. Nickum was the equipment operator. The navigator was seated in the copilot position, the equipment operator was seated behind the pilot and the equipment pallet was placed in the seat behind the navigator.

The aircraft was positioned on the ramp in front of the Avionics Engineering Center hangar at the Albany airport. The flight test software and Mini-L receiver were initialized before the aircraft engine was started. After the aircraft was started and idling on the ramp the software was initialized with the time and the software auto-logger was started. This auto-logger will record in memory the time differences and a modified GRI count after every 1200 GRI's (approximately every 2 minutes).[2] The RUSTRAK chart recorder used to chart the TD's was also started before the aircraft began to taxi. After the receiver was in sync, the Mini-L PLL receiver never lost lock. It continued to track the Loran-C through the entire flight (The receiver battery is seperate from the computer battery). The Mini-L receiver showed no difficulties in tracking the Loran-C during the flight. The Loran-C reception in the air was quite good even for the distant Nantucket slave.

After all the equipment was checked for proper operation the aircraft taxied out to takeoff. Runway 24 was used with a left turn after takeoff to head toward Pomeroy, Ohio.

The plan upon arrival at Pomeroy was to fly over a predetermined landmark several times and manually take data with the computer. After making three passes over the designated landmark the aircraft was rolled out on a heading along the desired flight path (LOP 67950). Initially, there was some confusion about what command sense the LOP deviation indicator was showing. On the flight from Pomeroy to Huntington, W. Va. the LOP deviation indicator was operating in the reverse sensing mode. After this was recognized the rest of the flight to Huntington progressed uneventfully. In the vicinity of the Huntington area there seemed to be a substantial increase in the background noise on the Loran oscilloscope monitor. Huntington is a highly industrial area and it is possible that, due to this heavy industry, the electrical noise might be higher in this area than over an unpopulated area. The flight over Huntington was at 5500 ft. MSL. This relates to approximately 4700 ft. AGL in the Huntington area.

After passing Huntington a 180° turn was made about 3 miles south of the Tri-State airport. The LOP was then intercepted for the return trip to Pomeroy. During the return the software began intermittent execution. It was determined that the computer system battery voltage was low and about to fail. An effort to dump the data memory in the computer to cassette tape ended in partial success. The flight from Albany to Huntington and a return of about 15 miles was actually saved on tape before the computer failed. The flight was continued to Albany. The Mini-L PLL receiver continued to function with no problems during the entire flight. The receiver never required any attention except to monitor its performance.

For future flights a battery with a higher capacity has been obtained and should provide a longer flight time than the battery used for this flight.

IV. LORAN CONFIGURATION

Figure 1 shows a map of Loran-C lines-of-position (LOP's) over an area which was used for flight data collection. The U.S. East Coast (9930) chain is used in this case, with the Nantucket to Cape Fear and Dana to Cape Fear pairs selected.[3] As may be noted, the LOP for pair Z (Dana - Cape Fear) is very nearly a straight line over the area of interest. Indeed, this area is located almost half-way between the master and station Z. Also, the signals should be strong because of the relatively small distances involved and the station power levels. [4] Again referring to Figure 1, it may be seen that the second LOP is nearly orthogonal to the Dana pair. The large crossing angle assures that a small change in position along the Dana LOP will cause a maximum change in the time difference reading for the Nantucket pair, which allows a better estimation of location.

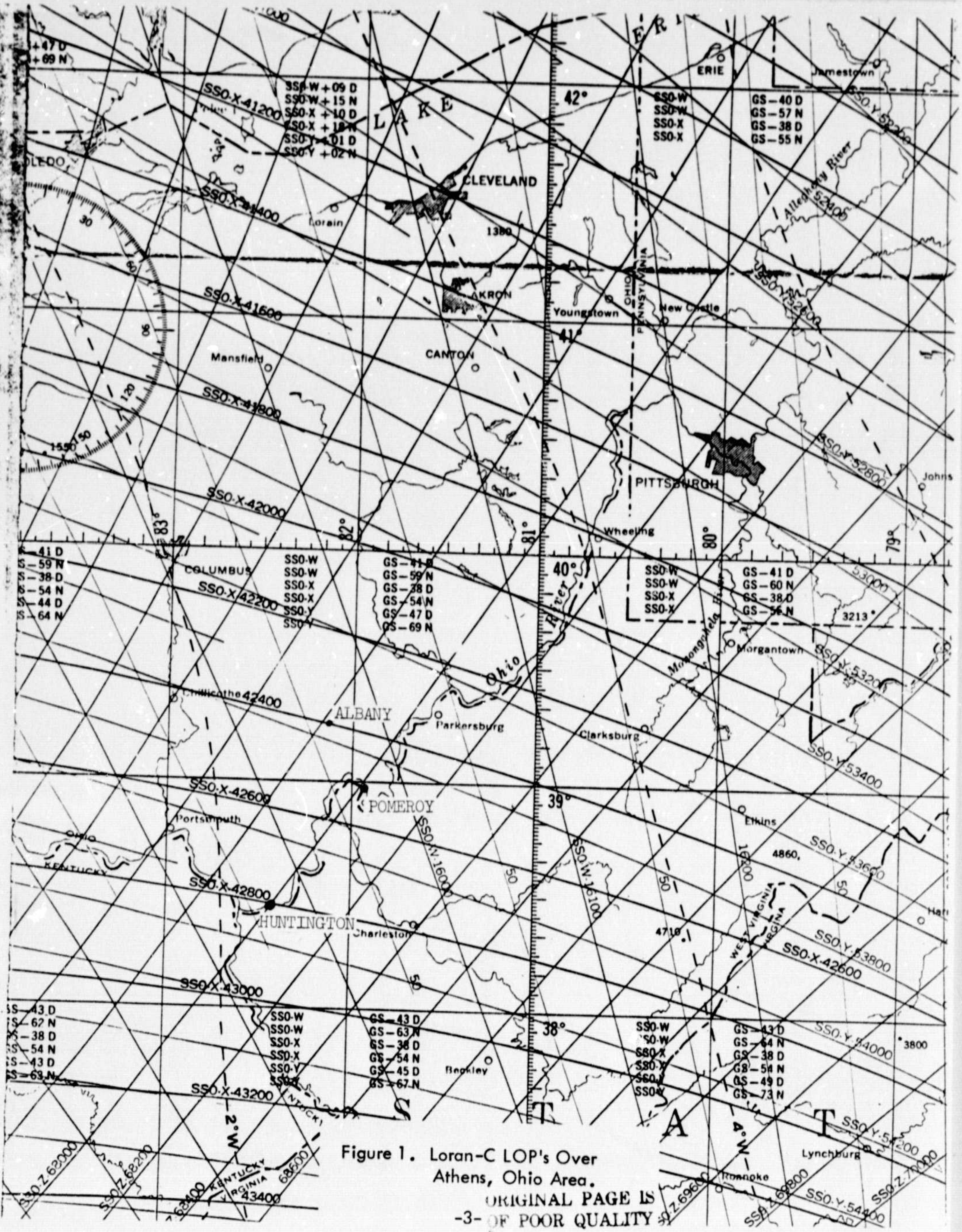

Figure 1. Loran-C LOP's Over Athens, Ohio Area.

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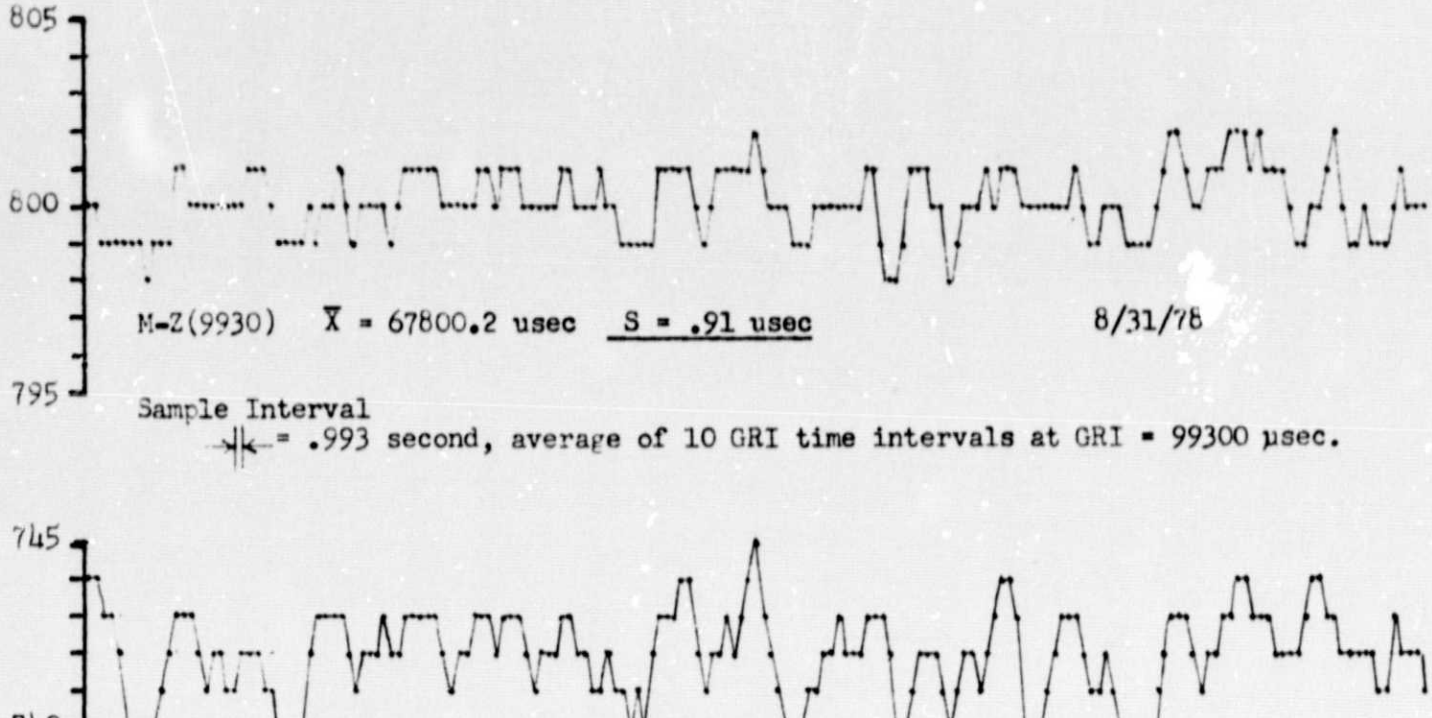

Mean($\bar{X}$) & Standard Deviation(S) of Loran-C, daytime at Athens,OH, for 227 data points (180 points illustrated above). Note, the modulation in peaks and valleys at 33 sec. intervals from 9960 chain cross rate interference.

AUGUST 31, 1978

Figure 2. Loran-C Data Statistics From Mini-L Envelope - PLL Processor.

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It is helpful to bear in mind the effect of distance from a transmitter on the accuracy of a TD reading. [5] Generally, when operating further than 300-400 km. from a Loran station, the hyperbolas are not well defined and the effect of propagation delays is more significant. [6,7] For the particular case being considered here, it would be expected that TD readings from pair Z would be fairly reliable, while those from pair Y would be less reliable; this is compounded by the fact that the signal level from Nantucket is much weaker than Dana and is more subject to skywave contamination. It has been observed in the lab (see Figure 2) that the variation in TD readings for pair Z is 2-3μs while the variation for pair Y can be as much as 10 μs (assuming the effects of skywaves are small, generally true during daytime hours).

Cross-rate interference is often responsible for variations in TD readings, particularily for weak signals. When observing a TD reading over a period of one hour or more, it may be noticed that there is a cyclic variation in the reading because of strong cross-rate interference. Managing this problem is usually considered to be up to the receiver; based on statistics, it may be possible to model this effect and correct for it.

Bringing the above considerations together, it could be expected that a worst-case condition might result in Loran readings which are one-half to one kilometer in error.

Absolute accuracy is not one of the prime considerations for this test; rather, it is desired to fly along a strong LOP and relate TD readings taken in the air to various checkpoints on the ground. Since the pilot will be trying to center a needle while in flight, and including cross-rate interference, a slight sinusoidal flight path could be anticipated.

V. CHOOSING A FLIGHT PATH

Summarizing the above discussion, the U.S. East Coast (9930) chain will be used for the flight analysis. The station pairs to be used are Y (Nantucket) and Z (Dana). The test will be made along an LOP for pair Z. The discussion will now center on methods to choose LOP's and map them.

A Loran-C chart [8] will provide information on the geometry of available LOP's over an area of interest. From the chart, an estimate may be made as to which range of LOP's for pair Z should be used. A sectional aviation chart [9] is then consulted to locate areas where good landmarks may be obtained. Good landmarks include major road-highway intersections, large industries, schools, and buildings, or points along a river.

Now that a particular area has been selected, it is desirable to map Loran time differences on this area. By choosing various points on the map, the corresponding time differences may be found by the use of mathematical [10,11] calucations or computer programs. [3,7,12] To map an LOP, one pair is selected as constant, the other LOP is incremented by a fixed amount, and the corresponding geographic coordinates are computed [3,13] and plotted. Figure 3 shows a flow-chart designed for this procedure; a corresponding

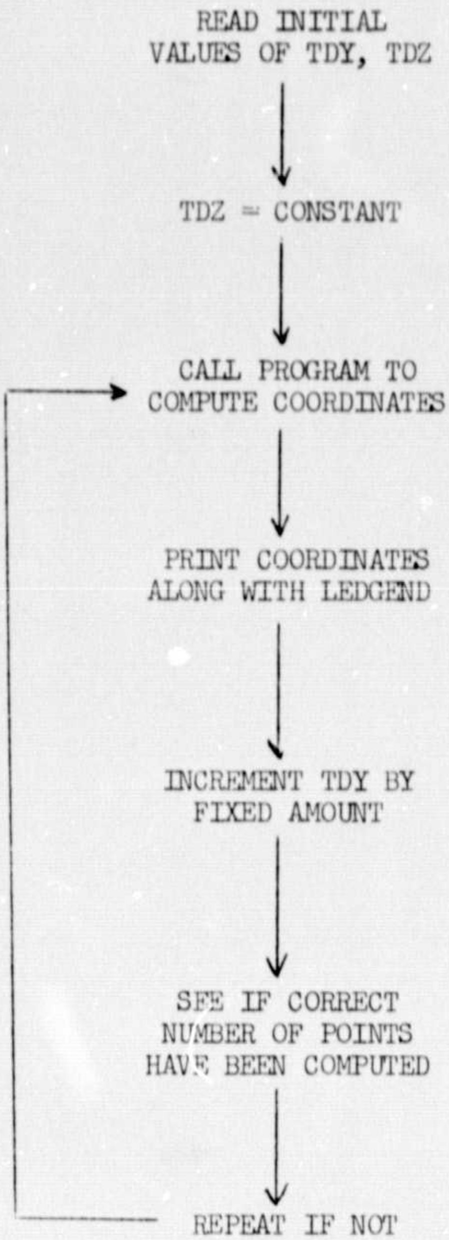

Figure 3. LOP Mapping Flowchart.

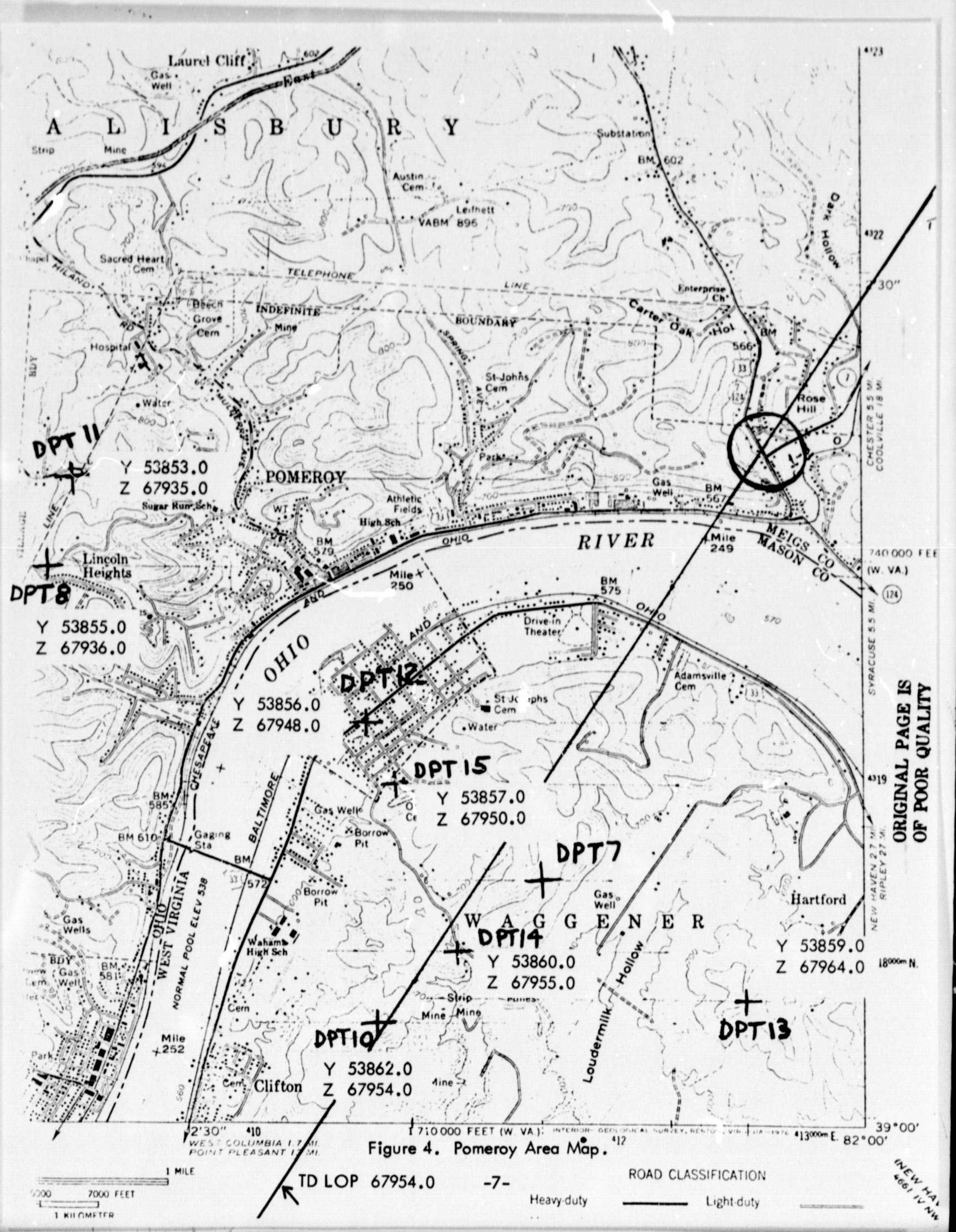

Figure 4. Pomeroy Area Map.

TD LOP 67954.0

ROAD CLASSIFICATION

Heavy-duty Light-duty

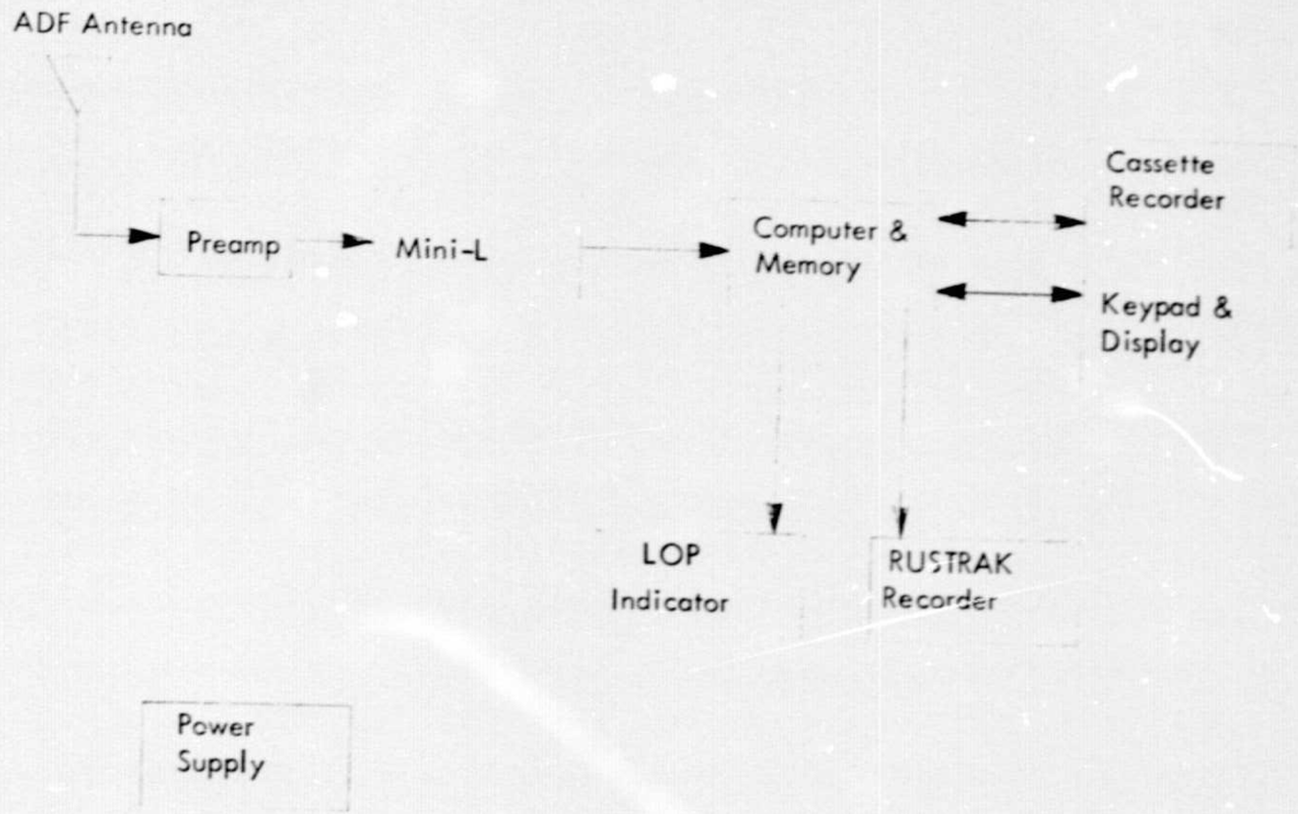

Figure 5. System Block Diagram.

computer program is shown in Appendix A. The program is designed so that many LOP's may be plotted to give a better choice of which one to use.

For plotting LOP's on the sectional map, it is only necessary to plot two or three points and draw a line through them. As mentioned earlier, the LOP for pair Z is almost a straight line. Once these LOP's are plotted on the sectional, they are examined to see if they pass over or near good landmarks. In some cases, it may be necessary to adjust them somewhat so as to cover more landmarks. To obtain greater detail, these coordinates may then be plotted on a topographic map, such as those published by the U.S. Geological Survey. A topographic map with a scale of 1:24000 was used and shows many good land details. An example of an LOP plotted on the topographic map is shown in Figure 4.

VI. AIRCRAFT CONFIGURATION

The aircraft configuration included in a crew of 3 and the Loran-C equipment pallet. The Loran-C system description as configured for this flight included the following.

The receiver [2] used the aircraft ADF antenna. The preamp was not placed directly at the antenna terminals. A short piece of RG-58 coax cable connected the antenna to the preamp. The coax length was approximately 1.5 meters. The preamp used was a higher gain version of the one used in the lab tests. The approximate gain is 30 dB. The receiver, computer, cassette tape recorder and RUSTRAK chart recorder are all mounted on a small pallet which can be secured sideways on one of the aircraft seats. The system battery pack and another cassette recorder, used for voice recording, were placed on the floor of the aircraft. The lines of position (LOP) deviation indicator was positioned under the throttle pedestal so that the pilot could see it. A block diagram of the system is included in Figure 5.

VII. DATA REDUCTION

During the flight several different schemes are used to record the data collected during the flight. The first method is the ability of the flight test software to record two time differences and the clock time the TD's are recorded. This data is saved in RAM memory and later, after the flight, is transferred to cassette tape.

The second method is that the two least significant digits of both TD's are charted on a RUSTRAK chart recorder. This allows an immediately-visible record of the flight track.

The third data recording method is a data planning/recording form. This form, shown in Figure 6, can serve two purposes. First, the flight is planned using this form. Landmarks are chosen and written in before the flight. Second, during the flight if a data point is taken manually the time and data point number (DPTn) is recorded on the form

DATE ____________ SI ____________ PILOT ____________ CREW ____________

RATE ____________ S2 ____________ SST ____________ ____________

Map No.	Landmark	DPT	Time	LOP/Track TD	Coments

Coments:

Figure 6. Flight Planning Form.

0001	000040	053806	067787
0002	000365	053810	067775
0003	000485	053824	067795
0004	000605	053832	067837
0005	000725	053847	067880
0006	000845	053854	067915
0007	000965	053858	067956
0008	001085	053855	067936
0009	001205	053866	067969
0010	001264	053862	067954
0011	001325	053853	067935
0012	001390	053856	067948
0013	001445	053859	067964
0014	001565	053860	067955
0015	001569	053857	067950
0016	001685	053880	067968
0017	001805	053910	067978
0018	001925	053929	067964
0019	001938	053932	067963
0020	002045	053957	067959
0021	002045	053957	067958
0022	002093	053966	067959
0023	002165	053981	067950
0024	002285	054006	067948
0025	002405	054031	067957
0026	002525	054057	067962
0027	002645	054082	067955
0028	002765	054110	067948
0029	002885	054135	067949
0030	003005	054155	067952
0031	003125	054184	067954
0032	003135	054183	067949
0033	003245	054211	067948
0034	003365	054229	067950
0035	003485	054210	067955
0036	003605	054181	067953
0037	003721	054158	067955
0038	003725	054161	067956
0039	003845	054140	067945
0040	003965	054116	067947
0041			

KIM
0734 88

Figure 7. Flight Test Data From Micro.

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LORAN C FLIGHT TEST DATA

FLIGHT DATE: 9-5-78

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GRI: 993 TDA = MY, TDB = MZ

DATA POINT	TIME	TDA	TDB
1	10:45:40	53806.0	67787.0
2	10:51: 2	53810.0	67775.0
3	10:53: 2	53824.0	67795.0
4	10:55: 1	53832.0	67837.0
5	10:56:60	53847.0	67880.0
6	10:58:59	53854.0	67915.0
7	11: 0:58	53858.0	67956.0
8	11: 2:57	53855.0	67936.0
9	11: 4:57	53866.0	67969.0
10	11: 5:55	53862.0	67954.0
11	11: 6:56	53853.0	67935.0
12	11: 8: 0	53856.0	67948.0
13	11: 8:55	53859.0	67964.0
14	11:10:54	53860.0	67955.0
15	11:10:58	53857.0	67950.0
16	11:12:53	53880.0	67968.0
17	11:14:52	53910.0	67978.0
18	11:16:52	53929.0	67964.0
19	11:17: 4	53932.0	67963.0
20	11:18:51	53957.0	67959.0
21	11:18:51	53957.0	67958.0
22	11:19:38	53966.0	67959.0
23	11:20:50	53981.0	67950.0
24	11:22:49	54006.0	67948.0
25	11:24:48	54031.0	67957.0
26	11:26:47	54057.0	67962.0
27	11:28:46	54082.0	67955.0
28	11:30:46	54110.0	67948.0
29	11:32:45	54135.0	67949.0
30	11:34:44	54155.0	67952.0
31	11:36:43	54184.0	67954.0
32	11:36:53	54183.0	67947.0
33	11:38:42	54211.0	67948.0
34	11:40:41	54229.0	67950.0
35	11:42:41	54210.0	67955.0
36	11:44:40	54181.0	67953.0
37	11:46:35	54158.0	67955.0
38	11:46:39	54161.0	67956.0
39	11:48:38	54140.0	67945.0
40	11:50:37	54116.0	67947.0

Figure 8. Flight Test Data From 370.

along with any comments. Blank forms can be carried to record any landmarks or related data not planned initially. This allows for the reconstruction of data points taken manually with the computer.

A data reduction program has been written which will allow the stored data points to be printed out on a standard TTY. The complete program is listed in Appendix C along with a sample output. Essentially, the data reduction program reads the time, TDA and TDB as recorded in memory and prints them on the TTY. The program stops when it finds a record of all zeros. The time that is printed out is not clock time but a GRI count. This can be related to clock time because each GRI count is exactly 0.993 sec. (every 10 Loran-C GRI at the 99300 rate). Therefore, knowing the time the software is started we can add the GRI count time, as recorded, and arrive at the correct clock time the data was recorded to the nearest second. Since the floating point software required for the microprocessor to compute this time is quite large, it was decided that the data could be loaded to the IBM 370. Currently there is no provision for outputting data directly from the microprocessor to the IBM 370. Possible solutions to this problem are being considered. Meanwhile the data for this flight test, (GRI count TDA and TDB) were entered manually. A small FORTRAN program written to perform the time calculation and to output the data is provided and listed in the Appendix D. Figure 7 and 8 show the output from this program using the data collected during the flight test. The time differences were then used by a Loran-C to Geographic conversion program which then relates the Loran-C time differences to latitude and longitude.[3] The resulting data were then plotted on a Cincinnati Sectional, Figure 9. In this figure the dotted line is the desired track, the solid line is the Loran-C geographic data from the flight test. This only represents the data recorded on the Pomeroy to Huntington leg of the flight. The large deviation from the desired track south of Pomeroy, about 2.5 miles, was due to the initial confusion about the indicating sense of the LOP deviation indicator. Initially it was believed that the LOP deviation indicator was direct sensing thereby causing the flight to track away from the desired track. After this was discovered note the correction back to the desired track. For the rest of the flight the desired track differed from the actual track by no more than about one mile.

The LOP deviation indicator, as set-up for this flight, provides a left/right indication calibrated at $\pm 10\,\mu s$ full scale. As it turned out this is a much too sensitive scale factor. Also, due to the lack of any statistical smoothing of the raw Loran-C data the indicator has a very high sample-to-sample deviation rate causing pilot confusion as to the validity of the tracking information presented in the short term sense. Also, due to the software algorithm there are invalid LOP deviation indications when the Loran data is greater than $\pm 10\,\mu s$ from the desired track. This shows up as a nearly on-track indication. Since it was hoped that the aircraft would be on track or near enough that this condition would not occur, or it would be obvious that it is occuring, this condition was accepted. Future plans include changes in the software algorithm which presents data to the LOP deviation indicator to correct this problem.

Figure 10 is the chart recorder output of the flight. The flight test data begins in front of the hangar at Albany airport. This is shown at the bottom left of the figure.

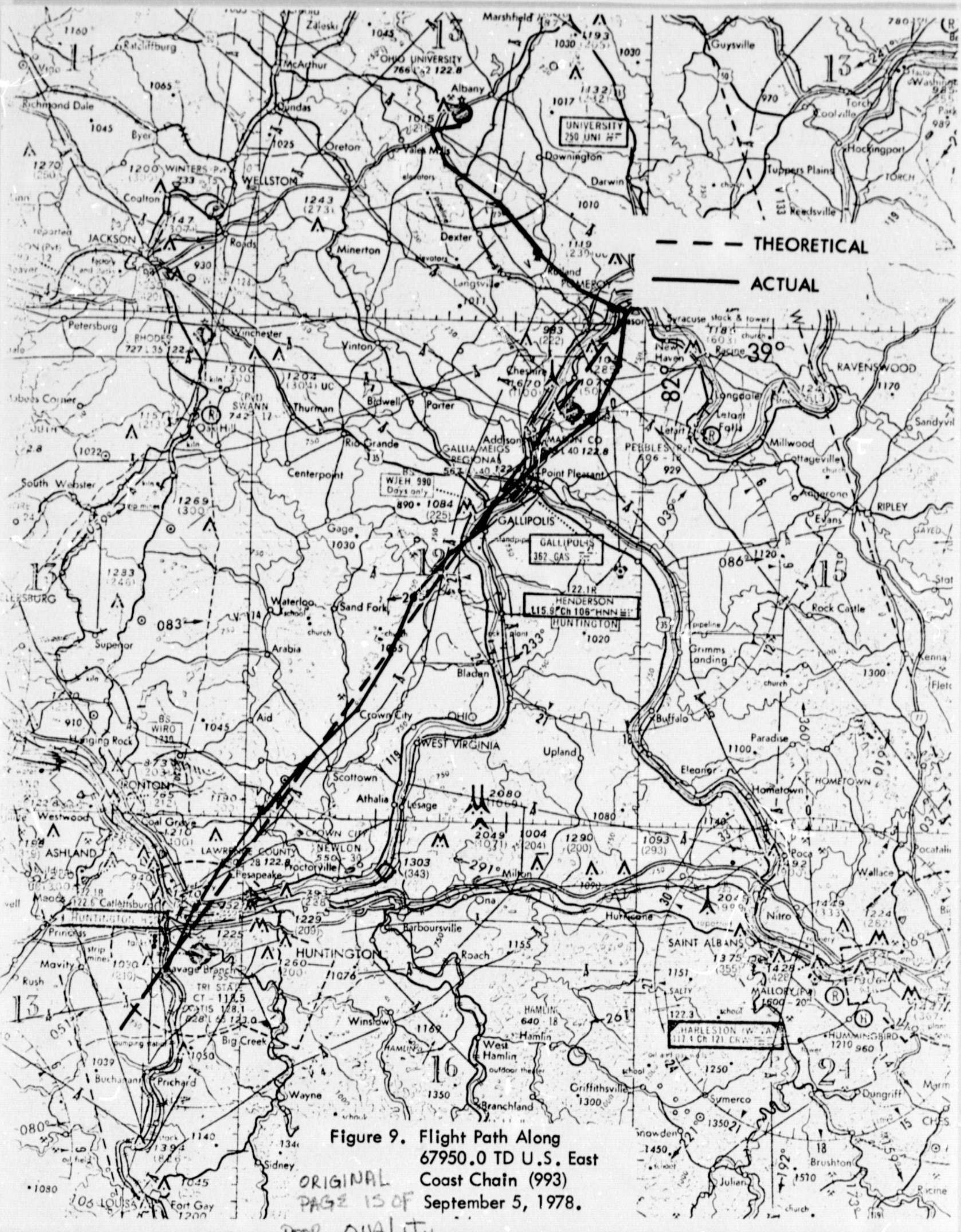

Figure 9. Flight Path Along 67950.0 TD U.S. East Coast Chain (993) September 5, 1978.

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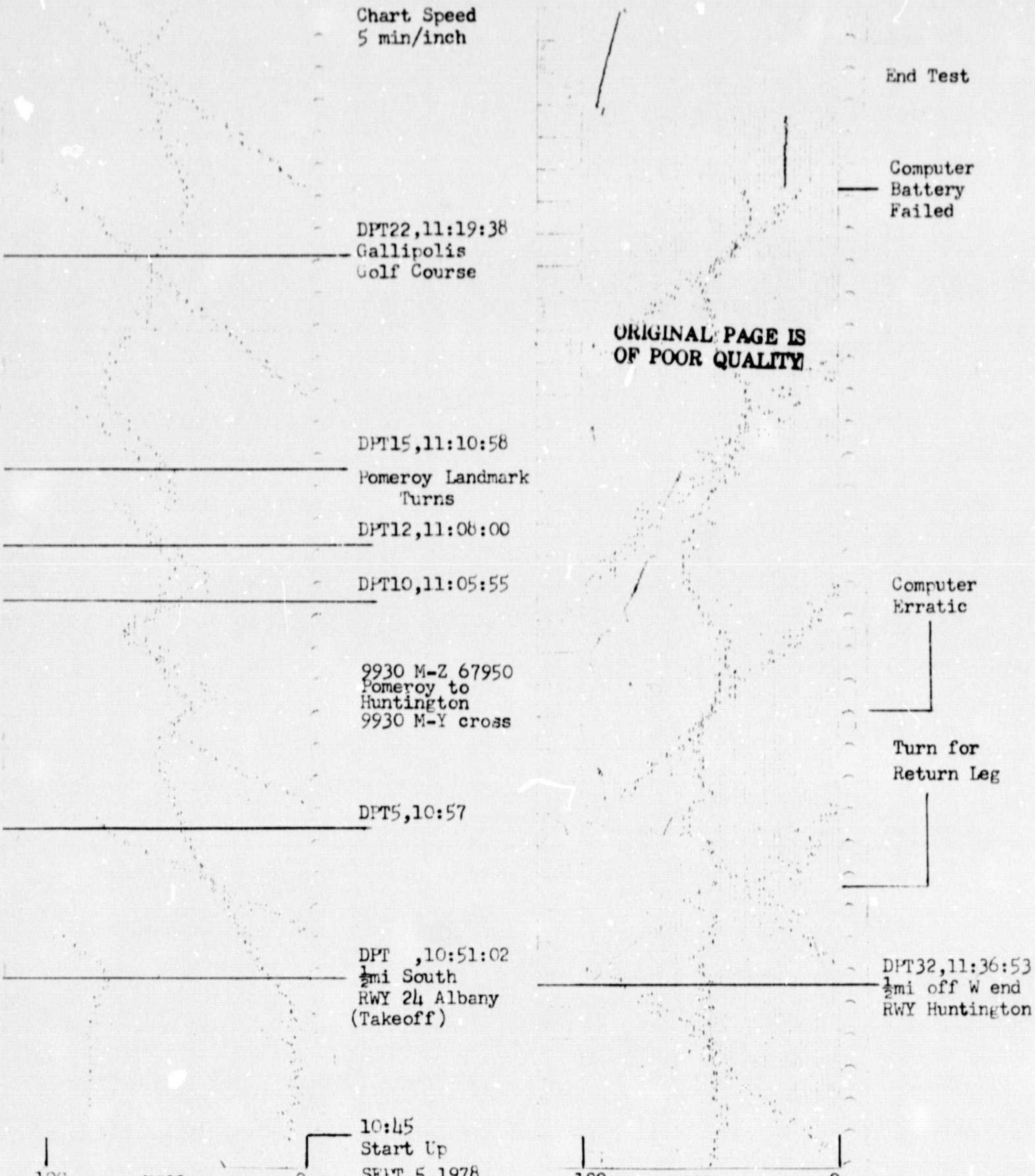

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Figure 10. Loran-C Flight Test (Mini-L with KIM 1)

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Figure 11. Albany Area Map.

The flight progresses up the chart and then down to the bottom right of the figure and to the top again. Figure 11 is a part of the topographical map used to plot the landmarks. The data points (DPTn) on Figure 11 are the same ones referred to in Figures 4,8,9,10.

The flight path was flown with reference to the M-Z LOP as 67950μs instead of the 67954 LOP plotted on the maps because of a fairly constant -4μs difference between the calculated Loran LOP of the receiver and the geographic to Loran computer program. Referring to Figure 11 data points 10,12,15 are points taken directly over the landmark shown in the circle. The LOP's in this area are nearly orthogonal. The pair that provides the east-to-west position information is M-Z. This pair is the strongest of the two used during the flight. The M-Y pair which gives the north-south position information is a much weaker pair with much skywave contamination in the Y signal. Since the signal from Y is weaker the receiver would be expected to sample later in the waveform. This would provide the indication that the actual LOP is farther from the pair than it actually is. Examination of Figure 4 it is seen that the E-W position is very close to correct. The N-S position is south of the correct position which is what would be expected if the receiver was sampling late on the weak station. Since the positioning goal of this receiver developed here at Ohio University is a position error of about 1 mile,it appears that with the data shown, this may be available with the current receiver. It will definitely require much more information to evaluate the actual accuracy of the Mini-L PLL receiver.

Figure 11 is the topographical map for the Albany Airport area. The same shifting effects noted before are again present here. DPT 1 was taken in front of the hangar on the ramp. The position is shifted south-west of the actual position with respect to the M-Y LOP pair. The position information from the other pair is closer but this is only one data point, which could be noise-contaminated on a single sample basis.

The data collected consist of recorded time differences. Each of these time differences may be converted to its corresponding geographic coordinates using techniques discussed earlier. Once the coordinates are computed, they may be processed by the computer in such a manner so that they may be plotted on a graphic plotter. The computed data points may also be plotted on a map as shown in Figure 11. Appendix E shows a FORTRAN program which may be used to process the flight data and plot the results. This program reads in the time differences and places them in tables which are then sent to the plotter. Based on this program, other programs may be written to, for example, read the recorded time differences, convert them to geographic coordinates, place these coordinates in tables and plot the results. All of these programs use the standard plotter subroutines which are available on the IBM System 370 in use at Ohio University.

Figures 12,13, and 14 show the results of using this procedure to plot various arrangements of flight data. Figure 12 is simply the ideal flight course, plotted for comparison purposes. Figure 13 shows a plot of the actual LOP flown with time difference Z as the dependent variable and time difference Y as the independent variable. An interesting point to note here, is the resemblance of this graph to that of a damped sinusoid. The initial wide excursion from the mean (the mean is plotted in Figure 12) indicates the flight crews' "catching on" to the sensing of the metering system. Thereafter, the deviation from the mean is much less.

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Figure 12. Mini-L KIM 1 Flight Check Computed Flight Path.

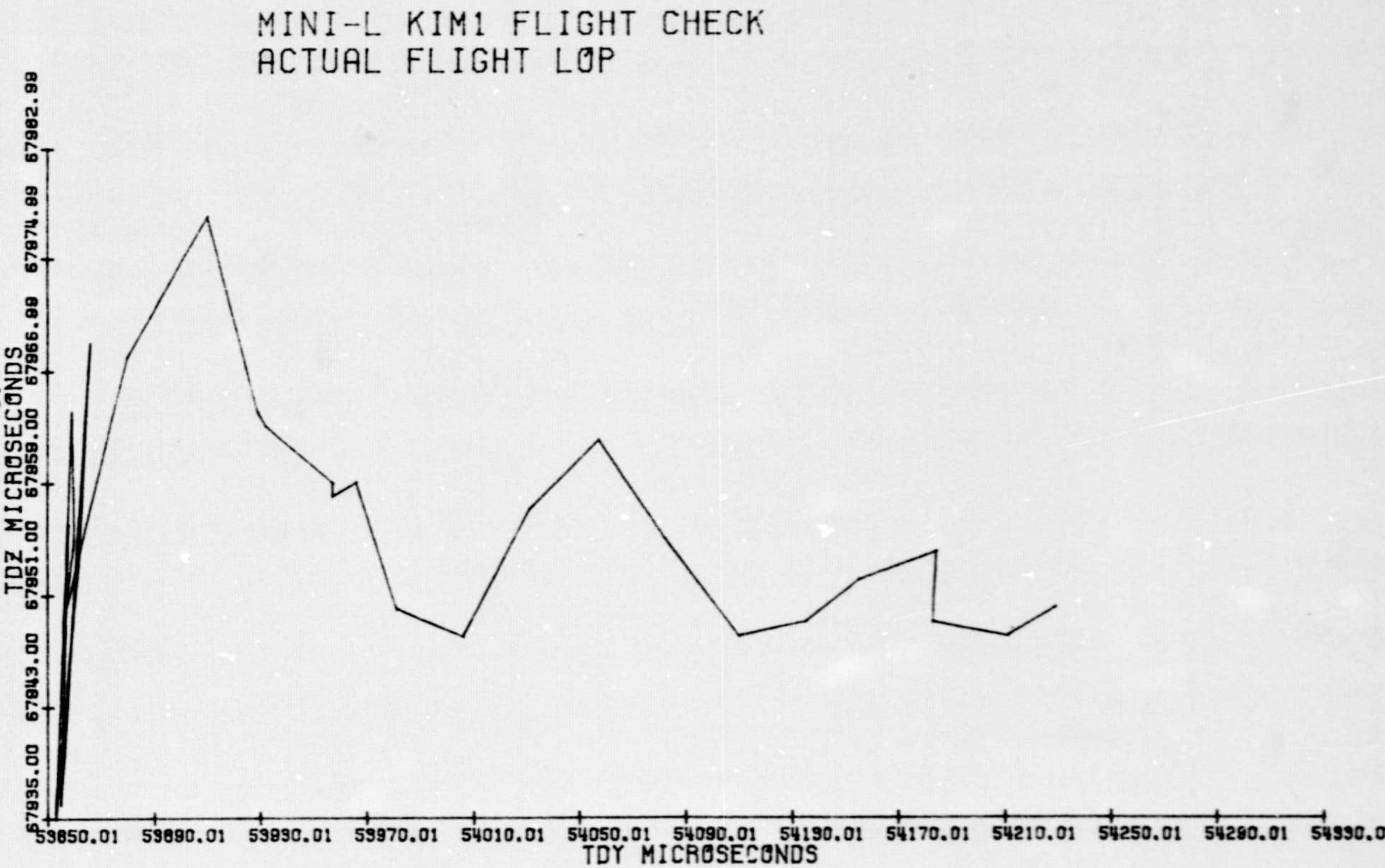

Figure 13. Mini-L KIM 1 Flight Check Actual Flight LOP.

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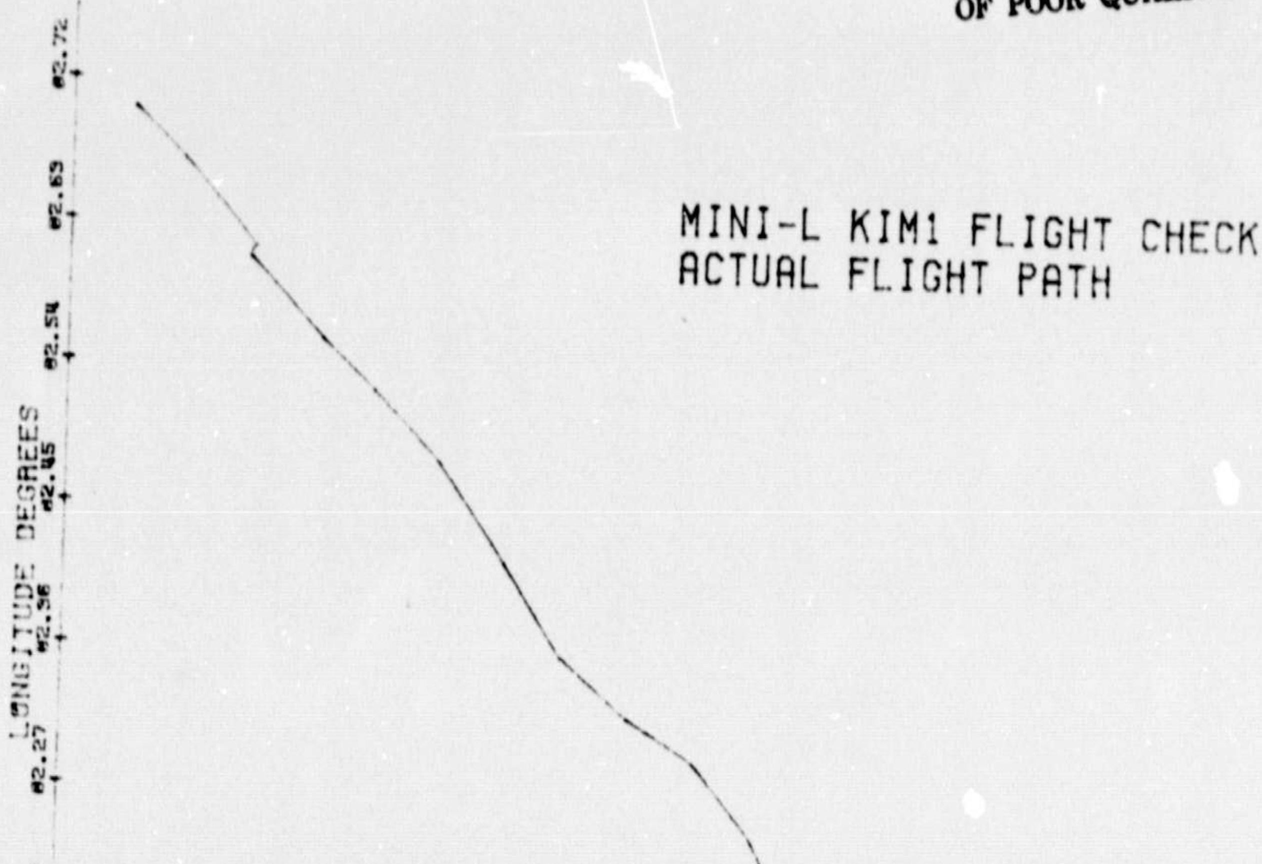

Figure 14. Mini-L KIM 1 Flight Check Actual Flight Path.

A first glance at Figure 13 may suggest a poor performance at flying an LOP. However, an analysis of Figure 14 gives a somewhat more forgiving result. This is a plot of position with the longitude vs. latitude. Here it may be seen that even at the worst deviation from the mean, the actual displacement is about two kilometers. The excursions indicated to the left of Figure 13 and the lower right of Figure 14 are the passes made at the beginning of the trip over the first checkpoint. The location of the checkpoint is midway between the looping lines.

Using the computer and the mechanical plotter to graph flight test results saves much manual labor. Steps are currently being taken to make it easier to load the flight test data from the microcomputer to the IBM 370. Also being planned are new computer programs for plotting data on standard size maps for easier analysis. The use of a computing facility greatly reduces the time and work required to reduce and analyze flight test data.

VIII. ACKNOWLEDGEMENTS

The authors wish to thank Dr. Robert W. Lilley and Ralph W. Burhans for their suggestions and help with the flight test procedures. Also we would like to thank Edwin Jones for his help with the hardware.

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[14] Topographic Map, AMS 456 I NW-Series V852, Scale 1:24000, Department of the Interior, Geological Survey, Washington, D. C., 1960.

X. APPENDICES

A. Loran LOP Mapping Program.

```
      DIMENSION IQSV(2),QSV(2),SEC1(2)
      DIMENSION ANG(8),AD(8),DM(8),CS(8),ASR(2),ISPR(2),MID(2),DEL(2)
      DIMENSION IDR(2),IC(2),DRD(2),DRM(2),TH(2),A(11),B(11),C(11),D(11)
     :,E(8),AA(8),BB(8),CC(8),TM(2),BLEM(2),BEDEL(2),RADR(2),BETA(2)
      DIMENSION OMC(2),IWD(2),FWM(2),ASK(2),DE(6),A78(6),MSV(6),MIN1(2)
      DATA ISTART/' '/
      DATA A1/24.0305/, A2/-0.40758/, A3/0.00346776/, B1/0.510483/, B2
     :/-0.011402/, B3/0.001760/, RD/0.17453293E-1/, RM/0.29088820E-3/,
     :RS/0.48481368E-5/, PI/3.14159265/, A4/299.6929037/
C -
C - READ TIME DIFFERENCES AND CALCULATE POSITION.
C -
C - ENTRY FORMAT AS FOLLOWS (EACH ENTRY ON SEPARATE INPUT LINE):
C -
C -      TDY      -      TIME DIFFERENCE READING FOR PAIR 'Y'
C -      TDZ      -      TIME DIFFERENCE READING FOR PAIR 'Z'
C -      TDEL     -      TIME STEP INCREMENT FOR 'Y' LOP
C -      LLMT     -      LIMIT FOR NUMBER OF POSITION POINTS CALCULATED
C -
      WRITE(13,811)
  811 FORMAT(1H1,T40,'LORAN01 LOP MAPPING PROGRAM.  VERSION 2.0  08-28-7
     :8'//)
      LOOPC=1
      READ800,TH,TDEL,LLMT
  800 FORMAT(F10.0/F10.0/F5.0/I3)
      GOTO808
  999 CONTINUE
      DO818I=1,2
      MIN1(I)=FWM(I)
  818 SEC1(I)=(FWM(I)-MIN1(I))*60.
      WRITE(13,819)LOOPC,TH,LOOPC,(IWD(I),MIN1(I),SEC1(I),I=1,2)
  819 FORMAT(1H0,I3,T10,'TDY =',F10.3,5X,'TDZ =',F10.3,10X,I3/1X,T10,'LA
     :TITUDE  =',I5,1X,I2,1X,F5.2/1X,T10,'LONGITUDE =',I5,1X,I2,1X,F5.2)
      IF(LOOPC.EQ.LLMT)GOTO999
      LOOPC=LOOPC+1
      TH(1)=TH(1)+TDEL
C -
C - BEGIN TIME DIFFERENCE TO POSITION CONVERSION.
C -
  808 REWIND 12
      DRD(1)=38.
      DRD(2)=82.
      DRM(1)=20.
      DRM(2)=0.
      ISP=0
  207 ICDN=0
  101 FORMAT(I1,F1.0,I2,I1,F5.0,2F10.3,4(F4.0,F2.0,F4.2),I4,A1,T80,A1)
  100 READ (12,101)KID,(ASR(I),MID(I),ISPR(I),DEL(I),I=1,1),
     :A5,A6,(AD(K),DM(K),CS(K),K=1,4),(IDR(I),I=1,1)
  105 READ (12,101)KID,(ASR(I),MID(I),ISPR(I),DEL(I),I=2,2),
     :A5,A6,(AD(K),DM(K),CS(K),K=5,8),(IDR(I),I=2,2)
  407 L=1
      I=1
      ASK(L)=ASR(I)
      L=2
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```
      I=2
      ASK(L)=ASR(I)
      A10=(A5*A5-A6*A6)/(A5*A5)
      A14=1.0-A6/A5
      A50=(1.0+A14*A14*A14)
      A51=(A50-1.0)
      A52=(A14*A14)/2.0
      A53=-A51/2.0
      A54=(A14*A14)/16.0
      A55=(A14*A14)/8.0
      A56=A14*A14
      A57=A56*1.25
      A58=A56/4.0
  122 DO 128 K=1,8
      IF(AD(K))124,126,126
  124 ANG(K)=RD*AD(K)-RM*DM(K)-RS*CS(K)
      GO TO 128
  126 ANG(K)=RD*AD(K)+RM*DM(K)+RS*CS(K)
  128 CONTINUE
      A12=(ANG(1)-ANG(5)+ANG(2)-ANG(6))
      A12=ABS(A12)
      IF(A12-0.00001)7,7,8
    7 A11=-1.0
      GO TO 9
    8 A11=1.0
C -
C - APPROXIMATE POSITIONS AND STATION COORDINATES.
C -
    9 E(1)=ANG(1)
      E(2)=ANG(2)
      CC(1)=ANG(3)
      CC(2)=ANG(4)
      E(3)=SIN(E(1))
      E(4)=COS(E(1))
      E(5)=E(3)/E(4)
      E(8)=(E(5))*(1.0-A14)
      A62=ATAN(E(8))
      E(6)=SIN(A62)
      E(7)=COS(A62)
      CC(3)=SIN(CC(1))
      CC(4)=COS(CC(1))
      CC(5)=CC(3)/CC(4)
      CC(8)=(CC(5))*(1.0-A14)
      A62=ATAN(CC(8))
      CC(6)=SIN(A62)
      CC(7)=COS(A62)
      I=1
      L=1
      GO TO 500
   15 E(9)=A45
      E(10)=A46
      E(11)=A47
      DO 17 J=1,11
      A(J)=E(J)
   17 B(J)=CC(J)
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```
      E(1)=ANG(5)
      E(2)=ANG(6)
      CC(1)=ANG(7)
      CC(2)=ANG(8)
      E(3)=SIN(E(1))
      E(4)=COS(E(1))
      E(5)=E(3)/E(4)
      E(8)=(E(5))*(1.0-A14)
      A62=ATAN(E(8))
      E(6)=SIN(A62)
      E(7)=COS(A62)
      CC(3)=SIN(CC(1))
      CC(4)=COS(CC(1))
      CC(5)=CC(3)/CC(4)
      CC(8)=(CC(5))*(1.0-A14)
      A62=ATAN(CC(8))
      CC(6)=SIN(A62)
      CC(7)=COS(A62)
      I=0
      L=2
      GO TO 500
   10 E(9)=A35
      E(10)=A46
      E(11)=A47
      DO 21 J=1,11
      C(J)=E(J)
   21 D(J)=CC(J)
   20 TM(1)=A(10)+A(11)
      TM(2)=C(10)+C(11)
   40 DO 45 M=1,2
      BETA(M)=TM(M)
      BEDEL(M)=BETA(M)+DEL(M)
   45 BLEM(M)=BETA(M)+BEDEL(M)
      IQSV(1)=99999
      IQSV(2)=99999
      ITER=0
   82 SDR=DRD(1)+DRM(1)+DRD(2)+DRM(2)
      IF(SDR)83,84,83
   83 DO 30 K=1,2
      IF(DRD(K))32,34,34
   32 RADR(K)=RD*DRD(K)-RM*DRM(K)
      GO TO 30
   34 RADR(K)=RD*DRD(K)+RM*DRM(K)
   30 CONTINUE
      E(1)=RADR(1)
      E(2)=RADR(2)
      A28=-1.0
   84 E(3)=SIN(E(1))
      E(4)=COS(E(1))
      E(5)=E(3)/E(4)
      E(8)=(E(5))*(1.0-A14)
      A62=ATAN(E(8))
      E(6)=SIN(A62)
      E(7)=COS(A62)
   85 DO 86 J=1,8
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86  CC(J)=D(J)
    I=3
    GO TO 500
90  C1=A35
    C2=A44
    C3=A45
    C101=A47
91  DO 92 J=1,8
92  CC(J)=C(J)
    I=4
    GO TO 500
95  C4=A35
    C5=A44
    C6=A45
    C104=A47
49  DO 50 J=1,8
50  CC(J)=B(J)
    I=5
    L=1
    GO TO 500
55  C7=A35
    C8=A44
    C9=A45
    C107=A47
    IF(A11)52,99,53
53  C10=C7
    C11=C8
    C12=C9
    C110=C107
56  DO 63 J=1,8
63  CC(J)=A(J)
    I=6
    L=1
    GO TO 500
65  C7=A35
    C8=A44
    C9=A45
    C107=A47
    C13=TH(2)-C(10)-C(11)-C101+C104-DEL(2)
    C17=C13-A4
    C18=TH(1)-A(10)-A(11)-C110+C107-DEL(1)
    C22=C18+A4
    C23=C1-C17
    C24=C4
    C25=C7+C22
    C26=C10
    C27=((C2-C5)*(C25-C26)+(C23-C24)*(C11-C8))
    C29=((C2-C5)*(C12-C9)+(C3-C6)*(C8-C11))
    C30=C27/C29
    C28=(C23-C24+C30*(C3-C6))/(C5-C2)
    GO TO 130
52  C13=TH(2)-C(10)-C(11)-C101+C104-DEL(2)
    C17=C13-A4
    C18=TH(1)-A(10)-A(11)-C107+C104-DEL(1)
    C22=C18+A4
```

```
      C23=C1-C17
      C24=C4
      C25=C7-C22
      C27=(C2*(C25-C24)+C23*(C5-C3)+C3*C24-C5*C25)
      C29=(C2*(C6-C9)+C3*(C8-C5)+C5*C9-C8*C6)
      C30=C27/C29
      C28=(C23-C24+C30*(C3-C5))/(C5-C2)
  130 C31=(A5*A4*(1.0-A10))/(1.0-A10*E(3)*E(3))**1.5
      C32=(A5*A4)/(1.0-A10*E(3)*E(3))**0.5
      C33=(C30/C31)
      C34=(-C28/(C32*E(4)))
      E(1)=E(1)+C33
      E(2)=E(2)+C34
      IF(A28)132,99,134
  132 A28=1.0
      GO TO 84
C -
C - CONVERSION DONE. RETURN TO DISTANCE-BEARING ROUTINE.
C -
  900 IF(IGSV(1).NE.IWD(1))GO TO 7713
      IF(IGSV(2).NE.IWD(2))GO TO 7713
      IF(ABS(GSV(1)-FWM(1)).GT.0.1)GO TO 7713
      IF(ABS(GSV(2)-FWM(2)).GT.0.1)GO TO 7713
 7715 IDR(1)=IDR(1)+10
      REWIND 12
      GO TO 49
C -
C - CONTINUE ITERATIONS.
C -
 7713 DO 7712 M=1,2
      DRD(M)=0.0
      DRM(M)=0.0
      GSV(M)=FWM(M)
 7712 IGSV(M)=IWD(M)
      ITER=ITER+1
      IF(ITER.LT.100)GO TO 82
      PRINT 8815
 8815 FORMAT(' NO SOLUTION')
      GO TO 999
  134 OMG(1)=E(1)
      OMG(2)=E(2)
      DO 4840 M=1,2
      W=OMG(M)/RD
      IWD(M)=W
      FWD=IWD(M)
      DWD=W-FWD
      EWM=DWD*60.0
      FWM(M)=ABS(EWM)
      IF(FWM(M)-59.9995)4840,4810,4810
 4810 FWM(M)=0.0
      IF(IWD(M))4820,4830,4830
 4820 IWD(M)=IWD(M)-1
      GO TO 4840
 4830 IWD(M)=IWD(M)+1
 4840 CONTINUE
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      GO TO 900
C -
C - CALCULATION OF INVERSE VARIABLES.
C -
500   A59=-CC(2)
      A60=-E(2)
      C35=A59-A60
      C36=ABS(C35)
      IF(C36-PI)501,502,502
502   A16=2.0*PI-C36
      GO TO 505
501   A16=C36
505   IF(A16)506,507,506
507   A16=0.00000005
506   A17=SIN(A16)
      A18=COS(A16)
      A19=E(6)*CC(6)
      A20=E(7)*CC(7)
      A21=A19+A20*A18
      A22=((A17*CC(7))**2+(CC(6)*E(7)-E(6)*CC(7)*A18)**2)**0.5
      A23=(A20*A17)/A22
      A24=1.0-A23*A23
      A25=ARSIN(A22)
      A26=A25*A25
      A27=1.0/A22
      A28=A21/A22
      A29=A28*A28
      A30=(A50*A25)+A19*(A51*A22-A52*A26*A27)
      A31=A24*(A53*A25+A53*A22*A21+A52*A26*A28)
      A32=A19*A19*(-A52*A21*A22)
      A33=A29*(A54*A25+A54*A21*A22-A52*A26*A28-A55*A22*(A21**3))
      A34=A19*A24*(A52*A26*A27+A52*A22*A21*A21)
      A35=(A30+A31+A32+A33+A34)*A6*A4
      A36=(A51*A25)+A19*(-A52*A22-A14*A14*A26*A27)
      A37=A24*(-A57*A25+A58*A22*A21+A14*A14*A26*A28)
      A38=(A36+A37)*A20+A16
      A39=SIN(A38)
      A40=COS(A38)
      A41=(CC(6)*E(7)-A40*E(6)*CC(7))/(A39*CC(7))
      IF(A41)510,509,510
509   A41=0.00000005
510   A42=1.0/A41
      A43=ATAN(A42)
      IF(C35)515,514,514
514   IF(C35-PI)511,512,512
511   IF(A41)520,521,521
520   A43=PI+A43
      GO TO 521
512   IF(A41)517,518,518
515   IF(C35+PI)511,511,516
516   IF(A41)517,518,518
517   A43=PI-A43
      GO TO 521
518   A43=2.0*PI-A43
521   A43=A43+PI
```

```
      A43=A43-2.0*PI
      IF(A43)522,523,523
  522 A43=A43+2.0*PI
  523 A44=SIN(A43)
      A45=COS(A43)
      A46=A35/1609.344
      IF(ASK(L))524,513,524
  513 A47=0.0
      GO TO 527
  524 IF(A46-100.0)525,526,526
  525 A47=B1/A46+B2+B3*A46
      GO TO 527
  526 A47=A1/A46+A2+A3*A46
  527 A46=A35/A4
  528 GO TO(15,19,90,95,55,65),I
  999 REWIND 12
      STOP
      END
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B. Data Produced by LOP Mapping Program.

```
1     TDY = 53721.000        TDZ = 67954.000        1
      LATITUDE  =   39 16 42.50
      LONGITUDE =   81 47 46.39

2     TDY = 53731.000        TDZ = 67954.000        2
      LATITUDE  =   39 15 33.51
      LONGITUDE =   81 48 45.22

3     TDY = 53741.000        TDZ = 67954.000        3
      LATITUDE  =   39 14 24.40
      LONGITUDE =   81 49 44.22

4     TDY = 53751.000        TDZ = 67954.000        4
      LATITUDE  =   39 13 15.14
      LONGITUDE =   81 50 43.43

5     TDY = 53761.000        TDZ = 67954.000        5
      LATITUDE  =   39 12  5.76
      LONGITUDE =   81 51 42.81

6     TDY = 53771.000        TDZ = 67954.000        6
      LATITUDE  =   39 10 56.27
      LONGITUDE =   81 52 42.25

7     TDY = 53781.000        TDZ = 67954.000        7
      LATITUDE  =   39  9 46.61
      LONGITUDE =   81 53 41.85

8     TDY = 53791.000        TDZ = 67954.000        8
      LATITUDE  =   39  8 36.91
      LONGITUDE =   81 54 41.62

9     TDY = 53801.000        TDZ = 67954.000        9
      LATITUDE  =   39  7 27.03
      LONGITUDE =   81 55 41.60

10    TDY = 53811.000        TDZ = 67954.000        10
      LATITUDE  =   39  6 17.05
      LONGITUDE =   81 56 41.64

11    TDY = 53821.000        TDZ = 67954.000        11
      LATITUDE  =   39  5  6.96
      LONGITUDE =   81 57 42.01

12    TDY = 53831.000        TDZ = 67954.000        12
      LATITUDE  =   39  3 56.65
      LONGITUDE =   81 58 42.38

13    TDY = 53841.000        TDZ = 67954.000        13
      LATITUDE  =   39  2 46.28
      LONGITUDE =   81 59 42.97

14    TDY = 53851.000        TDZ = 67954.000        14
      LATITUDE  =   39  1 35.75
      LONGITUDE =   82  0 43.78

15    TDY = 53861.000        TDZ = 67954.000        15
      LATITUDE  =   39  0 25.05
      LONGITUDE =   82  1 44.75
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LONGITUDE = 82 2 45.73

17 TDY = 53881.000 TDZ = 67954.000 17
LATITUDE = 28 58 3.27
LONGITUDE = 82 3 47.09

18 TDY = 53891.000 TDZ = 67954.000 18
LATITUDE = 28 56 52.13
LONGITUDE = 82 4 48.50

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19 TDY = 53901.000 TDZ = 67954.000 19
LATITUDE = 28 55 40.89
LONGITUDE = 82 5 50.24

20 TDY = 53911.000 TDZ = 67954.000 20
LATITUDE = 28 54 29.53
LONGITUDE = 82 6 51.99

21 TDY = 53921.000 TDZ = 67954.000 21
LATITUDE = 28 53 17.90
LONGITUDE = 82 7 54.91

22 TDY = 53931.000 TDZ = 67954.000 22
LATITUDE = 28 52 6.10
LONGITUDE = 82 8 56.35

23 TDY = 53941.000 TDZ = 67954.000 23
LATITUDE = 28 50 54.20
LONGITUDE = 82 9 58.70

24 TDY = 53951.000 TDZ = 67954.000 24
LATITUDE = 28 49 42.13
LONGITUDE = 82 11 1.43

25 TDY = 53961.000 TDZ = 67954.000 25
LATITUDE = 28 48 29.84
LONGITUDE = 82 12 4.22

26 TDY = 53971.000 TDZ = 67954.000 26
LATITUDE = 28 47 17.49
LONGITUDE = 82 13 7.12

27 TDY = 53981.000 TDZ = 67954.000 27
LATITUDE = 28 46 4.93
LONGITUDE = 82 14 10.51

28 TDY = 53991.000 TDZ = 67954.000 28
LATITUDE = 28 44 52.19
LONGITUDE = 82 15 14.01

29 TDY = 54001.000 TDZ = 67954.000 29
LATITUDE = 28 43 39.20
LONGITUDE = 82 16 17.73

30 TDY = 54011.000 TDZ = 67954.000 30
LATITUDE = 28 42 26.08
LONGITUDE = 82 17 21.67

31 TDY = 54021.000 TDZ = 67954.000 31
LATITUDE = 28 41 12.75
LONGITUDE = 82 18 25.83

32 TDY = 54031.000 TDZ = 67954.000 32
LATITUDE = 28 39 59.25

```
33      TOY = 54041.000        TOZ = 67954.000            33
        LATITUDE  =    38 38 45.44
        LONGITUDE =    82 20 34.64

34      TOY = 54051.000        TOZ = 67954.000            34
        LATITUDE  =    38 37 31.55
        LONGITUDE =    82 21 39.57

35      TOY = 54061.000        TOZ = 67954.000            35
        LATITUDE  =    38 36 17.43
        LONGITUDE =    82 22 44.67

36      TOY = 54071.000        TOZ = 67954.000            36
        LATITUDE  =    38 35  3.22
        LONGITUDE =    82 23 49.98

37      TOY = 54081.000        TOZ = 67954.000            37
        LATITUDE  =    38 33 48.68
        LONGITUDE =    82 24 55.68

38      TOY = 54091.000        TOZ = 67954.000            38
        LATITUDE  =    38 32 33.92
        LONGITUDE =    82 26  1.39

39      TOY = 54101.000        TOZ = 67954.000            39
        LATITUDE  =    38 31 18.99
        LONGITUDE =    82 27  7.46

40      TOY = 54111.000        TOZ = 67954.000            40
        LATITUDE  =    38 30  3.90
        LONGITUDE =    82 28 13.98

41      TOY = 54121.000        TOZ = 67954.000            41
        LATITUDE  =    38 28 48.48
        LONGITUDE =    82 29 20.67

42      TOY = 54131.000        TOZ = 67954.000            42
        LATITUDE  =    38 27 32.84
        LONGITUDE =    82 30 27.52

43      TOY = 54141.000        TOZ = 67954.000            43
        LATITUDE  =    38 26 16.92
        LONGITUDE =    82 31 34.81

44      TOY = 54151.000        TOZ = 67954.000            44
        LATITUDE  =    38 25  0.90
        LONGITUDE =    82 32 42.27

45      TOY = 54161.000        TOZ = 67954.000            45
        LATITUDE  =    38 23 44.54
        LONGITUDE =    82 33 50.16

46      TOY = 54171.000        TOZ = 67954.000            46
        LATITUDE  =    38 22 27.91
        LONGITUDE =    82 34 58.22

47      TOY = 54181.000        TOZ = 67954.000            47
        LATITUDE  =    38 21 11.12
        LONGITUDE =    82 36  6.45

48      TOY = 54191.000        TOZ = 67954.000            48
        LATITUDE  =    38 19 54.16
        LONGITUDE =    82 37 15.11
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49     TDY = 54201.000      TDZ = 67954.000      49
       LATITUDE  =   .8 18 36.71
       LONGITUDE =   .2 38 24.16

50     TDY = 54211.000      TDZ = 67954.000      50
       LATITUDE  =   .8 17 19.30
       LONGITUDE =   .2 39 33.60
```

C. Data Reduction Program.

END PASS 1:   0 ERRORS

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                      *
                      *
                      *
                      *       THIS PROGRAM WILL PROVIDE A DOCUMENTABLE RECORD
                      *       OF THE DATA TAKEN DURING A FLIGHT AS RECORDED
                      *       IN RAM MEMORY.
                      *       THE FORM OF THE OUTPUT IS AS FOLLOWS:
                      *
                      *       GRI COUNT          TDA              TDB
                      *
                      *       THE TIME DIFFERENCES ARE IN MICROSECONDS AND
                      *       THE GRI COUNT IS ONE COUNT FOR EVERY 10 LORAN
                      *       GRI.
                      *
                      *       PRINTING IS COMPLETED WHEN THE NEXT RECORD READ
                      *       FROM RAM IS ALL ZEROS (ONE RECORD IS 9 BYTES).
                      *
                      *       THIS PROGRAM BEGINS READING RECORDS AT MEMORY
                      *       LOCATION $0400 AND CONTINUES UNTIL THE ZERO
                      *       RECORD IS READ.
                      *
                      *
                      *       ASSEMBLER DEFINITIONS FOLLOW.
                      *
0000                  KIM     EQU $1C00
0000                  PRTBYT  EQU $1E3B
0000                  SPACE   EQU $1E9E
0000                  OUTCH   EQU $1EA0
0050                          ORG $0050
                      *
                      *
                      *       THIS IS THE SCRATCH PAD MEMORY FOR THIS PROGRAM.
                      *
                      *
0050 00 00            NUMP    BSS 2
0052 00 00            ADPT    BSS 2
0054 00               END     BSS 1
0055                  BUFF    BSS 9
0800                          ORG $0800
                      *
                      *       THE PROGRAM STARTS HERE.
                      *
0800 D8                       CLD            CLEAR DECIMAL FLAG
0801 A9 0A                    LDA =$0A       SET DPT ADDRESS
0803 85 53                    STA ADPT+1
0805 A9 00                    LDA =00
0807 85 52                    STA ADPT
0809 85 54                    STA END
080B 85 50                    STA NUMP
080D A9 01                    LDA =01
080F 85 51                    STA NUMP+1
0811 A2 04                    LDX =04
```

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```
0813 20 A5 08   LOOP1   JSR CRLF      OUTPUT CRLF
0816 CA                 DEY
0817 10 FA              BPL LOOP1     LOOP IF POSITIVE
0819 A0 00      LOOP6   LDY =00
081B A5 50              LDA NUMP
081D 20 3B 1E           JSR PRTBYT    PRINT
0820 C8                 INY
0821 A5 51              LDA NUMP+1
0823 20 3B 1E           JSR PRTBYT
0826 20 9E 1E           JSR SPACE
0829 20 9E 1E           JSR SPACE
082C 18                 CLC
082D A2 06              LDX =06
082F A0 00              LDY =00
0831 B1 52      LOOP2   LDA (ADPT),Y
0833 99 55 00           STA BUFF,Y
0836 D0 05              BNE CONT1
0838 E6 54              INC END
083A 4C 41 08           JMP CONT3
083D A9 00      CONT1   LDA =00
083F 85 54              STA END
0841 C8         CONT3   INY
0842 CA                 DEX
0843 10 EC              BPL LOOP2
0845 18                 CLC
0846 A9 09              LDA =09
0848 65 52              ADC ADPT
084A 85 52              STA ADPT
084C A9 00              LDA =00
084E 65 53              ADC ADPT+1
0850 85 53              STA ADPT+1
0852 A5 54              LDA END
0854 C9 09              CMP =09
0856 F0 3B              BEQ STOP
0858 A2 00              LDX =00
085A B5 55      LOOP3   LDA BUFF,X
085C 20 3B 1E           JSR PRTBYT
085F E8                 INX
0860 E0 03              CPX =03
0862 D0 F6              BNE LOOP3
0864 20 9E 1E           JSR SPACE
0867 B5 55      LOOP4   LDA BUFF,X
0869 20 3B 1E           JSR PRTBYT
086C E8                 INX
086D E0 06              CPX =06
086F D0 F6              BNE LOOP4
0871 20 9E 1E           JSR SPACE
0874 B5 55      LOOP5   LDA BUFF,X
0876 20 3B 1E           JSR PRTBYT
0879 E8                 INX
087A E0 09              CPX =09
087C D0 F6              BNE LOOP5
087E 20 A5 08           JSR CRLF
0881 F8                 SED
0882 18                 CLC
```

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```
108  0883 A5 51                 LDA NUMP+1
109  0885 69 01                 ADC =01
110  0887 85 51                 STA VJMP+1
111  0889 A5 50                 LDA NUMP
112  088B 69 00                 ADC =00
113  088D 85 50                 STA NUMP
114  088F D8                    CLD
115  0890 4C 19 08              JMP LOOP6
116  0893 20 A5 08    STOP      JSR CRLF
117  0896 20 A5 08              JSR CRLF
118  0899 20 A5 08              JSR CRLF
119  089C 20 A5 08              JSR CRLF
120  089F 20 A5 08              JSR CRLF
121  08A2 4C 00 1C              JMP KIM
122                   .
123                   .         SUBROUTINE FOR CARRIAGE RETURN AND LINEFEED.
124                   .
125  08A5 A9 0D       CRLF      LDA =$0D
126  08A7 20 A0 1E              JSR OUTCH
127  08AA A9 0A                 LDA =$0A
128  08AC 20 A0 1E              JSR OUTCH
129  08AF 60                    RTS
130                             END

END PASS 2:   0 ERRORS
```

1 SYM:	ADDR	DEF	REFERENCES							
ADPT	0052	36	45	47	79	80	82	83	87	
BUFF	0056	38	63	88	94	100				
CONT1	0839	72	69							
CONT3	0841	74	71							
CRLF	08A5	125	55	105	116	117	118	119	120	
END	0054	37	44	70	73	84				
KIM	1C00	25	121							
LOOP1	0813	53	55							
LOOP2	0831	67	76							
LOOP3	085A	88	92							
LOOP4	0867	94	98							
LOOP5	0874	100	104							
LOOP6	0819	56	115							
NUMP	0050	35	44	51	57	60	109	110	111	113
OUTCH	1EA0	28	126	128						
PRTBYT	1E3B	26	58	61	89	95	101			
SPACE	1E9E	27	62	63	93	99				
STOP	0893	116	86							

D. Loran-C Flight Test Data.

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```
      Z =0
      N = 1
      WRITE (6,41)
41    FORMAT(//////////////////,5X,'LORAN C FLIGHT TEST DATA')
      WRITE (6,44)
44    FORMAT(//,5X,'FLIGHT DATE:  9-5-78')
      WRITE(6,42)
42    FORMAT(/,5X,'GRI: 993  TDA = MY,  TDB = MZ',///)
      WRITE (6,40)
40    FORMAT(5X,'DATA POINT',5X,'TIME',9X,'TDA',9X,'TDB')
100   READ (3,30) A,B,C
30    FORMAT (F10.0,F10.0,F10.0)
      IF(A.EQ.Z) GO TO 200
       TIME = 10.75
       D = (A*.993/3600.0)+TIME
       E = AINT(D)
       F = D-E
       G =F*60.0
       H = AINT(G)
       O =G-H
       P = O*60.0
       Q = AINT(P)
       R = P-Q
      I = INT(E)
      J = INT (H)
      IF(R.LT.0.5) GO TO 50
      Q = Q+1
50    K = INT(Q)
       WRITE (6,20) N,I,J,K,B,C
20    FORMAT (9X,I5,4X,I2,':',I2,':',I2,5X,F7.1,5X,F7.1)
      N = N+1
      GO TO 100
200   CONTINUE
      WRITE(6,48)
48    FORMAT(////////////////////)
      END

R;
```

LORAN C FLIGHT TEST DATA

FLIGHT DATE: 9-5-78

GRI: 993 TDA = MY, TDB = MZ

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DATA POINT	TIME	TDA	TDB
1	10:45:40	53806.0	67787.0
2	10:51: 2	53810.0	67775.0
3	10:53: 2	53824.0	67795.0
4	10:55: 1	53832.0	67837.0
5	10:56:60	53847.0	67880.0
6	10:58:59	53854.0	67915.0
7	11: 0:58	53858.0	67956.0
8	11: 2:57	53855.0	67936.0
9	11: 4:57	53866.0	67969.0
10	11: 5:55	53862.0	67954.0
11	11: 6:56	53853.0	67935.0
12	11: 8: 0	53856.0	67948.0
13	11: 8:55	53859.0	67964.0
14	11:10:54	53860.0	67955.0
15	11:10:58	53857.0	67950.0
16	11:12:53	53880.0	67968.0
17	11:14:52	53910.0	67978.0
18	11:16:52	53929.0	67964.0
19	11:17: 4	53932.0	67963.0
20	11:18:51	53957.0	67959.0
21	11:18:51	53957.0	67958.0
22	11:19:38	53966.0	67959.0
23	11:20:50	53981.0	67950.0
24	11:22:49	54006.0	67948.0
25	11:24:48	54031.0	67957.0
26	11:26:47	54057.0	67962.0
27	11:28:46	54082.0	67955.0
28	11:30:46	54110.0	67948.0
29	11:32:45	54135.0	67949.0
30	11:34:44	54155.0	67952.0
31	11:36:43	54184.0	67954.0
32	11:36:53	54183.0	67949.0
33	11:38:42	54211.0	67948.0
34	11:40:41	54229.0	67950.0
35	11:42:41	54210.0	67955.0
36	11:44:40	54181.0	67953.0
37	11:46:35	54158.0	67955.0
38	11:46:39	54161.0	67956.0
39	11:48:38	54140.0	67945.0
40	11:50:37	54116.0	67947.0

E. Program Listing for Plotting Flight Data.

```
      DIMENSION BUF(5000),Y(36),Z(36)
C -
C - PROGRAM TO PLOT ON GRAPHIC PLOTTER THE RESULTS OF FLIGHT TEST.
C - DATASET 12 IS A FILE CONTAINING THE TIME DIFFERENCES TAKEN
C - DURING THE FLIGHT.
C - SCALE FACTORS ARE READ IN TO ALLOW ADJUSTING TO DESIRED
C - DIMENSIONS.
C - DATASET 11 CONTAINS DATA POINTS FOR PLOTTER.
C -
      PRINT 5
    5 FORMAT('OENTER SCALE DIMENSIONS.')
      READ 6,YLNGTH,ZLNGTH,YSIZE,ZSIZE
    6 FORMAT(F10.0)
      CALL PLOTS(BUF,20000,11)
      READ(12,1)(Y(I),Z(I),I=1,34)
    1 FORMAT(2F5.0)
C -
C - SCALE INPUT DATA
C -
      CALL SCALE(Y,YLNGTH,121,1,10.)
      CALL SCALE(Z,ZLNGTH,121,1,10.)
C -
C - DRAW AXIS
C -
      CALL AXIS(1.0,1.0,'TDY MICROSECONDS',-16,YSIZE,0.0,Y(35),Y(36),10.
     :)
      CALL AXIS(1.0,1.0,'TDZ MICROSECONDS',16,ZSIZE,90.,Z(35),Z(36),10.)
C -
C - PLOT DATA (CONNECTING DATA POINTS)
C -
      CALL PLOT(1.,1.,23)
      CALL LINE(Y,Z,121,1,1,1)
C -
C - PRINT THE HEADING
C -
      CALL PLOT(4.0,8.0,23)
      CALL SYMBOL(0.0,0.0,.17,'MINI-L KIM1 FLIGHT CHECK',0.0,24)
      CALL SYMBOL(999.,999.,.17,21,0.0,-1)
      CALL SYMBOL(999.,999.,.17,'ACTUAL FLIGHT LOP',0.0,17)
C -
C - FINISHED!
C -
      CALL PLOT(0.0,0.0,999)
      STOP
      END
```

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