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BMR Microform MF8

Digital data aquisition system in geophysical survey aircraft VH–BMG

by D.N. Downie

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CONTENTS

PLATES

SUMMARY

When BMR's new Twin Otter aircraft was being fitted out for geophysical surveying, an integrated system for acquisition of digital data was developed. The system records information from one magnetic channel, four gamma-ray spectrometer channels, and two Doppler navigation channels, in addition to altitude and fiducial numbers. Sampling rate is one second, except for magnetic data, which are sampled every 0.2 seconds.

The integrated system is built around a Hewlett-Packard 2114B general-purpose digital computer, interfaced to a 16-channel digital input multiplexer and magnetic tape recorder. A visible and permanent analogue record of the input data is maintained by chart recorders, to enable the operator to monitor data quality and to assist later in interpretation of the data. The chart drive motors can be run at five fixed speeds or coupled to the Doppler signal so that chart speed is proportional to ground speed. The Doppler signals are also coupled to a display unit which assists the pilot to follow the planned flight path.

The system is extremely reliable, and error-free flights are common.

1. INTRODUCTION

Towards the end of 1970 the Bureau of Mineral Resources (BMR) took delivery of a new geophysical survey aircraft, a Twin Otter, VH-BMG. The aircraft replaced a DC.3 that had been used for regional aeromagnetic and radiometric surveys throughout Australia since 1954. One of the tasks in preparing the new aircraft for survey work was the installation of an integrated digital data acquisition system. This Report gives a brief description of the system and the results obtained in two years' use.

Since 1960 the DC.3 had operated with digital data acquisition equipment that recorded magnetometer readings and fiducial timing information on punched paper tape. This equipment had evolved through several stages in the succeeding years and had established a good record of reliability. The functions of the data acquisition system were controlled by a hardwired sequencer designed and constructed by BMR and built into the aircraft timer unit.

In the Twin Otter it was intended to record, in digital form, the geophysical and Doppler navigational data using one central acquisition system. As the Twin Otter was to carry more equipment than its predecessor, and also sample the magnetometer more frequently, a tenfold increase in data output had to be accommodated. It was decided to build the system around a compact, but powerful, general-purpose digital computer, suitably interfaced to a digital input multiplexer and magnetic tape recorder, rather than use a hardwire controller. This choice allows the acquisition, checking, and recording of data to be controlled by a computer program, which should be easy to produce and modify. It was expected that a computer-based system would prove more adaptable for future additions to the geophysical equipment carried. Also, if needed, different types of airborne survey operation with different sets of equipment could be accommodated merely by loading a new computer program. Moreover, when not being used in this role the computer could be used on other data processing or computational work.

The initial intention was to have the necessary computer program written by a professional programming organization that would work under contract to BMR. While this arrangement was being organized a simple preliminary program was written in BMR to test some of the broad principles of system operation. By April 1971 it was apparent that the BMR program could be modified to meet the specification required by the proposed contract. Consequently, the external contract proposal was abandoned, and by May 1971 the upgraded BMR data acquisition program was ready for airborne testing. This flight testing revealed no

serious deficiencies, and the BMR program has come through the two succeeding years of survey use with only minor modification and additions.

A block diagram of the data acquisition system is displayed in Plate 1. A simplified flowchart showing the main decisions and actions taken by the computer program is displayed in Plate 2.

2. DATA INPUT

In the present configuration of the system the geophysical and navigational data channels and their respective sampling rates are as tabulated below:

Data channel	Sample rate	Data format
Magnetometer (2 channels)	0.2 sec	5 BCD* digits
Gamma-ray spectrometer		
Channel 1 (Total)	1 sec	4 BCD* digits
Channel 2 (K)	1 sec	4 BCD* digits
Channel 3 (U)	1 sec	4 BCD* digits
Channel 4 (Th)	1 sec	4 BCD* digits
Altitude	1 sec	3 BCD* digits
Doppler along track	1 sec	14-bit binary
Doppler across track	1 sec	14-bit binary
Fiducial number	1 sec	4 BCD digits
Flight number	1 per flight	3 BCD digits

* BCD - Binary Coded Decimal

All the above data channels are attached to the computer via a 16-channel digital input multiplexer. Five of the 16 channels are not required at present and are available for future growth.

As well as geophysical data the computer program requires certain timing and control information. Every 0.2 seconds a signal from the timer unit instructs the computer to take the readings required at that instant. Another timing signal, synchronized with the start of the 10-second fiducial interval, allows data acquisition to start and stop in step with the fiducial system. A command to start or stop recording data on magnetic tape is generated when the equipment operator presses a button at the start or end of a

survey line. Two additional logic signals control the operation of the pilot's Doppler position indicators as described in detail in Section 4.

These auxiliary data inputs enter the computer via a 16-bit input/output interface.

The timing of the 'read' commands is arranged so that the digital outputs from the instruments have settled to a steady state when the computer takes a reading. The computer responds to a 'read' command, which has the highest internal priority, in less than 10 microseconds. This fast response eliminates any possibility of 'parallax errors' between geophysical readings and the fiducial timing system.

3. ANALOGUE CHART RECORDER OUTPUT

Incoming readings on all geophysical data channels are passed by the computer to the digital-to-analogue multiplexer. The resultant d.c. voltage analogues of the data are recorded on chart recorders, giving a visible and permanent record of the information input to the system. The charts are used to evaluate data quality during and after the survey flight and also for later interpretation of the geophysical information.

On a survey mission the chart records are the only monitor of data quality. The operator has to maintain a watch on the charts and, in the event of serious degradation of data quality, decide whether to abandon the flight. This procedure is simple and flexible and, provided the operator makes an intelligent assessment of the situation, works well. It is unlikely that any attempt will be made in the future to involve the computer in a significant real-time data validation role.

Zero and full-span outputs are displayed on the chart recorders automatically at the end of a survey line to allow the checking of recorder calibration. Recorder calibration outputs can be manually initiated by the operator, during intervals when data are not being recorded, by setting bit 1 on the computer switch register.

The paper drive on the chart recorders has two modes of operation. In TIME mode, five fixed speed ranges from 0.6 cm/min to 12 cm/min are available. In DOPPLER mode, the chart drive stepper motors are driven at a rate proportional to aircraft ground speed. Five switchable ranges provide chart scales from 1:500 000 to 1:25 000. For

DOPPLER mode operation the computer produces a control voltage on one channel of the digital-to-analogue multiplexer. This voltage, derived from along-track velocity, regulates the frequency of a voltage-controlled oscillator, which in turn governs the speed of the chart drive.

4. DOPPLER NAVIGATION

The Marconi AD560 Doppler navigation system installed in VH-BMG is essentially an analogue device. Using a system of mechanical counters, the standard equipment provides a digital readout of distances (in nautical miles) along and across track. Survey use requires a method of converting the Doppler co-ordinates to electronic digital form, with a much higher resolution. This is achieved by means of a pair of commercially available synchro-to-digital converters; these are coupled to the electrical signal lines that drive the standard Doppler display counters, and have a reading accuracy equivalent to a Doppler distance of about 3 cm.

The computer simultaneously maintains two Doppler co-ordinate systems. The Doppler data recorded on magnetic tape are referred to one fixed origin for the duration of the survey flight. This origin can be set by the operator by flying the aircraft over some known reference point before starting the first survey line. If this procedure is not adopted an arbitrary origin, which is located at the point of commencement of the first survey line, is used. Doppler position is recorded on magnetic tape every 10 seconds, the least significant digit being equivalent to a distance of 10 metres.

The other Doppler co-ordinate system provides the aircraft pilot with accurate navigational data for aircraft guidance along the required survey path. This system, which is entirely controlled by the pilot from the flight compartment, produces a readout of distance across track (in the format 00.00 km) and along track (in the format 000.0 km) on a display, which is updated every second. An across-track analogue voltage is also produced on one digital-to-analogue converter channel. This signal is used to deflect the needle of a steering indicator on the pilot's instrument panel. Full-scale deflection of the needle to the left or right is equivalent to an across-track error of about 1 km. Two switches situated next to the Doppler display allow the pilot to tell the computer when to reset the Doppler distances to zero and when to reverse the indication of left

and right. The latter facility is required to maintain the correct sense of the steering data irrespective of whether the aircraft track is towards or away from the Doppler origin.

5. MAGNETIC TAPE RECORDING

Data are accumulated in the memory of the computer to form 10-second blocks for recording on magnetic tape. This block size was chosen mainly for compatibility with the 10-second fiducial timing system. With blocks of this size, the total loss of a block in the event of irrecoverable recording errors can be tolerated.

To simplify later processing of the field data tapes in a large-scale computer system (currently CSIRO's CDC 3600 and CYBER 76 computers), and also to lessen the dependence on a particular computer system, a simple binary format was chosen for the field tape. All data are recorded in the form of 24-bit binary words, with 116 words per record. A checksum word, being the arithmetic sum of all the data words in the block, is appended to the record and is used as a validity check when the record is read by the field data processing programs. Records having checksum errors are ignored. As error rates are very low it is generally not necessary to manually recover data contained in bad blocks.

A 10-second data record occupies about 7.5 cm of tape. A 1200-foot reel of tape would allow 13 hours of recording - double the maximum flight endurance.

One of the prime advantages of the computer-controlled acquisition system is the considerable amount of checking incorporated in the magnetic tape recording phase of the operations. Two levels of checking have been implemented. Firstly the Kennedy tape transport has a read-after-write facility ('flux check') that allows certain types of writing errors to be detected as writing takes place. On completion of a write operation the 'flux check' will indicate if any errors were detected in the recording of that block of data.

When a 'flux check' error occurs, the computer rewrites the data record on a new section of tape, leaving the incorrect record in situ. Three such attempts are allowed before a data block is abandoned. The computer notifies the operator of 'flux check' errors by incrementing a counter on the timer unit.

The second level of checking is done on a small sample of data blocks. After a record has been written, with no 'flux check' error, the tape transport backspaces over the data record and reads the recorded information back into the computer memory, where it is checked bit by bit against the original version, still retained in the computer. If errors are detected the record is rewritten, as it is for a 'flux check' error. The check reading process is invoked from time to time by operator action (setting bit 0 of the computer switch register) but an option allows for automatic check reading at a predetermined sample rate.

6. RESULTS AND CONCLUSIONS

Two serious problems appeared in the first few months of operation. Both occurred at infrequent intervals and affected the computer input/output system. The more common trouble produced a condition where all computer-controlled data transfers ceased. The other problem, almost as serious, prevented the recording of data onto magnetic tape because the tape recorder returned 'busy' status indefinitely to the computer. Small modifications to the computer program allowed the computer to recognize the symptoms of both these problems and automatically re-initiate input/output with little or no loss of data.

Since these problems were cleared up the operation of the system has been completely satisfactory. The reliability of individual system sub-units has been exceptionally high. Magnetic tape has proved to be a very reliable recording medium. A sample check on system performance showed that only 12 out of 27 000 records contained timing or recording errors. As this sample size is equivalent to the data produced in 75 hours of survey flying, error-free flights are common.

A number of small improvements to the acquisition system are currently planned. A light-weight thermal printer and keyboard has been acquired and will be interfaced to the computer. This will provide greatly increased communication and interaction between the system and the operator during flight, and also will allow better checking and playback of recorded data after a survey flight. It is also planned to increase the resolution of the recorded Doppler co-ordinates by a factor of 10 to give distances in metres. This may improve the accuracy of line/tie cross-over positions extracted from the Doppler data in the course of data reduction.

It is expected that further changes will be made from time to time as the system evolves and further experience accumulates.

The choice of employing a software-controlled data acquisition system based on a digital computer has been vindicated by the results obtained. The major advantages this system offers over a hardware-controlled system are:

(a) The comprehensive checking of recorded data, making use of the 'flux check' facility and the backspace-and-read option.

(b) The conversion of data to fixed-length binary words, and the inclusion of a checksum word when recording on magnetic tape.

(c) The availability of the computer for Doppler navigation calculations.

(d) The relative ease of making changes to the controlling software.

The current workload on the computer is very low: probably only one to two percent of the available computer time is usefully spent. This unused computer time could be used for background tasks, but at present there does not appear to be much scope for this line of development in the aircraft environment.

Some disadvantages of this system are also apparent, mainly the higher initial cost and the large physical size and weight of the computer. Both these disadvantages are likely to disappear in the future, as mini-computers are rapidly becoming smaller and cheaper.

APPENDIX 1

TECHNICAL SPECIFICATIONS: DATA ACQUISITION EQUIPMENT

Digital computer

Make & model:	Hewlett-Packard 2114B
Memory size:	8192 words
Word size:	16 bits
Cycle time:	2 microseconds

Digital input multiplexer

Make & model:	Hewlett-Packard 12566A
Number of channels:	16
Word size:	16 bits

Digital-to-analogue multiplexer

Make & model:	Hewlett-Packard 12555
Number of channels:	16
Word size:	10 bits including sign bit
Output voltage:	-10 to +10 volts

Magnetic tape recorder

Make & model:	Kennedy 1600, RH 7-track incremental recorder with 'flux check' option
Recording:	NRZI mode at 200 bpi, even or odd parity
Writing rate:	500 characters per second
Reading rate:	1000 characters per second

APPENDIX 2

DATA ACQUISITION PROGRAM: ASSEMBLY LANGUAGE LISTING

```
0002  00000                    NAM BMGV2
0003***
0004* GEOPHYSICAL DATA ACQUISITION PROGRAM FOR HEWLETT-PACKARD 2114B
0005* DIGITAL COMPUTER INSTALLED IN SURVEY AIRCRAFT VH-BMG
0006*
0007* SYSTEM HARDWARE CONFIGURATION -
0008*
0009*   H-P 2114B DIGITAL COMPUTER WITH 8K MEMORY
0010*   BMR AIRCRAFT TIMER NZA1
0011*   H-P 16 CHANNEL DIGITAL INPUT MULTIPLEXER
0012*   H-P 16 CHANNEL DIGITAL TO ANALOGUE OUTPUT MULTIPLEXER
0013*   KENNEDY 1600 READ/WRITE INCREMENTAL MAGNETIC TAPE RECORDER
0014*   H-P 40 BIT OUTPUT REGISTER
0015*   16 BIT INPUT/OUTPUT INTERFACE
0016*
0017* SIMPLE OUTLINE OF PROGRAM OPERATION -
0018*
0019* THE MAIN PRORGAM CONSISTS OF A LOOP THAT CONTINUALLY MONITORS THE
0020* CURRENT STATUS OF DATA ACQUISITION AND DATA OUTPUT ONTO MAGNETIC
0021* TAPE, IF THE AVAILIBILITY OF DATA MEANS THAT WORK CAN BE DONE IN
0022* ONE OF THESE AREAS THAT JOB IS DONE, OTHERWISE CONTROL PASSES ON
0023* AROUND THE LOOP, NORMALLY THIS LOOP IS COMPLETED THOUSANDS OF
0024* TIMES PER SECOND - THAT IS THE COMPUTER SPENDS A LARGE PART OF ITS
0025* TIME WAITING FOR WORK.
0026*
0027* THE TIMER INTERRUPTS THE MAIN PROGRAM EVERY 0.2 SECONDS, A SPECIAL
0028* SUBROUTINE SEIZES CONTROL OF THE COMPUTER AND READS ALL REQUIRED
0029* DATA CHANNELS STORING THE READINGS IN THE INPUT BUFFER, THE
0030* MAGNETOMETER IS READ 5 TIMES PER SECOND BUT ALL OTHER CHANNELS ARE
0031* SAMPLED ONCE PER SECOND, A SPECIAL COUNTER IS INCREMENTED
0032* INDICATING TO THE MAIN PROGRAM THAT READINGS ARE AVAILABLE,
0033* CONTROL THEN RETURNS TO THE MAIN PROGRAM AT THE POINT OF INTERRUPT
0034*
0035* A SHORT TIME AFTER A TIMER INTERRUPT HAS OCCURED THE MAIN PROGRAM
0036* WILL DETECT THAT MORE READINGS ARE WAITING, THE READINGS ARE
0037* TRANSFERRED TO A CYCLIC HOLDING BUFFER, THE PROGRAM HAS FOUR OF
0038* THESE BUFFERS WHICH ARE USED ON A CYCLIC BASIS, EACH BUFFER HOLDS
0039* DATA ACQUIRED OVER A 10 SECOND FIDUCIAL PERIOD,
0040*
0041* AT THE SAME TIME MAGNETOMETER, GAMMA-RAY SPECTROMETER AND
0042* ALTIMETER READINGS ARE OUTPUT TO THE D/A CONVERTER PRODUCING
0043* VOLTAGE ANALOGUES OF THE GEOPHYSICAL DATA WHICH IS DISPLAYED ON
0044* CHART RECORDERS PROVIDING A USEFUL RECORD AS WELL AS BEING A
0045* VISUAL MONITOR OF SYSTEM OPERATION; DOPPLER ALONG AND CROSS TRACK
0046* COORDINATES ARE CALCULATED AND THE PILOTS DOPPLER DISPLAY IS
0047* UPDATED, DOPPLER POSITION AT THE START OF THE FIDUCUAL PERIOD IS
0048* STORED FOR INCLUSION ON THE MAGNETIC TAPE,
```

0051*
0052* AT THE END OF A FIDUCIAL INTERVAL THE CURRENT CYCLIC BUFFER IS
0053* FULL UP AND IS FLAGGED FOR OUTPUT ONTO MAGNETIC TAPE. THE FLOW OF
0054* INPUT DATA IS SWITCHED TO START FILLING THE NEXT BUFFER. THE
0055* MAGNETIC TAPE OUTPUT ROUTINE NOTICES WHEN A FULL CYCLIC BUFFER IS
0056* AVAILABLE AND COMMENCES THE PROCESS OF OUTPUTING THAT BLOCK OF
0057* DATA ONTO TAPE. DATA STORED IN BCD FORMAT IS CONVERTED TO 24 BIT
0058* BINARY FORMAT AND TRANSFERRED TO THE MAGNETIC TAPE OUTPUT BUFFER.
0059* A CHECKSUM WORD USED FOR CHECKING DURING PROCESSING IN CANBERRA
0060* IS ADDED AND THE BLOCK OF DATA IS WRITTEN ONTO TAPE AS ONE RECORD.
0061* ALL MT RECORDER OPERATIONS USE THE INTERRUPT SYSTEM,
0062* ALLOWING PROCESSING TO OVERLAP WITH INPUT/OUTPUT. WHEN THE WRITE
0063* OPERATION IS COMPLETE THE STATUS OF THE KENNEDY RECORDER
0064* FLUX-CHECK FACILITY IS USED TO DETECT IF ANY ERRORS WERE MADE IN
0065* WRITING THAT BLOCK, IF AN ERROR IS DETECTED ANOTHER ATTEMPT IS
0066* MADE AT RECORDING THE BLOCK. THREE ATTEMPTS ARE ALLOWED BEFORE
0067* THE BLOCK IS ABANDONNED. AS A FURTHER CHECK A RECORD CAN BE READ
0068* BACK INTO THE COMPUTER AND COMPARED WITH THE ORIGINAL DATA.

0070* MULTIPLEXER CHANNEL ASSIGNMENTS AND CHART RECORDER SENSITIVITIES
0071*

0072* CHANNEL	INPUT MULTIPLEXER	D/A MULTIPLEXER
0073*		
0074* 1	MOST SIGNIFICANT MAG DIGIT	MAG 250 GAMMAS FSD
0075* 2	LOWER 4 MAG DIGITS	MAG 500 GAMMAS FSD
0076* 3	RADIO ALTIMETER	MAG 1000 GAMMAS FSD
0077* 4	FIDUCIAL NUMBER	ALTITUDE 500 METRES FSD
0078* 5	TOTAL COUNT	TOTAL COUNT 1000 FSD
0079* 6	POTASSIUM COUNT	K 250 COUNTS FSD
0080* 7	URANIUM COUNT	U 100 COUNTS FSD
0081* 8	THORIUM COUNT	TH 100 COUNTS FSD
0082* 9	DOPPLER ALONG TRACK	DOPPLER CROSS TRACK DC
0083* 10	DOPPLER CROSS TRACK	CHART SPEED CONTROL
0084* 11	FLIGHT NUMBER	

0086*
0087* COMPUTER I/O SLOT ASSIGNMENTS
0088*
0089* 10 MICROCIRCUIT INTERFACE
0090* 11 INPUT MULTIPLEXER - NON INTERRUPT DEVICE
0091* 12 D/A MULTIPLEXER - NON INTERRUPT DEVICE
0092* 13 TELEPRINTER, UNIT REFERENCE 7
0093* 14 KENNEDY RECORDER, UNIT REFERENCE 10
0094* 15 PAPER TAPE READER, UNIT REFERENCE 11
0095* 16 40 BIT REGISTER - NON INTERRUPT DEVICE

```
0098***** MAGNETIC TAPE FORMAT *****
0099*
0100* ALL RECORDING IS IN ODD PARITY. THE FIRST INFORMATION ON THE TAPE
0101* IS THE FLIGHT HEADER, THIS RECORD IS 80 CHARACTERS IN LENGTH AND
0102* CONTAINS THE FLIGHT NUMBER, SURVEY DATA IS RECORDED IN 460
0103* CHARACTER RECORDS, ONE RECORD IS PRODUCED EVERY 10 SECONDS, SURVEY
0104* LINES ARE SEPARATED BY END-OF-FILE RECORDS AND THE FLIGHT IS
0105* CONCLUDED BY 2 CONSECUTIVE EOF RECORDS
0106*
0107* DATA RECORDS HAVE A SIMPLE BINARY FORMAT WITH ALL INFORMATION
0108* CONTAINED IN 24 BIT BINARY WORDS. THE ORDER OF INFORMATION WITHIN
0109* A RECORD IS SET OUT BELOW.
0110*
0111*          WORD 1     BLOCK NUMBER
0112*               2     ATTEMPT NUMBER
0113*               3     DOPPLER ALONG TRACK
0114*               4     DOPPLER CROSS TRACK
0115*
0116*           DATA FOR FIRST SECOND OF FIDUCIAL PERIOD
0117*
0118*               5     ALTITUDE
0119*               6     FIDUCIAL NUMBER
0120*               7     TOTAL COUNT
0121*               8     POTASSIUM COUNT
0122*               9     URANIUM COUNT
0123*              10     THORIUM COUNT
0124*              11     MAGNETOMETER READING AT 0.0 SEC
0125*              12     MAGNETOMETER READING AT 0.2 SEC
0126*              13     MAGNETOMETER READING AT 0.4 SEC
0127*              14     MAGNETOMETER READING AT 0.6 SEC
0128*              15     MAGNETOMETER READING AT 0.8 SEC
0129*
0130*           DATA FOR NEXT 9 SECONDS IN WORDS 16-114 REPETITION OF
0131*               SEQUENCE FOR FIRST SECOND
0132*
0133*             115     CHECKSUM WORD
```

```
0136                            ENT BMG1
0137                            EXT .IOC,.DINIT,DOP00
0138                            COM BUFIN(200),BUFA(170),BUFB(170),BUFC(170)
0139                            COM BUFD(170),BUFY(235),BUFZ(235)
0140  00000 000000  BMG1  NOP
0141***
0142* RESET PROGRAM STARTING CONDITIONS
0143***
0144  00001 107710          CLC MCR,C       CLEAR MICROCIRCUIT INTERFACE
0145  00002 102100          STF 0           TURN ON INTERRUPT SYSTEM
0146  00003 016001X         JSB .IOC,       CLEAR SYSTEM
0147  00004 000000          OCT 0
0148***
0149* SET INPUT AND OUTPUT POINTERS TO THE FIRST CYCLIC BUFFER
0150* SADD AND QADD CONTAIN BUFFER STARTING ADDRESS, P AND R
0151* CONTAIN ADDRESS OF BUFFER STATUS WORD, P1 POINTS TO
0152* STATUS WORD OF THE NEXT CYCLIC BUFFER
0153***
0154  00005 060014B         LDA POINT       INITIALISE CYCLIC HOLDING BUFFER
0155  00006 070026B         STA QADD          SET INPUT BUFFER ADDRESS
0156  00007 070027B         STA SADD            SET OUTPUT BUFFER ADDRESS
0157  00010 002004          INA
0158  00011 070022B         STA P           SET BUFFER STATUS WORD ADDRESS
0159  00012 070022B         STA R
0160  00013 042023R         ADA =D3
0161  00014 070021B         STA P1
0162  00015 002400          CLA
0163  00016 070002B         STA TAB+1       CLEAR BUFFER STATUS WORDS
0164  00017 070005B         STA TAB+4
0165  00020 070010B         STA TAB+7
0166  00021 070013B         STA TAB+10
0167  00022 070053B         STA LINE        LINE ON FLAG
0168  00023 070054B         STA LEC         LINE END CHART CALIBRATE FLAG
0169  00024 070062B         STA SFLAG       SHORT BLOCK FLAG
0170  00025 070063B         STA TOTAL       INTERRUPT DATA INPUT COUNTER
0171  00026 070050B         STA CAL1
0172  00027 070052B         STA CAL3
0173  00030 070066B         STA CAL5
0174  00031 002004          INA
0175  00032 070061B         STA BEGIN
0176  00033 070073B         STA BOUT1
0177  00034 070071B         STA BLOUT
0178  00035 063166R         LDA WRITA       CLEAR MT OUTPUT ROUTINE
0179  00036 073164R         STA MTFN
0180  00037 002400          CLA
0181  00040 070103B         STA MTFLG
0182  00041 070074B         STA MTFN2
0183  00042 063274R         LDA READC
0184  00043 003004          CMA,INA
0185  00044 070072B         STA RCNTR
0186  00045 016002X         JSB DINIT       INITIALISE DOPPLER ROUTINE
0187  00046 000053R         DEF *+5
0188  00047 000032B         DEF K3
0189  00050 000053B         DEF LINE
0190  00051 000035B         DEF INPUT
0191  00052 001746R DISPA   DEF DDATA
```

```
0194***
0195* EXAMINE SWITCH REGISTER, IF ZERO, TAPE IS REWOUND TO LOAD POINT AN
0196* HEADER RECORD IS WRITTEN - THIS IS  NORMAL STARTING PROCEDURE.
0197* IF BIT 15 IS SET TAPE IS NOT REWOUND AND NO HEADER IS RECORDED.
0198* THIS PROCEDURE IS USED FOR RESTARTING PROGRAM DURING A SURVEY
0199* FLIGHT WITHOUT OVERWRITING PREVIOUSLY RECORDED DATA
0200***
0201   00053 102501  SWREG LIA 1
0202   00054 006400        CLB
0203   00055 106601        STB 1             CLEAR SWITCH REGISTER
0204   00056 052024R       CPA =B100000      IS BIT 15 OF SWITCH REG S T?
0205   00057 026142R       JMP AA1           YES CONTINUE RECORDING
0206   00060 002003        SZA,RSS
0207   00061 026064R       JMP *+3
0208   00062 102000        HLT 0             ILLEGAL SWITCH REGISTER - SET
0209   00063 026053R       JMP SWREG          CORRECTLY AND TOUCH RUN TO GO
0210   00064 016001X REWMT JSB .IOC,         REWIND MT AND LOAD FORWARD TO
0211   00065 030410        OCT 030410          BEGINNING OF TAPE MARKER
0212   00066 102033        HLT 33B           REQUEST REJECTED
0213   00067 000000        NOP
0214   00070 000000        NOP
0215   00071 016001X       JSB .IOC,         GET STATUS
0216   00072 040010        OCT 040010
0217   00073 002020        SSA               READY?
0218   00074 026071R       JMP *-3           NO - KEEP LOOPING
0219   00075 103711        STC MPX,C         STROBE DATA INTO MPX INPUTS
0220   00076 062025R       LDA =B2000        SELECT CHANNEL  11
0221   00077 102611        OTA MPX
0222   00100 102511        LIA MPX           READ FLIGHT NO. FROM THUMBWHEELS
0223   00101 001727        ALF,ALF
0224   00102 070001        STA 1
0225   00103 012026R       AND =B17          ISOLATE FIRST DIGIT
0226   00104 032027R       IOR =B26400       MERGE IN CHARACTER T
0227   00105 042030R       ADA =B33
0228   00106 073756R       STA FLNO
0229   00107 060001        LDA 1
0230   00110 001700        ALF
0231   00111 070001        STA 1
0232   00112 012026R       AND =B17          ISOLATE THIRD DIGIT
0233   00113 001727        ALF,ALF
0234   00114 070041B       STA TT1
0235   00115 060001        LDA 1
0236   00116 001700        ALF
0237   00117 012026R       AND =B17          ISOLATE SECOND DIGIT
0238   00120 030041B       IOR TT1
0239   00121 042031R       ADA =B15433
0240   00122 073757R       STA FLNO+1        STORE IN LABEL
```

```
0243***
0244* FLIGHT NUMBER IS PART OF 80 CHARACTER HEADER RECORD - CODE IS
0245* CDC 7600 BCD, THE FIRST 10 CHARACTERS ARE FLIGHT 123, THE REST
0246* OF THE RECORD IS BLANK CHARACTERS.
0247***
0248   00123 016001X          JSB .IOC.       WRITE HEADER RECORD ON MT
0249   00124 020110           OCT 20110
0250   00125 102007           HLT 7B          REQUEST REJECTED BY .IOC.
0251   00126 001753R          DEF LABEL         - THIS SHOULD NOT OCCUR
0252   00127 177660           DEC -80
0253   00130 016001X          JSB .IOC.       GET STATUS
0254   00131 040010           OCT 040010
0255   00132 002020           SSA             READY?
0256   00133 026130R          JMP *-3         NO - KEEP LOOPING
0257   00134 001323           RAR,RAR         POSITION WRITE ENABLE BIT
0258   00135 000010           SLA             TEST
0259   00136 102011           HLT 11B         WRITE ENABLE RING MISSING
0260   00137 001200           RAL             POSITION FLUX CHECK BIT
0261   00140 000010           SLA             TEST
0262   00141 026064R          JMP REWMT       WRITE ERROR - KEEP TRYING
0263   00142 063745R AA1      LDA AJSBI       ESTABLISH INTERRUPT LINK
0264   00143 070010           STA MCR
0265   00144 103710           STC MCR,C       SET CONTROL ON GPIO INTERFACE
0266   00145 026277R          JMP AAA         THEN ENTER MAIN PROGRAM LOOP
```

```
0270***
0271* PROCESSOR FOR TIMER INTERRUPTS - TIMER SETS FLAG ON MCR INTERFACE
0272* EVERY 0.2 SEC CAUSING INTWRUPT ROUTINE TO READ AND STORE DATA
0273***
0274  00146 000000  INTRR NOP            INTERRUPT PROCESSOR
0275  00147 070045B       STA SAVA       ----A
0276  00150 074046B       STB SAVB       ------B      SAVE REGISTERS
0277  00151 001520        ERA,ALS        --------E
0278  00152 102201        SOC            ----------=0
0279  00153 002004        INA
0280  00154 070047B       STA SAVEO
0281  00155 103711        STC MPX,C      OUTPUT READ COMMAND TO INPUT MPX
0282  00156 062276R       LDA TIMEF      RESET INTERRURT FAIL COUNTER
0283  00157 072275R       STA TIMEC
0284  00160 102510        LIA MCR        GET SYSTEM CONTROL DATA
0285  00161 001300        RAR
0286  00162 070035B       STA INPUT      SAVE
0287  00163 002020        SSA            IS THE 10 SECOND BIT ON?
0288  00164 026200R       JMP STARB      YES
0289  00165 060071B       LDA BLOUT
0290  00166 002003        SZA,RSS        ARE READINDS TO BE ACCEPTED?
0291  00167 026224R       JMP READ       YES
0292  00170 060073B       LDA BOUT1      10 SEC SIGNAL HAS BEEN MISSED
0293  00171 002002        SZA            IS THIS 1ST TIME?
0294  00172 026261R       JMP RETRN      NO - WAIT FOR 10 SEC SIGNAL
0295  00173 002004        INA            YES - PR TEND THIS IS A 10 SEC
0296  00174 070073B       STA BOUT1      INTERRU. ' AND CONTINUE ON BUT
0297  00175 060035B       LDA INPUT      ONLY ONCE. NO FURTHER BLOCKS
0298  00176 032024R       IOR =B100000    UNTIL 10 SEC PULSE SEEN
0299  00177 070035B       STA INPUT
0300  00200 002400        CLA
0301  00201 026212        JMP BLOK+2
0302  00202 060071B STARB LDA BLOUT      LAST 10 SEC BLOCK COMPLETE
0303  00203 002002        SZA
0304  00204 026211R       JMP BLOK       YES
0305  00205 002400        CLA            NO - SET SHORT BLOCK FLAG
0306  00206 070063B       STA TOTAL
0307  00207 002004        INA
0308  00210 070062B       STA SFLAG
0309  00211 002400  BLOK  CLA
0310  00212 070073B       STA BOUT1
0311  00213 070071B       STA BLOUT
0312  00214 060015B       LDA INBUF      SET ADDRESS POINTER TO START OF
0313  00215 070016B       STA INBUF       THE INTERRUPT BUFFER
0314  00216 062032R       LDA =D-50
0315  00217 070030B       STA K1         SET 10 SEC TIMING COUNTER
0316  00220 003400        CCA
0317  00221 070031B       STA K2         SET 1 SEC TIMING COUNTER
0318  00222 060035B       LDA INPUT      GET SYSTEM STATUS AT START OF
0319  00223 070064B       STA SSTAT         10 SEC BLOCK AND SAVE
```

```
0322  00224 034031B READ  ISZ K2          IS IT A 1 SEC INTERRUPT?
0323  00225 026242R       JMP TSEC
0324  00226 066033R       LDB =B4         YES
0325  00227 062034R       LDA =D-8
0326  00230 070076B       STA ALOOP
0327  00231 106611  NCHAN OTB MPX         SELECT MPX CHANNEL
0328  00232 005200        RBL             ROTATE BIT TO NEXT CHANNEL
0329  00233 102511        LIA MPX         READ SELECTED CHANNEL
0330  00234 170016B       STA INBUF,I     STORE IN INPUT BUFFER
0331  00235 034016B       ISZ INBUF       BUMP BUFFER ADDRESS
0332  00236 034076B       ISZ ALOOP
0333  00237 026231R       JMP NCHAN       BACK FOR NEXT CHAN
0334  00240 062035R       LDA =D-5
0335  00241 070031B       STA K2          RESET 1 SEC COUNTER
0336  00242 006404  TSEC  CLB,INB
0337  00243 106611        OTB MPX         SELECT CHANNEL  1
0338  00244 005200        RBL
0339  00245 102511        LIA MPX         READ MAGNETOMETER CHAN  1
0340  00246 170016B       STA INBUF,I     STORE
0341  00247 034016B       ISZ INBUF       BUMP ADDRESS
0342  00250 106611        OTB MPX         SELECT CHANNEL  2
0343  00251 102511        LIA MPX         READ MAG CHANNEL 2
0344  00252 170016B       STA INBUF,I     STORE
0345  00253 034016B       ISZ INBUF       BUMP ADDRESS
0346  00254 034063B       ISZ TOTAL       INCREMENT DATA INPUT COUNTER
0347  00255 034030B       ISZ K1          50TH INTERRUPT SINCE 10 SEC?
0348  00256 026261R       JMP RETRN       NO - TAKE READINGS
0349  00257 002404        CLA,INA         YES - SET FLAG TO INDICATE 10
0350  00260 070071B       STA BLOUT       SEC SIGNAL EXPECTED NEXT TIME
0351  00261 060036B RETRN LDA OTPUT       GPIO SYSTEM CONTROL OUTPUT
0352  00262 102610        OTA MCR
0353  00263 002400        CLA
0354  00264 070036B       STA OTPUT
0355  00265 060047B       LDA SAVEO
0356  00266 103101        CLO
0357  00267 000036        SLA,ELA         ----E
0358  00270 102101        STF 1           ------O       RESTORE REGISTERS
0359  00271 060045B       LDA SAVA        --------A
0360  00272 064046B       LDB SAVB        ----------B
0361  00273 103710        STC MCR,C       RESET CONTROL ON GP INTERFACE
0362  00274 126146R       JMP INTRR,I     RETURN TO INTERRUPTED PROGRAM
```

```
0365* TIMEF IS A VARIABLE WHICH MUST BE ADJUSTED WHEN CHANGES ARE MADE
0366* EFFECTING THE BASIC LOOP FREQUENCY OF THE MAIN PROGRAM.
0367   00275 000000   TIMEC NOP
0368   00276 160000   TIMEF OCT 160000
0369***
0370* THE FOLLOWING SECTION OF THE PROGRAM CHECKS IF DATA IS
0371* WAITING IN THE INPUT BUFFER. IF SO THE DATA IS TRANSFERRED
0372* TO A CYCLIC HOLDING BUFFER AND ALSO OUTPUT TO D/A FOR CHART
0373* RECORDER
0374***
0375   00277 036275R AAA    ISZ TIMEC      INTERRUPT FAIL COUNTER RUN DOWN?
0376   00300 026315R        JMP INTOK      NO
0377   00301 103100         CLF 0          YES - TIMER INTERRUPT OVERDUE
0378   00302 016001X        JSB ,IOC,      TURN OFF INTERRUPT SYSTEM AND
0379   00303 000000         OCT 0           CLEAR IOC
0380   00304 002404         CLA,INA
0381   00305 070101B        STA GAPMT      RESET MT OUTPUT ROUTINE
0382   00306 063166R        LDA WRITA       TO RE-WRITE ANY PARTLY
0383   00307 073164R        STA MTFN         COMPLETED RECORD
0384   00310 060036B        LDA OTPUT
0385   00311 032036R        IOR =D2        BUMP ERROR COUNTER
0386   00312 070036B        STA OTPUT
0387   00313 102100         STF 0          TURN ON INTERRUPT SYSTEM
0388   00314 103710         STC MCR,C      AND SET CONTROL ON MCR
0389   00315 060062B INTOK  LDA SFLAG
0390   00316 002002         SZA            SHORT BLOCK?
0391   00317 026723R        JMP SHORT      YES - PROCESS SHORT BLOCK
0392   00320 060063B        LDA TOTAL      NEW DATA WAITING IN INPUT BUFFER
0393   00321 002003         SZA,RSS
0394   00322 027120R        JMP MTO        NO - CONTINUE AROUND LOOP
0395   00323 042037R        ADA =D-1       YES
0396   00324 070063B        STA TOTAL      ADJUST DATA INPUT COUNTER
0397   00325 060061B        LDA BEGIN
0398   00326 002003         SZA,RSS        START OF 10 SEC BLOCK?
0399   00327 026425R        JMP BLK1       NO
0400   00330 160026B        LDA QADD,I     YES - GET ADDRESS OF NEXT
0401   00331 070023B        STA Q            CYCLIC BUFFER
0402   00332 072675R        STA DOPAD      SAVE DOPPLER STORAGE ADDRESS
0403   00333 042033R        ADA =D4         SKIP OVER DOPPLER STORAGE
0404   00334 070024B        STA Q1
0405   00335 070025B        STA Q2
0406   00336 003400         CCA
0407   00337 070033B        STA K4         SET 1 SEC COUNTER
0408   00340 062040R        LDA =D-2
0409   00341 070056B        STA RESET      SCINTO RESET COUNTER
0410   00342 062032R        LDA =D-50
0411   00343 070032B        STA K3         SET 10 SEC COUNTER
0412   00344 002400         CLA
0413   00345 070061B        STA BEGIN      SET BLOCK IN PROGRESS FLAG
0414   00346 060015B        LDA IBUFF
0415   00347 070017B        STA INBF2      INPUT BUFFER ADDRESS
0416   00350 060064B        LDA SSTAT
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0419  00351 000010          SLA             IS A LINE BEING FLOWN?
0420  00352 026407R          JMP SLINE       YES
0421  00353 060053B          LDA LINE        NO  HAS LINE JUST ENDED?
0422  00354 002002          SZA
0423  00355 026367R          JMP ENDLI       YES
0424  00356 102501           LIA 1           GET SWITCH REGISTER CONTENTS
0425  00357 052037R          CPA =D-1        ALL BITS SET?
0426  00360 002001          RSS
0427  00361 026425R          JMP BLK1        NO
0428  00362 160022B          LDA R,I         YES - END THE FLIGHT
0429  00363 002002          SZA              WAIT FOR MT OUTPUT TO END
0430  00364 026425R          JMP BLK1                THEN
0431  00365 102601           OTA 1           CLEAR SWITCH REGISTER
0432  00366 027373R          JMP ENDIT                TERMINATE
0433  00367 002404  ENDLI    CLA,INA
0434  00370 070054B          STA LEC         SET LINE END CALIBRATE FLAG
0435  00371 003400           CCA             SET BUFFER STATUS TO -1
0436  00372 170020B          STA P,I           TO WRITE EOF AT END OF LINE
0437  00373 034020B          ISZ P           MOVE POINTERS TO NEXT BUFFER
0438  00374 160020B          LDA P,I
0439  00375 070026B          STA QADD
0440  00376 002004          INA
0441  00377 070020B          STA P
0442  00400 034021B          ISZ P1
0443  00401 160021B          LDA P1,I
0444  00402 002004          INA
0445  00403 070021B          STA P1
0446  00404 002400          CLA
0447  00405 070053B          STA LINE        REMOVE LINE ON FLAG
0448  00406 026425R          JMP BLK1
0449  00407 160021B SLINE    LDA P1,I
0450  00410 002003          SZA,RSS         NEXT CYCLIC BUFFER FREE?
0451  00411 026413R          JMP **2
0452  00412 002404          CLA,INA          NO, SET ABORT FLAG
0453  00413 070040B          STA ABORT
0454  00414 060053B          LDA LINE
0455  00415 002002          SZA             HAS LINE JUST STARTED?
0456  00416 026425R          JMP BLK1        NO
0457  00417 002404          CLA,INA
0458  00420 070053B          STA LINE
0459*
0460* KENNEDY IS PRONE TO ERRORS ON FIRST WRITE AFTER A LONG PAUSE -
0461* THIS PROBLEM IS OVERCOME BY WRITING A GAP BEFORE STARTING LINE
0462*
0463  00421 070101B          STA GAPMT       SET MT GAP FLAG
0464  00422 060036B          LDA OTPUT       MAGNETOMETER CALIBRATE AT START
0465  00423 032033R          IOR =B4               OF LINE
0466  00424 070036B          STA OTPUT
0467  00425 034033B BLK1     ISZ K4          ONE SECOND READING?
0468  00426 026450R          JMP ,2MAG       NO
0469  00427 062041R          LDA =D-6
0470  00430 070034B          STA K5
```

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0473  00431 160017B ONE,0 LDA  INBF2,I   TAKE READING FROM INPUT BUFFER
0474  00432 170024B       STA  Q1,I        AND STORE IN CYCLIC BUFFER
0475  00433 034017B       ISZ  INBF2     BUMP ADDRESSES
0476  00434 034024B       ISZ  Q1
0477  00435 034034B       ISZ  K5
0478  00436 026431R       JMP  ONE,0
0479  00437 160017B       LDA  INBF2,I   STORE DOPPLER SYNCHRO READINGS
0480  00440 034017B       ISZ  INBF2
0481  00441 070077B       STA  LSYN        ALONG TRACK
0482  00442 160017B       LDA  INBF2,I
0483  00443 034017B       ISZ  INBF2
0484  00444 070100B       STA  XSYN        CROSS TRACK
0485  00445 062035R       LDA  =D-5
0486  00446 070033B       STA  K4        SET ONE SECOND COUNTER
0487  00447 070065B       STA  ONES
0488  00450 160017B ,2MAG LDA  INBF2,I   TRANSFER MAGNETOMETER READINGS
0489  00451 003000        CMA            COMPLEMENT DANA LOGIC
0490  00452 170024B       STA  Q1,I
0491  00453 034017B       ISZ  INBF2
0492  00454 034024B       ISZ  Q1
0493  00455 160017B       LDA  INBF2,I
0494  00456 003000        CMA
0495  00457 170024B       STA  Q1,I
0496  00460 034017B       ISZ  INBF2
0497  00461 034024B       ISZ  Q1
```

```
0001***
0002* FOLLOWING SECTION CONTROLS DATA OUTPUT TO CHART RECORDERS, THE 3
0003* LEAST SIGNIFICANT DIGITS OF EACH DATA CHANNEL ARE CONVERTED TO
0004* BINARY AND OUTPUT TO D/A CONVERTER, CHART RECORDERS ARE ADJUSTED
0005* TO 4.89 VOLTS FOR FULL SPAN, CALIBRATE FACILITY IS PROVIDED
0006* WHEREBY ZERO AND FULL SCALE IS OUTPUT TO ALL RECORDERS TO ALLOW
0007* ADJUSTMENTS TO BE MADE WHEN BIT 1 OF SWITCH REGISTER IS SET, AT
0008* END OF LINE ZERO IS OUTPUT FOR 5 SEC FULL SCALE FOR 5 SEC.
0009***
0010  00462 060053B        LDA LINE      LINE IN PROGRESS?
0011  00463 002002         SZA
0012  00464 026556R        JMP LIN1      YES
0013  00465 060054B        LDA LEC
0014  00466 002003         SZA,RSS       LINE END CALIBRATE?
0015  00467 026477R        JMP CBCH
0016  00470 002400         CLA           YES
0017  00471 070054B        STA LEC
0018  00472 070050B        STA CAL1
0019  00473 070052B        STA CAL3
0020  00474 002004         INA
0021  00475 070066B        STA CALS      SET CALIBRATE FLAG
0022  00476 026514R        JMP CBCH0
0023  00477 060066B CBCH   LDA CALS      CALIBRATE IN PROGRESS?
0024  00500 002002         SZA
0025  00501 026514R        JMP CBCH0     YES
0026  00502 060032B        LDA K5
0027  00503 052032R        CPA =D-50     START OF 10 SEC BLOCK?
0028  00504 002001         RSS
0029  00505 026556R        JMP LIN1      NO
0030  00506 102501         LIA 1         GET SWITCH REGISTER
0031  00507 052036R        CPA =D2       IS CALIBRATE BIT SET?
0032  00510 002001         RSS
0033  00511 026556R        JMP LIN1      NO
0034  00512 002404         CLA,INA
0035  00513 070066B        STA CALS     SET CALIBRATE FLAG
0036  00514 060052B CBCH0  LDA CAL3
0037  00515 002002         SZA
0038  00516 026535R        JMP CBCH5     DO FULL SCALE PART NOW
0039  00517 060050B        LDA CAL1      START OF CALIBRATE CYCLE?
0040  00520 002002         SZA
0041  00521 026526R        JMP *+5       NO
0042  00522 002404         CLA,INA
0043  00523 070050B        STA CAL1
0044  00524 062042R        LDA =D-25
0045  00525 070051B        STA CAL2      SET 5 SECOND COUNTER
0046  00526 034051B        ISZ CAL2      5 SEC UP?
0047  00527 026533R        JMP CBCH1
0048  00530 002404         CLA,INA       YES - START FULL SCALE CAL
0049  00531 070052B        STA CAL3
0050  00532 026535R        JMP *+3
0051  00533 006400 CBCH1   CLB           OUTPUT ZERO ON ALL CHANNELS
0052  00534 026553R        JMP CALCH
```

```
0055  00535 060032B CBCH5 LDA K3
0056  00536 052032R       CPA =D-50      START OF 10 SEC BLOCK?
0057  00537 002001        RSS
0058  00540 026551R       JMP CBCH9      NO - CONTINUE CALIBRATE
0059  00541 006400        CLB            YES - RESET CALIBRATE ZERO
0060  00542 074050B       STB CAL1
0061  00543 074052B       STB CAL3
0062  00544 102501        LIA 1          IS CALIBRATE BIT STILL ON?
0063  00545 052036R       CPA =D2
0064  00546 026514R       JMP CBCH0      YES - CONTINUE
0065  00547 074066B       STB CALS       NO - CLEAR CALIBRATE FLAG
0066  00550 026556R       JMP LIN1
0067  00551 066043R CBCH9 LDB =D1000     OUTPUT FULL SCALE ON ALL PENS
0068  00552 026553R       JMP CALCH
0069  00553 062037R CALCH LDA =D-1
0070  00554 016764R       JSB ,DTA
0071  00555 026665R       JMP BLKE1
0072***
0073* GEOPHYSICAL DATA OUTPUT TO CHART RECORDERS ****
0074***
0075  00556 060065B LIN1  LDA ONES       ONE SECOND INTERVAL?
0076  00557 002003        SZA,RSS
0077  00560 026643R       JMP MCHAR      NO
0078  00561 062756R       LDA LRD
0079  00562 072757R       STA LRAD
0080  00563 034056B       ISZ RESET
0081  00564 026572R       JMP NOSET
0082  00565 002400        CLA
0083  00566 072760R       STA LR         SCALERS RESET IMMEDIATELY AFTER
0084  00567 072761R       STA LR+1        10 SEC SO CLEAR LAST READINGS
0085  00570 072762R       STA LR+2
0086  00571 072763R       STA LR+3
0087  00572 160025B NOSET LDA Q2,I       PICK UP RA READING
0088  00573 034025B       ISZ Q2         BUMP ADDRESS
0089  00574 017011R       JSB BCDB       CONVERT TO BINARY
0090  00575 017042R       JSB FS500      500 METRES FULL SCALE AND
0091  00576 003004        CMB,INB        INVERT ALTITUDE PROFILE
0092  00577 046043R       ADB =D1000
0093  00600 062023R       LDA =D3
0094  00601 016764R       JSB ,DTA       OUTPUT TO CHART THROUGH D/A
0095  00602 034025B       ISZ Q2         SKIP OVER FIDUCIAL NUMBER
0096  00603 160025B       LDA Q2,I       SPECTROMETER CHANNEL 1
0097  00604 034025B       ISZ Q2         BUMP ADDRESS
0098  00605 017011R       JSB BCDB       CONVERT TO BINARY
0099  00606 016745R       JSB DESCL      TAKE DIFFERENCE
0100  00607 046044R       ADB =D100      ADD 100 COUNTS TO SHIFT BASELINE
0101  00610 046045R       ADB =D-10000
0102  00611 006020        SSB            TEST IF NOW EXCEEDS 1000
0103  00612 046046R       ADB =D10000
0104  00613 062033R       LDA =D4        TOTAL COUNT 1000 FSD
0105  00614 016764R       JSB ,DTA        ON D/A CHANNEL 5
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```
0108  00615 160025B        LDA Q2,I      SPECTROMETER CHANNEL 2
0109  00616 034025B        ISZ Q2
0110  00617 017011R        JSB BCDB      CONVERT TO BINARY
0111  00620 016745R        JSB DESCL
0112  00621 017050R        JSB FS250     K COUNT 250 FSD
0113  00622 062047R        LDA =D5           ON
0114  00623 016764R        JSB ,DTA          D/A CHANNEL 6
0115  00624 160025B        LDA Q2,I      SPECTROMETER CHANNEL 3
0116  00625 034025B        ISZ Q2
0117  00626 017011R        JSB BCDB      CONVERT TO BINARY
0118  00627 016745R        JSB DESCL
0119  00630 046050R        ADB =D10      ADD 10 COUNTS TO SHIFT BASELINE
0120  00631 017057R        JSB FS100     U COUNT 100 FSD
0121  00632 062051R        LDA =D6
0122  00633 016764R        JSB ,DTA      ON D/A CHANNEL 7
0123  00634 160025B        LDA Q2,I      SPECTROMETER CHANNEL 4
0124  00635 034025B        ISZ Q2
0125  00636 017011R        JSB BCDB      CONVERT TO BINARY
0126  00637 016745R        JSB DESCL
0127  00640 017057R        JSB FS100     TH COUNT 100 FSD
0128  00641 062052R        LDA =D7        ON D/A CHANNEL 8
0129  00642 016764R        JSB ,DTA
0130  00643 160025B MCHAR  LDA Q2,I      GET MOST SIGNIFICANT MAG DIGIT
0131  00644 070057B        STA TPO           AND SAVE
0132  00645 034025B        ISZ Q2        BUMP ADDRESS
0133  00646 160025B        LDA Q2,I      GET 4 LEAST SIGNIFICANT MAG
0134  00647 070060B        STA TPO+1      DIGITS AND SAVE
0135  00650 034025B        ISZ Q2        BUMP ADDRESS
0136  00651 017011R        JSB BCDB      CONVERT
0137  00652 077072R        STB ,FST,
0138  00653 062036R        LDA =D2
0139  00654 016764R        JSB ,DTA      1000 GAMMAS ON D/A CHANNEL 3
0140  00655 067072R        LDB ,FST,
0141  00656 017042R        JSB FS500
0142  00657 002404         CLA,INA
0143  00660 016764R        JSB ,DTA      500 GAMMAS ON D/A CHANNEL 2
0144  00661 067072R        LDB ,FST,
0145  00662 017050R        JSB FS250
0146  00663 002400         CLA
0147  00664 016764R        JSB ,DTA      250 GAMMAS ON D/A CHANNEL 1
```

```
0150  00665 060065B BLKE1 LDA ONES      IS IT A ONE SEC INTERVAL?
0151  00666 002003       SZA,RSS
0152  00667 026700R       JMP NODOP     NO
0153  00670 002400       CLA
0154  00671 070065B       STA ONES
0155  00672 060077B       LDA LSYN
0156  00673 064100B       LDB XSYN      PICK UP DOPPLER READINGS AND
0157  00674 016003X       JSB DOP00     GO TO DOPPLER ROUTINE
0158  00675 000000 DOPAD  NOP           ADDRESS OF DOPPLER IN BUFFER
0159  00676 066052R       LDB DISPA
0160  00677 017073R       JSB REG40     OUTPUT TO 40 BIT REGISTER
0161  00700 034032B NODOP ISZ K3        END OF 10 SEC BLOCK?
0162  00701 027120R       JMP MTO       NO
0163***
0164* END OF 10 SEC PERIOD, IF FLYING LINE RELEASE FULL CYCLIC BUFFER
0165* FOR MAGNETIC TAPE OUTPUT AND MOVE INPUT POINTERS TO NEXT BUFFER
0166***
0167  00702 060053B       LDA LINE      FLYING LINE?
0168  00703 002003       SZA,RSS
0169  00704 026720R       JMP BLKE5     NO
0170  00705 002404 BLKE2  CLA,INA       YES - FLAG BUFFER FOR OUTPUT
0171  00706 170020B       STA P,I
0172  00707 034020B       ISZ P
0173  00710 160020B       LDA P,I       MOVE INPUT POINTERS TO NEXT
0174  00711 070026B       STA CADD         CYCLIC BUFFER
0175  00712 002004       INA
0176  00713 070020B       STA P
0177  00714 034021B       ISZ P1
0178  00715 160021B       LDA P1,I
0179  00716 002004       INA
0180  00717 070021B       STA P1
0181  00720 002404 BLKE5  CLA,INA       SET START NEW BLOCK FLAG
0182  00721 070061B       STA BEGIN
0183  00722 027120R       JMP MTO       GO TO MT OUTPUT CONTROL SECTION
```

```
0186***
0187* SHORT BLOCK PROCESSOR, IF LESS THAN FIFTY 0.2 SEC INTERRUPTS
0188* BETWEEN 10 SEC PULSES UNUSED PART OF CYCLIC BUFFER IS FILLED WITH
0189* ZEROS AND RELEASED FOR OUTPUT.
0190***
0191  00723 002400  SHORT CLA
0192  00724 070062B       STA SFLAG      CLEAR
0193  00725 060053B       LDA LINE
0194  00726 002003        SZA,RSS
0195  00727 026720R       JMP BLKE5      IGNORE IF LINE OFF
0196  00730 160021B       LDA P1,I
0197  00731 002002        SZA
0198  00732 026720R       JMP BLKE5      IGNORE IF BUFFERS FULL
0199  00733 060026B       LDA Q
0200  00734 003004        CMA,INA
0201  00735 040024B       ADA Q1         CALCULATE NUMBER OF UNUSED
0202  00736 042053R       ADA =D-164           WORDS IN RECORD
0203  00737 006400        CLB
0204  00740 174024B BFILL STB Q1,I       FILL UNUSED PART WITH ZEROS
0205  00741 034024B       ISZ Q1
0206  00742 034000        ISZ 0
0207  00743 026740R       JMP BFILL
0208  00744 026725R       JMP BLKE2
```

```
0211***
0212******** VARIOUS SUBROUTINES **************
0213***
0214***
0215*** DESCL CALCULATES 1 SECOND COUNT RATES BY TAKING SUCCESSIVE
0216*** DIFFERENCES OF SCALER READINGS
0217***
0218  00745 000000  DESCL NOP
0219  00746 074000        STB 0
0220  00747 146757R       ADB LRAD,I
0221  00750 003004        CMA,INA
0222  00751 172757R       STA LRAD,I
0223  00752 036757R       ISZ LRAD
0224  00753 006020        SSB
0225  00754 046043R       ADB =D1000
0226  00755 126745R       JMP DESCL,I
0227  00756 000760R LRD   DEF LR
0228  00757 000000  LRAD  BSS 1
0229  00760 000000  LR    BSS 4
0230***
0231*** ,DTA WORKS THE D/A MULTIPLEXER, ON ENTRY B CONTAINS THE OUTPUT
0232*** DATA AND A CONTAINS THE CHANNEL. IF A IS NEGATIVE OUTPUT IS
0233*** PRODUCED ON CHANNELS 1-8
0234***
0235  00764 000000  ,DTA  NOP
0236  00765 002020        SSA             OUTPUT ON ALL CHANNELS?
0237  00766 026775R       JMP I03         YES
0238  00767 001727        ALF,ALF
0239  00770 001700        ALF             POSITION CHANNEL NO.
0240  00771 030001        IOR 1           MERGE IN DATA
0241  00772 102612        OTA DASC
0242  00773 103712        STC DASC,C
0243  00774 126764R       JMP ,DTA,I

0245  00775 062034R I03   LDA =D-8
0246  00776 073010R       STA CC1         OUTPUT ON CHANS 0 TO 7
0247  00777 106612  LP8    OTB DASC
0248  01000 103712        STC DASC,C
0249  01001 005700        BLF
0250  01002 006004        INB
0251  01003 005727        BLF,BLF
0252  01004 005700        BLF
0253  01005 037010R       ISZ CC1
0254  01006 026777R       JMP LP8         NEXT CHANNEL
0255  01007 126764R       JMP ,DTA,I
0256  01010 000000  CC1    NOP
```

```
0259***
0260*** BCDB CONVERTS A THREE DIGIT BCD QUANTITY TO BINARY
0261***
0262  01011 000000  BCDB  NOP
0263  01012 001727        ALF,ALF        POSITION FIRST CHAR
0264  01013 073040R       STA TXX
0265  01014 012026R       AND =B17
0266  01015 064000        LDB 0
0267  01016 017032R       JSB MUL
0268  01017 063040R       LDA TXX
0269  01020 001700        ALF            POSITION SECOND CHAR
0270  01021 073040R       STA TXX
0271  01022 012026R       AND =B17
0272  01023 044000        ADB 0
0273  01024 017032R       JSB MUL
0274  01025 063040R       LDA TXX
0275  01026 001700        ALF            POSITION THIRD CHAR
0276  01027 012026R       AND =B17
0277  01030 044000        ADB 0
0278  01031 127011R       JMP BCDB,I     RETURN WITH BINARY IN B
0279  01032 000000  MUL   NOP
0280  01033 005000        BLS
0281  01034 077041R       STB TXY
0282  01035 005020        BLS,BLS
0283  01036 047041R       ADB TXY
0284  01037 127032R       JMP MUL,I
0285  01040 000000  TXX   BSS 1
0286  01041 000000  TXY   BSS 1
```

```
0289***
0290*** THE FOLLOWING GROUP OF SUBROUTINES PROVIDE 500,250 AND 100 UNITS
0291*** FULL SCALE OUTPUT ON THE CHART RECORDERS.
0292***
0293  01042 000000  FS500 NOP              500 UNITS FULL SCALE
0294  01043 046054R       ADB =D-500
0295  01044 006020        SSB
0296  01045 046055R       ADB =D500
0297  01046 005000        BLS
0298  01047 127042R       JMP FS500,I

0300  01050 000000  FS250 NOP              250 UNITS FULL SCALE
0301  01051 046056R       ADB =D-250
0302  01052 006021        SSB,RSS
0303  01053 027051R       JMP *-2
0304  01054 046057R       ADB =D250
0305  01055 005020        BLS,BLS
0306  01056 127050R       JMP FS250,I

0308  01057 000000  FS100 NOP              100 UNITS FULL SCALE
0309  01060 046060R       ADB =D-100
0310  01061 006021        SSB,RSS
0311  01062 027060R       JMP *-2
0312  01063 046044R       ADB =D100
0313  01064 005000        BLS
0314  01065 077071R       STB ,FSTM
0315  01066 005020        BLS,BLS
0316  01067 047071R       ADB ,FSTM
0317  01070 127057R       JMP FS100,I
0318  01071 000000  ,FSTM NOP
0319  01072 000000  ,FST, NOP
```

```
0322  01073 000000  REG40 NOP             40 BIT OUTPUT REGISTER DRIVER
0323  01074 106716         CLC REGSC      PRESET INTERFACE LOGIC
0324  01075 002400         CLA
0325  01076 102616         OTA REGSC       OUTPUT CONTROL WORD
0326  01077 160001         LDA 1,I
0327  01100 102616         OTA REGSC      OUTPUT 1ST 8 BITS
0328  01101 006004         INB
0329  01102 160001         LDA 1,I
0330  01103 102616         OTA REGSC      OUTPUT 2ND 8 BITS
0331  01104 006004         INB
0332  01105 160001         LDA 1,I
0333  01106 102616         OTA REGSC      OUTPUT 3RD GROUP
0334  01107 006004         INB
0335  01110 160001         LDA 1,I
0336  01111 102616         OTA REGSC      OUTPUT 4TH GROUP
0337  01112 006004         INB
0338  01113 160001         LDA 1,I
0339  01114 102616         OTA REGSC      OUTPUT FINAL 8 BITS
0340  01115 103716         STC REGSC,C    GIVE ENCODE COMMAND
0341  01116 127073R        JMP REG40,I
0342  01117 000000  REGCW  OCT 0
```

```
0001***
0002* MAGNETIC TAPE OUTPUT CONTROL ROUTINE**********
0003***
0004  01120 160022B MTO   LDA R,I        FULL CYCLIC BUFFER WAITING IN
0005  01121 002003        SZA,RSS          OUTPUT QUEUE?
0006  01122 026277R       JMP AAA        NO
0007  01123 016001X       JSB ,IOC,      GET MT RECORDER STATUS
0008  01124 040010        OCT 040010
0009  01125 002021        SSA,RSS        MT BUSY?
0010  01126 027157R       JMP MT02       NO
0011  01127 060103B       LDA MTFLG      YES
0012  01130 002002        SZA            JUST STARTING NEW OPERATION?
0013  01131 027142R       JMP MT01       NO
0014  01132 002004        INA            YES - SET FLAG AND COUNTER TO
0015  01133 070103B       STA MTFLG       ALLOW APPROX 3 SECONDS FOR
0016  01134 060032B       LDA K3          OPERATION TO BE COMPLETED
0017  01135 042061R       ADA =D18
0018  01136 002021        SSA,RSS
0019  01137 042032R       ADA =D-50
0020  01140 070102B       STA MTIME
0021  01141 026277R       JMP AAA
0022  01142 060102B MT01  LDA MTIME      HAS THE 3 SECOND TIME LIMIT
0023  01143 050032B       CPA K3           EXPIRED?
0024  01144 002001        RSS
0025  01145 026277R       JMP AAA        NO - GO BACK TO START OF LOOP
0026  01146 016001X       JSB ,IOC,      YES - CLEAR TAPE RECORDER AND
0027  01147 000010        OCT 000010       RESTART THE OPERATION
0028  01150 002400        CLA
0029  01151 070103B       STA MTFLG
0030  01152 070074B       STA MTFN2
0031  01153 002004        INA
0032  01154 070101B       STA GAPMT
0033  01155 027167R       JMP WRITA+1
0034  01156 027161R       JMP *+3
0035  01157 070067B MT02  STA MTSTF      SAVE MT STATUS
0036  01160 074070B       STB XLOG         AND TRANSMISSION LOG
0037  01161 002400        CLA
0038  01162 070103B       STA MTFLG
0039  01163 127164R       JMP *+1,I      JUMP TO APPROPRIATE MT ROUTINE
0040  01164 000000  MTFN    NOP          ADDRESS STORED HERE
0041  01165 177775  ATNUM  DEC -3        NUMBER OF WRITE ATTEMPTS ALLOWED
```

```
0044***
0045* INITIATE WRITE OPERATION AND SET JUMP ADDRESS TO CHECK ROUTINE
0046***
0047  01166 001167R WRITA DEF **1
0048  01167 160022B       LDA R,I
0049  01170 002020        SSA              DATA RECORD OR E-O-F?
0050  01171 027242R       JMP ENDF         WRITE END-OF-FILE
0051  01172 060101B       LDA GAPMT        FIRST RECORD OF LINE?
0052  01173 002003        SZA,RSS
0053  01174 027200R       JMP **4          NO
0054  01175 002400        CLA              CLEAR WRITE SELECT BIT ON MT
0055  01176 070101B       STA GAPMT        INTERFACE WILL CAUSE A GAP
0056  01177 102614        OTA MTRSC        AUTOMATICALLY ON NEXT WRITE
0057  01200 063165R       LDA ATNUM
0058  01201 070037B       STA ATTNO        ALLOW THREE WRITE ATTEMPTS
0059  01202 160027B       LDA SADD,I       GET ADDRESS OF CYCLIC BUFFER
0060  01203 067235R       LDB BUFFO        ADDRESS OF OUTPUT BUFFER
0061  01204 017423R       JSB BUFFI        CONVERT TO BINARY, ADD CHECKSUM
0062  01205 063274R       LDA READC        GET READBACK CONTROL WORD
0063  01206 002020        SSA              NEGATIVE?
0064  01207 027231R       JMP RETRY        YES - NO READBACK POSSIBLE
0065  01210 002003        SZA,RSS          ZERO?
0066  01211 027222R       JMP WRIT2        YES - NO AUTO CHECK READ
0067  01212 034072B       ISZ RCNTR        IS IT THE NTH RECORD?
0068  01213 027222R       JMP WRIT2        NO
0069  01214 063274R       LDA READC        YES?
0070  01215 003004        CMA,INA          RESET RECORD COUNTER?
0071  01216 070072B       STA RCNTR
0072  01217 002404  WRIT1 CLA,INA          SET CHECK READ FLAG
0073  01220 070074B       STA MTFN2
0074  01221 027231R       JMP RETRY
0075  01222 102501  WRIT2 LIA 1            HAVE A LOOK AT SWITCH REGISTER
0076  01223 052062R       CPA =D1          IF BIT 0 SET READ BACK AND
0077  01224 002001        RSS                CHECK THIS RECORD
0078  01225 027231R       JMP RETRY
0079  01226 002400        CLA
0080  01227 102601        OTA 1
0081  01230 027217R       JMP WRIT1
0082  01231 036136C RETRY ISZ BUFZ+3       INSERT ATTEMPT NUMBER
0083  01232 016001X       JSB ,IOC,        INITIATE WRITE
0084  01233 020110        OCT 020110
0085  01234 102033        HLT 33B          REQUEST REJECTED?
0086  01235 002133C BUFFO DEF BUFZ
0087  01236 177064        DEC -460
0088  01237 063252R       LDA MTCHK        SET JUMP ADDRESS TO NEXT
0089  01240 073164R       STA MTFN           MT PROCESSOR ROUTINE
0090  01241 026277R       JMP AAA
0091  01242 016001X ENDF  JSB ,IOC,        WRITE END-OF-FILE
0092  01243 030110        OCT 030110
0093  01244 102033        HLT 33B          REQUEST REJECTED BY ,IOC,?
0094  01245 000000        NOP
0095  01246 000000        NOP
0096  01247 063252R       LDA MTCHK
0097  01250 073164R       STA MTFN
0098  01251 026277R       JMP AAA
```

```
0101***
0102* CHECK WRITE ON COMPLETION OF OPERATION THEN IF READING BACK
0103* REQUIRED INITIATE BACKSPACE
0104***
0105   01252 001253R MTCHK DEF *+1
0106   01253 160022B       LDA R,I
0107   01254 002020        SSA              DATA RECORD OR EOF?
0108   01255 027311R       JMP OKAY         EOF
0109   01256 060067B       LDA MTSTF        GET STATUS
0110   01257 012063R       AND =B40         TEST END-OF-TAPE BIT
0111   01260 002002        SZA
0112   01261 102055        HLT 55B          *****-END-OF-TAPE *****
0113   01262 060067B       LDA MTSTF
0114   01263 001323        RAR,RAR          POSITION WRITE ENABLE BIT
0115   01264 000010        SLA              TEST
0116   01265 102044        HLT 44B          WRITE ENABLE RING MISSING
0117   01266 001200        RAL              POSITION PARITY ERROR BIT
0118   01267 002011        SLA,RSS          TEST
0119   01270 060074B       LDA MTFN2
0120   01271 002002        SZA
0121   01272 027324R       JMP CHECR
0122   01273 027311R       JMP OKAY
0123   01274 000000  READC OCT 0
0124   01275 060036B NXTRY LDA OTPUT        BUMP ERROR COUNTERS
0125   01276 032062R       IOR =B1
0126   01277 070036B       STA OTPUT
0127   01300 034037B       ISZ ATTNO        ANOTHER ATTEMPT?
0128   01301 002001        RSS
0129   01302 027306R       JMP QUIT         GIVE UP
0130   01303 060040B       LDA ABORT
0131   01304 002003        SZA,RSS          ALL BUFFERS FULL?
0132   01305 027231R       JMP RETRY        NO - TIME FOR ANOTHER TRY
0133   01306 060036B QUIT  LDA OTPUT        YES - FORGO FURTHER ATTEMPTS
0134   01307 032036R       IOR =D2           AND BUMP ERROR COUNTER 2
0135   01310 070036B       STA OTPUT
0136   01311 002400  OKAY  CLA
0137   01312 070040B       STA ABORT        CLEAR POSSIBLE ABORT FLAG
0138   01313 170022B       STA R,I          RELEASE BUFFER
0139   01314 034022B       ISZ R            MOVE POINTERS TO NEXT BUFFER
0140   01315 160022B       LDA R,I
0141   01316 070027B       STA SADD
0142   01317 002004        INA
0143   01320 070022B       STA R
0144   01321 063166R       LDA WRITA        SET JUMP ADDRESS
0145   01322 073164R       STA MTFN
0146   01323 026277R       JMP AAA
```

```
0149  01324 016001X CHECK JSB ,IOC,      ISSUE BSP COMMAND
0150  01325 031010       OCT 31010
0151  01326 102033       HLT 33B        REQUEST REJECTED?
0152  01327 000000       NOP
0153  01330 000000       NOP
0154  01331 063336R      LDA READR      SET JUMP ADDRESS
0155  01332 073164R      STA MTFN
0156  01333 002400       CLA            RESET FLAG TO READ ONLY
0157  01334 070074B      STA MTFN2
0158  01335 026277R      JMP AAA
0159***
0160* INITIATE READ ON COMPLETION OF BACKSPACE
0161***
0162  01336 001337R READR DEF *+1
0163  01337 016001X      JSB ,IOC,      READ BACK THE RECORD
0164  01340 010010       OCT 10010
0165  01341 102033       HLT 33B        REQUEST REJECTED?
0166  01342 001560C BINY  DEF BUFY
0167  01343 177064       DEC -460
0168  01344 063347R      LDA VERFY      SET JUMP ADDRESS
0169  01345 073164R      STA MTFN
0170  01346 026277R      JMP AAA
0171***
0172* CHECK READ OPERATION AND COMPARE DATA READ BACK WITH DATA IN
0173* OUTPUT BUFFER
0174***
0175  01347 001350R VERFY DEF *+1
0176  01350 064070B      LDB XLOG       GET TRANSMISSION LOG
0177  01351 005665       ELR,CLE,ERB    CLEAR MODE BIT
0178  01352 056064R      CPB =D460      CHECK FOR CORRECT LENGTH
0179  01353 002001       RSS
0180  01354 027275R      JMP NXTRY      WRONG  TRY AGAIN
0181  01355 062065R      LDA =D-230
0182  01356 073737R      STA INX1
0183  01357 063342R      LDA BINY
0184  01360 073740R      STA INX2
0185  01361 067235R      LDB BUFFO
0186  01362 163740R CMPAR LDA INX2,I
0187  01363 150001       CPA 1,I
0188  01364 002001       RSS
0189  01365 027275R      JMP NXTRY      ERROR
0190  01366 006004       INB
0191  01367 037740R      ISZ INX2
0192  01370 037737R      ISZ INX1
0193  01371 027362R      JMP CMPAR
0194  01372 027311R      JMP OKAY       NO ERRORS
```

```
0197***
0198* AT END OF FLIGHT WRITE 3 EOFS THEN REWIND AND UNLOAD TAPE
0199***
0200   01373 062066R ENDIT LDA =D-3
0201   01374 073737R       STA INX1
0202   01375 016001X EOFS  JSB ,IOC,      WRITE EOF
0203   01376 030110        OCT 30110
0204   01377 102033        HLT 33B        REQUEST REJECTED?
0205   01400 000000        NOP
0206   01401 000000        NOP
0207   01402 016001X       JSB ,IOC,
0208   01403 040010        OCT 40010
0209   01404 002020        SSA
0210   01405 027402R       JMP *-3
0211   01406 037737R       ISZ INX1
0212   01407 027375R       JMP EOFS
0213   01410 016001X       JSB ,IOC,      UNLOAD TAPE
0214   01411 030510        OCT 30510
0215   01412 102033        HLT 33B        REQUEST REJECTED?
0216   01413 000000        NOP
0217   01414 000000        NOP
0218   01415 016001X       JSB ,IOC,
0219   01416 040010        OCT 40010
0220   01417 002020        SSA
0221   01420 027415R       JMP *-3
0222   01421 102077        HLT 77B        THE END
0223   01422 027421R       JMP *-1
```

```
0226***
0227* TRANSFER DATA FROM CYCLIC BUFFER AND AFTER CONVERSION TO 24 BIT
0228* BINARY STORE IN OUTPUT BUFFER, CALCULATE 24 BIT CHECKSUM AND
0229* STORE WITH DATA
0230***
0231  01423 000000  BUFFI NOP             CONVERT BCD TO BINARY AND
0232  01424 073731R       STA BUFRx        IN THE MT OUTPUT BUFFER
0233  01425 077735R       STB BUFAD
0234  01426 063736R       LDA BLNUM
0235  01427 002004        INA              INCREMENT THE BLOCK NUMBER
0236  01430 073736R       STA BLNUM
0237  01431 012067R       AND =B170000
0238  01432 001700        ALF
0239  01433 170001        STA 1,I          STORE UPPER FOUR BITS
0240  01434 006004        INB
0241  01435 063736R       LDA BLNUM
0242  01436 012070R       AND =B7777
0243  01437 170001        STA 1,I          STORE LOWER 12 BITS
0244  01440 006004        INB
0245  01441 002400        CLA              CLEAR ATTEMPT NUMBER
0246  01442 170001        STA 1,I
0247  01443 006004        INB
0248  01444 170001        STA 1,I
0249  01445 006004        INB
0250  01446 077732R       STB BUFR1        SAVE START ADDRESS OF CKSUM
0251  01447 062071R       LDA =D-4
0252  01450 073737R       STA INX1
0253  01451 163731R DOP50 LDA BUFRx,I      TRANSFER DOPPLER COORDS
0254  01452 170001        STA 1,I          ALREADY IN BINARY
0255  01453 037731R       ISZ BUFRx
0256  01454 006004        INB
0257  01455 037737R       ISZ INX1
0258  01456 027451R       JMP DOP50
0259  01457 077734R       STB BUFR0
0260  01460 062072R       LDA =D-10
0261  01461 073737R       STA INX1
0262  01462 062041R FID1  LDA =D-6
0263  01463 073740R       STA INX2
0264  01464 163731R NXT   LDA BUFRx,I      GET A BCD WORD
0265  01465 017576R       JSB BCDI1        CONVERT TO BINARY
0266  01466 017664R       JSB BPACK        STORE IN OUTPUT BUFFER
0267  01467 037731R       ISZ BUFRx        BUMP ADDRESS
0268  01470 037740R       ISZ INX2
0269  01471 027464R       JMP NXT
0270  01472 062035R       LDA =D-5
0271  01473 073740R       STA INX2
0272  01474 163731R MAGZ  LDA BUFRx,I
0273  01475 070041B       STA TT1          SAVE MOST SIGNIFICANT DIGIT
0274  01476 037731R       ISZ BUFRx
0275  01477 163731R       LDA BUFRx,I
0276  01500 017576R       JSB BCDI1        CONVERT 4 LSD TO BINARY
0277  01501 002400        CLA
0278  01502 070042B       STA TT2
0279  01503 060041B       LDA TT1
0280  01504 017634R       JSB BCDI2        CONVERT MSD TO BINARY
```

```
0283  01505 017664R        JSB BPACK
0284  01506 037731R        ISZ BUFRX
0285  01507 037740R        ISZ INX2
0286  01510 027474R        JMP MAGZ
0287  01511 037737R        ISZ INX1        FINISHED BLOCK?
0288  01512 027462R        JMP FID1
0289  01513 063732R CHEKS  LDA BUFR1       CALCULATE 24 BIT CHECKSUM
0290  01514 002004         INA
0291  01515 073733R        STA BUFR2
0292  01516 002400         CLA
0293  01517 073741R        STA SUM
0294  01520 017544R        JSB CKSUM       ADD BITS 0-11
0295  01521 063732R        LDA BUFR1
0296  01522 073733R        STA BUFR2
0297  01523 063742R        LDA SUM1
0298  01524 073741R        STA SUM         ADD CARRY FROM PREVIOUS ADD
0299  01525 017544R        JSB CKSUM       ADD BITS 12-23
0300  01526 062065R        LDA =D-230
0301  01527 073737R        STA INX1
0302  01530 163735R PK232  LDA BUFAD,I     UNPACK 12 BIT WORDS TO FORM
0303  01531 012073R        AND =B7700        TWO 6 BIT BYTES FOR MT
0304  01532 001222         RAL,RAL
0305  01533 070041B        STA TT1
0306  01534 163735R        LDA BUFAD,I
0307  01535 012074R        AND =H77
0308  01536 030041B        IOR TT1
0309  01537 173735R        STA BUFAD,I
0310  01540 037735R        ISZ BUFAD
0311  01541 037737R        ISZ INX1
0312  01542 027530R        JMP PK232
0313  01543 127423R        JMP BUFFI,I

0315  01544 000000 CKSUM   NOP
0316  01545 002400         CLA
0317  01546 073743R        STA CARRY
0318  01547 062075R        LDA =D-112      SET WORD COUNTER
0319  01550 073744R        STA SNUM
0320  01551 163733R LOOPS  LDA BUFR2,I
0321  01552 000040         CLE
0322  01553 043741R        ADA SUM
0323  01554 002040         SEZ             CARRY FROM BIT 15?
0324  01555 037743R        ISZ CARRY       YES  BUMP CARRY COUNTER
```

```
0327  01556 073741R        STA SUM
0328  01557 037733R        ISZ BUFR2       INCREMENT ADDRESS BY 2
0329  01560 037733R        ISZ BUFR2
0330  01561 037744R        ISZ SNUM        FINISHED?
0331  01562 027551R        JMP LOOPS       NO
0332  01563 063741R        LDA SUM
0333  01564 012067R        AND =B170000    ISOLATE CARRIES FROM BIT 11
0334  01565 001700          ALF             POSITION IN LOWER WORD
0335  01566 067743R        LDB CARRY       GET ANY CARRIES FROM BIT 15
0336  01567 005700          BLF             MULTIPLY BY 16
0337  01570 040001          ADA 1           FORM TOTAL CARRY FROM 12 BIT
0338  01571 073742R        STA SUM1                ADDITION
0339  01572 063741R        LDA SUM
0340  01573 012070R        AND =B7777
0341  01574 173733R        STA BUFR2,I
0342  01575 127544R        JMP CKSUM,I

0344***
0345* SUBROUTINES USED IN DATA CONVERSION FOR MT OUTPUT
0346***
0347  01576 000000  BCDI1 NOP             CONVERTS 4 DIGIT BCD TO BINARY
0348  01577 001700        ALF             POSITION FIRST CHARACTER
0349  01600 070042B       STA TT2
0350  01601 012026R       AND =B17
0351  01602 064000        LDB 0
0352  01603 017626R       JSB BY10
0353  01604 060042B       LDA TT2
0354  01605 001700        ALF             POSITION SECOND CHARACTER
0355  01606 070042B       STA TT2
0356  01607 012026R       AND =B17
0357  01610 044000        ADB 0
0358  01611 017626R       JSB BY10
0359  01612 060042B       LDA TT2
0360  01613 001700        ALF             POSITION THIRD CHARACTER
0361  01614 070042B       STA TT2
0362  01615 012026R       AND =B17
0363  01616 044000        ADB 0
0364  01617 017626R       JSB BY10
0365  01620 060042B       LDA TT2
0366  01621 001700        ALF             POSITION 4TH CHARACTER
0367  01622 012026R       AND =B17
0368  01623 044000        ADB 0
0369  01624 002400        CLA
0370  01625 127576R       JMP BCDI1,I     RETURN WITH BINARY IN AB
0371  01626 000000  BY10  NOP
0372  01627 005000        BLS
0373  01630 074044B       STB TT4
0374  01631 005020        BLS,BLS
0375  01632 044044B       ADB TT4
0376  01633 127626R       JMP BY10,I
```

```
0379  01634 000000  BCDI2 NOP
0380  01635 012026R        AND =B17
0381  01636 070043B        STA TT3
0382  01637 042072R        ADA =D-10
0383  01640 002021         SSA,RSS          CHARACTER LE 9
0384  01641 027661R        JMP ERRA3        NO
0385  01642 060043B        LDA TT3
0386  01643 001000         ALS
0387  01644 043704R        ADA SS4          FORM ADDRESS OF BINARY EQUIV.
0388  01645 070043B        STA TT3
0389  01646 000040         CLE
0390  01647 144000         ADB 0,I          ADD 16 LEAST SIGNIF BITS
0391  01650 002040         SEZ              OVERFLOW?
0392  01651 034042B        ISZ TT2          YES
0393  01652 074041B        STB TT1
0394  01653 060043B        LDA TT3
0395  01654 002004         INA
0396  01655 160000         LDA 0,I          GET MOST SIGNIF BITS
0397  01656 040042B        ADA TT2
0398  01657 064041B        LDB TT1
0399  01660 127634R        JMP BCDI2,I      RETURN WITH BINARY IN AB
0400  01661 002400  ERRA3 CLA
0401  01662 006400         CLB
0402  01663 127634R        JMP BCDI2,I      ERROR - SET RESULT TO ZERO

0404  01664 000000  BPACK NOP              UNPACK AB REGISTER AND STORE
0405  01665 074041B        STB TT1          AS TWO 12 BIT WORDS
0406  01666 012076R        AND =B777
0407  01667 001700         ALF
0408  01670 070042B        STA TT2
0409  01671 060001         LDA 1
0410  01672 012067R        AND =B170000
0411  01673 001700         ALF
0412  01674 030042B        IOR TT2
0413  01675 173734R        STA BUFRO,I
0414  01676 037734R        ISZ BUFRO
0415  01677 060041B        LDA TT1
0416  01700 012070R        AND =B7777
0417  01701 173734R        STA BUFRO,I
0418  01702 037734R        ISZ BUFRO
0419  01703 127664R        JMP BPACK,I
```

```
0422***
0423* LOOK UP TABLE FOR CONVERTING TENS OF THOUSANDS TO BINARY
0424***
0425   01704 001705R SS4    DEF **1
0426   01705 000000         OCT 0,0,23420,0,47040,0,72460,0,116100,0
       01706 000000
       01707 023420
       01710 000000
       01711 047040
       01712 000000
       01713 072460
       01714 000000
       01715 116100
       01716 000000
0427   01717 141520         OCT 141520,0,165140,0,10560,1,34200,1,57620,1
       01720 000000
       01721 165140
       01722 000000
       01723 010560
       01724 000001
       01725 034200
       01726 000001
       01727 057620
       01730 000001
0428   01731 000000  BUFRX  NOP
0429   01732 000000  BUFR1  NOP
0430   01733 000000  BUFR2  NOP
0431   01734 000000  BUFRO  NOP
0432   01735 000000  BUFAD  NOP
0433   01736 000000  BLNUM  NOP
0434   01737 000000  INX1   NOP
0435   01740 000000  INX2   NOP
0436   01741 000000  SUM    NOP
0437   01742 000000  SUM1   NOP
0438   01743 000000  CARRY  NOP
0439   01744 000000  SNUM   NOP
```

```
0442  00010           MCR    EQU 10B        16 BIT I/O INTERFACE SELECT CODE
0443  00011           MPX    EQU 11B        INPUT MPX SELECT CODE
0444  00012           DASC   EQU 12B        D/A MPX SELECT CODE
0445  00014           MTRSC  EQU 14B        KENNEDY SELECT CODE
0446  00016           REGSC  EQU 16B        40 BIT REGISTER SELECT CODE
0447  01745 114000B AJSBI  JSB LINK,I
0448  00000                ORB
0449  00000 000146R LINK   DEF INTRR       INTERRUPT LINK
0450***
0451* CYCLIC BUFFER ADDRESS TABLE AND BUFFER STATUS WORDS ***
0452* NUMBER OF BUFFERS CAN BE INCREASED BY EXPANDING THE BUFFER TABLE
0453***
0454  00001 000310C TAB    DEF BUFA       ADDRESS OF BUFFER 1
0455  00002 000000         NOP            STATUS WORD FOR BUFFER 1
0456  00003 000004B        DEF *+1        POINTER TO BUFFER 2
0457  00004 000562C        DEF BUFB       ADDRESS OF BUFFER 2
0458  00005 000000         NOP               AND SO ON
0459  00006 000007B        DEF *+1
0460  00007 001034C        DEF BUFC
0461  00010 000000         NOP
0462  00011 000012B        DEF *+1
0463  00012 001396C        DEF BUFD
0464  00013 000000         NOP
0465  00014 000001B POINT  DEF TAB        POINTER BACK TO BUFFER 1
0466  00015 000000C INBUF  DEF BUFIN
0467  00016 000000  INBUF  NOP
0468  00017 000000  INBF2  NOP
0469  00020 000000  P      NOP
0470  00021 000000  P1     NOP
0471  00022 000000  Q      NOP
0472  00023 000000  Q      NOP
0473  00024 000000  Q1     NOP
0474  00025 000000  Q2     NOP
0475  00026 000000  QADD   NOP
0476  00027 000000  SADD   NOP
0477  00030 000000  K1     NOP
0478  00031 000000  K2     NOP
0479  00032 000000  K3     NOP
0480  00033 000000  K4     NOP
0481  00034 000000  K5     NOP
0482  00035 000000  INPUT  NOP
0483  00036 000000  OTPUT  NOP
0484  00037 000000  ATTNO  NOP
0485  00040 000000  ABORT  NOP
0486  00041 000000  TT1    NOP
0487  00042 000000  TT2    NOP
0488  00043 000000  TT3    NOP
0489  00044 000000  TT4    NOP
0490  00045 000000  SAVA   NOP
0491  00046 000000  SAVB   NOP
0492  00047 000000  SAVEO  NOP
0493  00050 000000  CAL1   NOP
0494  00051 000000  CAL2   NOP
0495  00052 000000  CAL3   NOP
0496  00053 000000  LINE   NOP
0497  00054 000000  LEC    NOP
0498  00055 000000  COUNT  NOP
```

```
0499  00056 000000  RESET NOP
0500  00057 000000  TPO   BSS 2
0501  00061 000000  BEGIN NOP
0502  00062 000000  SFLAG NOP
0503  00063 000000  TOTAL NOP
0504  00064 000000  SSTAT NOP
0505  00065 000000  GMES  NOP
0506  00066 000000  CALS  NOP
0507  00067 000000  MTSTF NOP
0508  00070 000000  XLOG  NOP
0509  00071 000000  BLOUT NOP
0510  00072 000000  RCNTR NOP
0511  00073 000000  BOUT1 NOP
0512  00074 000000  MTFN2 NOP
0513  00075 000000  BLEND NOP
0514  00076 000000  ALOOP NOP
0515  00077 000000  LSYN  NOP
0516  00100 000000  XSYN  NOP
0517  00101 000000  GAPNT NOP
0518  00102 000000  MTIME NOP
0519  00103 000000  MTFLG NOP
0520  01746         ORR
0521  01746 000000  UDATA BSS 5
0522  01753 003014  LABEL OCT 3014,4407,4024
      01754 004407
      01755 004024
0523  01756 000000  FLNO  NOP            FLIGHT NO INSERTED HERE
0524  01757 000000        NOP
0525  01760 026455        OCT 26455,26455,26455,26455,26455
      01761 026455
      01762 026455
      01763 026455
      01764 026455
0526  01765 026455        OCT 26455,26455,26455,26455,26455
      01766 026455
      01767 026455
      01770 026455
      01771 026455
0527  01772 026455        OCT 26455,26455,26455,26455,26455
      01773 026455
      01774 026455
      01775 026455
      01776 026455
0528  01777 026455        OCT 26455,26455,26455,26455,26455
      02000 026455
      02001 026455
      02002 026455
      02003 026455
0529  02004 026455        OCT 26455,26455,26455,26455,26455
      02005 026455
      02006 026455
      02007 026455
      02010 026455
0530  02011 026455        OCT 26455,26455,26455,26455,26455
      02012 026455
      02013 026455
      02014 026455
```

```
        02015 026455
0531    02016 026455          OCT 26455,26455,26455,26455,26455
        02017 026455
        02020 026455
        02021 026455
        02022 026455
        02023 000003
        02024 100000
        02025 002000
        02026 000017
        02027 026400
        02030 000033
        02031 015433
        02032 177716
        02033 000004
        02034 177770
        02035 177773
        02036 000002
        02037 177777
        02040 177776
        02041 177772
        02042 177747
        02043 001750
        02044 000144
        02045 154360
        02046 023420
        02047 000005
        02050 000012
        02051 000006
        02052 000007
        02053 177534
        02054 177014
        02055 000764
        02056 177406
        02057 000372
        02060 177634
        02061 000022
        02062 000001
        02063 000040
        02064 000714
        02065 177432
        02066 177775
        02067 170000
        02070 007777
        02071 177774
        02072 177766
        02073 007700
        02074 000077
        02075 177620
        02076 000777
0532                          END BMG1
**  NO ERRORS*
```

```
0002***
0003* THE DOPPLER SUBROUTINE HAS TWO ENTRY POINTS. DINIT IS CALLED ONCE
0004* TO SET UP INITIAL CONDITIONS, DOP00 IS CALLED EVERY SECOND TO
0005* COMPUTE THE PRESENT DOPPLER COORDINATES AND TO UPDATE THE PILOTS
0006* DISPLAY. ADDITIONALLY AT THE START OF EACH FIDUCIAL DOPPLER ALONG
0007* AND CROSS TRACK COORDINATES ARE RETURNED TO THE MAIN PROGRAM FOR
0008* INCLUSION ON THE MAGNETIC TAPE.
0009***
0010  00000                 NAM DOP00
0011                        ENT DOP00,DINIT
0012  00000 000000  DINIT   NOP
0013  00001 062000R         LDA DINIT
0014  00002 164000          LDB 0,I         GET RETURN ADDRESS
0015  00003 076000R         STB DINIT         AND STORE
0016  00004 002004          INA
0017  00005 164000          LDB 0,I         PICK UP PARAMETER ADDRESSES
0018  00006 074030B         STB DK3          AND STORE LOCALLY
0019  00007 002004          INA
0020  00010 164000          LDB 0,I
0021  00011 074026B         STB LINE
0022  00012 002004          INA
0023  00013 164000          LDB 0,I
0024  00014 074027B         STB INPUT
0025  00015 002004          INA
0026  00016 164000          LDB 0,I
0027  00017 074040B         STB REG40
0028  00020 002400          CLA             CLEAR ALL INTERNAL COUNTERS AND
0029  00021 070031B         STA ORIGN          FLAGS
0030  00022 070016B         STA LPKM0
0031  00023 070017B         STA LFKM0
0032  00024 070014B         STA XPKM0
0033  00025 070015B         STA XFKM0
0034  00026 070021B         STA LPKM1
0035  00027 070022B         STA LFKM1
0036  00030 070023B         STA XPKM1
0037  00031 070024B         STA XFKM1
0038  00032 070030B         STA ISTDP
0039  00033 070042B         STA ISTRS
0040  00034 070036B         STA DSPRS
0041  00035 070020B         STA ISTLN
0042  00036 070010B         STA LPART
0043  00037 070011B         STA LFULL
0044  00040 070012B         STA XPART
0045  00041 070013B         STA XFULL
0046  00042 126000R         JMP DINIT,I     RETURN TO MAIN PROGRAM
```

```
0049***
0050* THE DOPPLER PROGRAM INPUT DATA IS TAKEN FROM 14 BIT SYNCHRO TO
0051* DIGITAL CONVERTERS THAT LOOK AT THE 3 LINE OUTPUT FROM SYNCHRO
0052* CONTROL TRANSMITTERS ON THE ALONG AND CROSS TRACK OUTPUTS OF THE
0053* DOPPLER COMPUTER,  ONE REVOLUTION OF THESE OUTPUTS, EQUIVALENT TO
0054* A CHANGE IN SYNCHRO READING OF 16384, IS EQUAL TO 10/3 NAUTICAL
0055* MILES, THE PROGRAM KEEPS TRACK OF THE TOTAL CHANGE IN SYNCHRO
0056* POSITION, STORING THE RESULT IN TWO PARTS - INTEGRAL KILOMETRES
0057* EQUAL TO APPROX 29500 SYNCHRO UNITS AND A FRACTIONAL PART IN
0058* SYNCHRO UNITS
0059***
0060   00043 000000   DOP00 NOP
0061   00044 070002B        STA LSYN      STORE ALONG TRACK
0062   00045 074003B        STB XSYN        CROSS TRACK READINGS
0063   00046 060000B        LDA ISTDP     FIRST READING OF FLIGHT?
0064   00047 002002         SZA
0065   00050 026062R        JMP DOP01     NO
0066   00051 002004         INA           YES - SAVE INITIALSYNCHRO
0067   00052 070000B        STA ISTDP      READINGS THEN RETURN
0068   00053 060002B        LDA LSYN      TAKE ALONG TRACK DOPPLER SYNCHRO
0069   00054 003004         CMA,INA        READING AND STORE
0070   00055 070004B        STA LSYN0
0071   00056 060003B        LDA XSYN      TAKE CROSS TRACK DOPPLER SYNCHRO
0072   00057 003004         CMA,INA        READING AND STORE
0073   00060 070005B        STA XSYN0
0074   00061 026432R        JMP DOP31
```

```
0077***
0078* INTERNAL DOPPLER ALONG AND CROSS TRACK COORDINATES ARE BASED ON
0079* ARBITRARY ORIGIN LOCATED AT POINT OF STARTING DATA ACQUISITION
0080* PROGRAM.
0081***
0082***** PROCESS ALONG TRACK SYNCHRO DATA *****
0083***
0084  00062 060002B DOP01 LDA LSYN      TAKE ALONG TRACK SYNCHRO READING
0085  00063 064002B       LDB LSYN
0086  00064 040004B       ADA LSYN0     SUBTRACT PREVIOUS READING
0087  00065 007004        CMB,INB
0088  00066 074004B       STB LSYN0     SAVE CURRENT READING
0089  00067 070006B       STA LSYN1     SAVE DIFFERENCE
0090  00070 002020        SSA           TEST SIGN OF SYNCHRO CHANGE
0091  00071 026101R       JMP DOP02     NEGATIVE
0092  00072 042702R       ADA =D-8000
0093  00073 002020        SSA           IS CHANGE GT 8000?
0094  00074 026107R       JMP DOP03     NO
0095  00075 060006B       LDA LSYN1     YES - SYNCHRO CROSSED ZERO POINT
0096  00076 042703R       ADA =D-16384      - SUBTRACT 16384 TO GIVE
0097  00077 070006B       STA LSYN1         - SMALL NEGATIVE CHANGE
0098  00100 026107R       JMP DOP03
0099  00101 042704R DOP02 ADA =D8000    IS CHANGE LT -8000?
0100  00102 002021        SSA,RSS
0101  00103 026107R       JMP DOP03     NO
0102  00104 060006B       LDA LSYN1     YES - SYNCHRO HAS CROSSED ZERO
0103  00105 042705R       ADA =D16384       - ADD 16384 TO GET SMALL
0104  00106 070006B       STA LSYN1         - POSITIVE CHANGE
0105  00107 060006B DOP03 LDA LSYN1
0106  00110 001100        ARS           DIVIDE BY 2
0107  00111 040010B       ADA LPART     ADD DIFERENCE TO PART KM COUNTER
0108  00112 064011B       LDB LFULL
0109  00113 016624R       JSB DPSUM     NORMALISE FULL AND PART KM
0110  00114 070010B       STA LPART       COUNTERS AND SAVE
0111  00115 074011B       STB LFULL
```

```
0114***
0115***** PROCESS CROSS TRACK SYNCHRO DATA *****
0116***
0117  00116 060003B        LDA XSYN       TAKE CROSS TRACK SYNCHRO READING
0118  00117 064003B        LDB XSYN
0119  00120 040005B        ADA XSYN0      SUBTRACT PREVIOUS READING
0120  00121 007004         CMB,INB
0121  00122 074005B        STB XSYN0      SAVE CURRENT READING
0122  00123 070007B        STA XSYN1      SAVE DIFFERENCE
0123  00124 002020         SSA            TEST SIGN OF CHANGE
0124  00125 026135R        JMP DOP04      NEGATIVE
0125  00126 042702R        ADA =D-8000
0126  00127 002020         SSA            IS CHANGE GT 8000?
0127  00130 026143R        JMP DOP05      NO
0128  00131 060007B        LDA XSYN1      YES - SYNCHRO HAS CROSSED ZERO
0129  00132 042703R        ADA =D-16384       - SUBTRACT 16384 TO GET
0130  00133 070007B        STA XSYN1          - SMALL POSITIVE CHANGE
0131  00134 026143R        JMP DOP05
0132  00135 042704R DOP04  ADA =D8000     IS CHANGE LT -8000?
0133  00136 002021         SSA,RSS
0134  00137 026143R        JMP DOP05      NO
0135  00140 060007B        LDA XSYN1      YES - SYNCHRO HAS CROSSED ZERO
0136  00141 042705R        ADA =D16384        - ADD 16384 TO GET
0137  00142 070007B        STA XSYN1          - SMALL POSITIVE CHANGE
0138  00143 060007B DOP05  LDA XSYN1
0139  00144 001100         ARS            DIVIDE BY 2
0140  00145 040012B        ADA XPART      ADD TO PART KM COUNTER
0141  00146 064013B        LDB XFULL
0142  00147 016624R        JSB DPSUM      NORMALISE RESULT AND SAVE
0143  00150 070012B        STA XPART,
0144  00151 074013B        STB XFULL
```

```
0147***
0148***** DOPPLER CHART SPEED CONTROLLER*****
0149***
0150* VOLTAGE CONTROLLED OSCILLATOR REQUIRES +10V FOR ZERO SPEED
0151* AND +7.5V FOR 200 KNOTS
0152***
0153  00152 060026B        LDA LSYN1     GET ALONG TRACK SYNCHRO CHANGE
0154  00153 002020         SSA             - APPROX 1500 AT 100 KNOTS
0155  00154 003004         CMA,INA       GET ABSOLUTE VALUE
0156  00155 006400         CLB
0157  00156 016001X        DIV =D6       DIVIDE BY 6 AND COMPLEMENT
      00157 000006R
0158  00160 003004         CMA,INA         TO GET V=-250 AT 100 KNOT
0159  00161 042007R        ADA =D2047    CALCULATE X=2047+V
0160  00162 070031B        STA DTMP1     AND SAVE RESULT
0161  00163 003004         CMA,INA
0162  00164 040043B        ADA MAXSP     CHECK IF SPEED TOO GREAT
0163  00165 002020         SSA
0164  00166 026171R        JMP *+3       OK
0165  00167 060043B        LDA MAXSP     USE MAX ALLOWED SPEED
0166  00170 026201R        JMP DOP08+1
0167  00171 060031B        LDA DTMP1
0168  00172 003004         CMA,INA
0169  00173 040044B        ADA MINSP     CHECK IF SPEED LESS THAN
0170  00174 002021         SSA,RSS         40 KNOTS
0171  00175 026200R        JMP DOP08
0172  00176 060044B        LDA MINSP     USE MIN ALLOWED SPEED
0173  00177 026201R        JMP DOP08+1
0174  00200 060031B DOP08  LDA DTMP1
0175  00201 070001         STA 1           AND PUT IN B REGISTER
0176  00202 062710R        LDA =D9
0177  00203 016673R        JSB .DTA      OUTPUT TO VCO ON D/A CHANNEL 10
```

```
0001***
0002***** PILOT S DOPPLER DISPLAY PROCESSOR *****
0003***
0004  00204 060040R DOP11 LDA REG40     GET ADDRESS OF PILTOTS DISPLAY
0005  00205 070041R       STA DDATA       BUFFER
0006  00206 160027R       LDA INPUT,I   GET 16 BIT INPUT REGISTER
0007  00207 012711R       AND =D2       ISOLATE DOPPLER RESET BIT
0008  00210 002003        SZA,RSS       IS IT ON?
0009  00211 026245R       JMP DOP13     NO
0010  00212 060012R       LDA XPART     YES - SAVE INITIAL COORDINATES
0011  00213 003004        CMA,INA          IE RESET CROSS TRACK DISPLAY
0012  00214 070014R       STA XPKM0
0013  00215 060013R       LDA XFULL
0014  00216 003004        CMA,INA
0015  00217 070015R       STA XFKM0
0016  00220 060042R       LDA ISTRS     FIRST RESET?
0017  00221 002002        SZA
0018  00222 026226R       JMP *+4
0019  00223 002004        INA
0020  00224 070042R       STA ISTRS
0021  00225 026237R       JMP DOP12+2
0022  00226 060036R       LDA DSPRS     CHECK IF RESET ON FOR 5 SEC
0023  00227 002002        SZA
0024  00230 026235R       JMP DOP12
0025  00231 002004        INA
0026  00232 070036R       STA DSPRS
0027  00233 062712R       LDA =D-5      INITILISE COUNTER
0028  00234 070037R       STA DCNTR
0029  00235 034037R DOP12 ISZ DCNTR     COUNT NUMBER OF SECONDS
0030  00236 026247R       JMP DOP13+2
0031  00237 060010R       LDA LPART     RESET ON FOR 5 SEC SO
0032  00240 003004        CMA,INA         RESET ALONG TRACK DISPLAY
0033  00241 070016R       STA LPKM0
0034  00242 060011R       LDA LFULL
0035  00243 003004        CMA,INA
0036  00244 070017R       STA LFKM0
0037  00245 002400 DOP13  CLA           RESET COUNTER FLAG
0038  00246 070036R       STA DSPRS
0039  00247 060010R       LDA LPART     SUBTRACT INITIAL ALONG TRACK
0040  00250 040016R       ADA LPKM0       POSITION FROM PRESENT POSITION
0041  00251 064011R       LDB LFULL
0042  00252 044017R       ADB LFKM0
0043  00253 016624R       JSB DPSUM     NORMALISE THE RESULT
0044  00254 070031R       STA DTMP1     THIS IS ALONG TRACK DISTANCE
0045  00255 074032R       STB DTMP2       TO BE DISPLAYED
0046  00256 006400        CLB
0047  00257 002020        SSA
0048  00260 007000        CMB
0049  00261 016001X       DIV SCL01     DIVIDE TO GET 0.1 S OF KM
      00262 000045R
```

```
0052  00263 070031B        STA DTMP1
0053  00264 060032B        LDA DTMP2
0054  00265 001000         ALS                 MULTIPLY KM BY 10
0055  00266 070001         STA 1
0056  00267 001020         ALS,ALS
0057  00270 040001         ADA 1
0058  00271 040031B        ADA DTMP1           ADD ON 0.1 S
0059  00272 002020         SSA                  IF NEGATIVE ADD 10000
0060  00273 042713R        ADA =D10000
0061  00274 016560R        JSB ENCOD           ENCODE RESULT TO 1-2-4-8 BCD
0062  00275 174041B        STA DDATA,I           AND STORE IN 40 BIT BUFFER
0063  00276 034041B        ISZ DDATA
0064  00277 174041B        STB DDATA,I
0065  00300 034041B        ISZ DDATA
0066  00301 060012B        LDA XPART           SUBTRACT INITIAL CROSS TRACK
0067  00302 040014B        ADA XPKM0             FROM PRESENT POSITION
0068  00303 064013B        LDB XFULL
0069  00304 044015B        ADB XPKM0
0070  00305 016624R        JSB DPSUM           NORMALISE RESULT
0071  00306 070031B        STA DTMP1           THIS IS CROSS TRACK RESULT
0072  00307 074032B        STB DTMP2            FOR DISPLAY OUTPUT
0073  00310 006400         CLB
0074  00311 002020         SSA
0075  00312 007000         CMB
0076  00313 016001X        DIV SCL02           DIVIDE TO GET 0.01 S OF KM
      00314 000046B
0077  00315 070031B        STA DTMP1
0078  00316 060032B        LDA DTMP2           MULTIPLY CROSS KM BY 100
0079  00317 001020         ALS,ALS
0080  00320 070001         STA 1
0081  00321 001020         ALS,ALS
0082  00322 001000         ALS
0083  00323 044000         ADB 0
0084  00324 001000         ALS
0085  00325 044000         ADB 0
0086  00326 040031B        ADB DTMP1           ADD ON 0.01 S KM
0087  00327 160027B        LDA INPUT,I         CHECK ON POSITION OF FORWARD/
0088  00330 012714R        AND =D8                 REVERSE SWITCH
0089  00331 002002         SZA                 IF ON COMPLEMENT RESULT
0090  00332 007004         CMB,INB
0091  00333 060001         LDA 1
0092  00334 070031B        STA DTMP1           SAVE FOR METER OUTPUT
0093  00335 006400         CLB
0094  00336 002021         SSA,RSS             IS IT POSITIVE?
0095  00337 026342R        JMP **3             YES
0096  00340 003004         CMA,INA             MAKE POSITIVE AND CHANGE
0097  00341 007000         CMB                 OVER THE LEFT/RIGHT LIGHT
0098  00342 074032B        STB DTMP2
0099  00343 016560R        JSB ENCOD           GET 4 DECIMAL DIGITS
0100  00344 170041B        STA DDATA,I         AND STORE IN 40 BIT BUFFER
0101  00345 034041B        ISZ DDATA
0102  00346 174041B        STB DDATA,I
0103  00347 034041B        ISZ DDATA
0104  00350 060032B        LDA DTMP2
0105  00351 170041B        STA DDATA,I
```

```
0108***
0109*** OUTPUT CROSS TRACK ANALOGUE VOLTAGE FOR LEFT-RIGHT
0110*** INDICATOR IN FRONT OF PILOT -10V TO +10V EQUIV
0111*** TO APPROX 1 KILOMETER
0112***
0113  00352 0600318        LDA DTMP1      PICK UP CROSS TRACK DISTANCE
0114  00353 001000         ALS            MULTIPLY BY 20 TO GIVE APPROX
0115  00354 070001         STA 1            1 KM FULL SCALE DEFLECTION
0116  00355 001020         ALS,ALS        ON THE METER
0117  00356 040001         ADA 1
0118  00357 001000         ALS
0119  00360 0700318        STA DTMP1
0120  00361 002020         SSA
0121  00362 026370R        JMP DOP21
0122  00363 042715R        ADA =D-2048    TEST IF GT 2048
0123  00364 002020         SSA
0124  00365 026375R        JMP DOP22
0125  00366 062707R        LDA =D2047     YES - SET EQUAL TO MAX POSSIBLE
0126  00367 026376R        JMP DOP22+1
0127  00370 042716R DOP21  ADA =D2048     TEST IF LT -2048
0128  00371 002021         SSA,RSS
0129  00372 026375R        JMP DOP22
0130  00373 062715R        LDA =D-2048    YES - SET EQUAL TO MIN POSSIBLE
0131  00374 026376R        JMP DOP22+1
0132  00375 0600318 DOP22  LDA DTMP1      OUTPUT CROSS TRACK TO INDICATOR
0133  00376 012717R        AND =B7777       METER
0134  00377 070001         STA 1
0135  00400 062714R        LDA =D8        ON CHANNEL 9 OF
0136  00401 016675R        JSB .DTA         D/A MPX
```

```
0139***
0140*** DOPPLER COORDINATES FOR OUTPUT ON MAGNETIC TAPE. ORIGIN FOR
0141*** FLIGHT CAN BE ESTABLISHED BY SETTING BIT 3 OF SWITCH REGISTER
0142*** BEFORE THE COMMENCEMENT OF RECORDING, OTHERWISE ORIGIN IS SET
0143*** AT START OF FIRST LINE
0144***
0145  00402 160030B DOP31 LDA DK3,I     IS IT START OF 10 SEC BLOCK?
0146  00403 052720R       CPA =D-50
0147  00404 002001        RSS
0148  00405 026472R       JMP EXDOP     NO
0149  00406 162043R       LDA DOP00,I   PICK UP ADDRESS OF MT BUFFER
0150  00407 070025B       STA DOPAD       AND STORE
0151  00410 060020B       LDA ISTLN     HAS RECORDING FOR FLIGHT STARTED
0152  00411 002002        SZA
0153  00412 026447R       JMP DOP34     YES
0154  00413 160026B       LDA LINE,I    NO - IS FIRST LINE STARTING NOW?
0155  00414 002002        SZA
0156  00415 026427R       JMP DOP32     YES
0157  00416 102501        LIA 1         NO - GET SWITCH REGISTER
0158  00417 052721R       CPA =D4       IS DOPPLER ORIGIN BIT ON?
0159  00420 002001        RSS
0160  00421 026447R       JMP DOP34     NO
0161  00422 002400        CLA           YES
0162  00423 102601        OTA 1         CLEAR SWITCH REGISTER
0163  00424 002004        INA
0164  00425 070031B       STA ORIGN     SET ORIGIN FLAG
0165  00426 026433R       JMP DOP33
0166  00427 070020B DOP32 STA ISTLN
0167  00430 060031B       LDA ORIGN     ORIGIN ALREADY SET?
0168  00431 002002        SZA
0169  00432 026447R       JMP DOP34     YES
0170  00433 060010B DOP33 LDA LPART     SET ORIGIN FOR MT DOPPLER
0171  00434 003004        CMA,INA
0172  00435 070021B       STA LPKM1     SAVE STARTING ALONG TRACK
0173  00436 060011B       LDA LFULL
0174  00437 003004        CMA,INA
0175  00440 070022B       STA LFKM1
0176  00441 060012B       LDA XPART     SAVE STARTING CROSS TRACK
0177  00442 003004        CMA,INA
0178  00443 070023B       STA XPKM1
0179  00444 060013B       LDA XFULL
0180  00445 003004        CMA,INA
0181  00446 070024B       STA XFKM1
```

```
0184  00447 060010B DOP34 LDA LPART     SUBTRACT INITIAL ALONG TRACK
0185  00450 040021B       ADA LPKM1       FROM PRESENT DISTANCE
0186  00451 064011B       LDB LFULL
0187  00452 044022B       ADB LPKM1
0188  00453 016624R       JSB DPSUM     NORMALISE RESULT
0189  00454 016474R       JSB DOPXY     GET 24 BIT BINARY RESULT
0190  00455 170025B       STA DOPAD,I     AND STORE IN BUFFER
0191  00456 034025B       ISZ DOPAD
0192  00457 174025B       STB DOPAD,I
0193  00460 034025B       ISZ DOPAD
0194  00461 060012B       LDA XPART     SUBTRACT INITIAL CROSS TRACK
0195  00462 040023B       ADA XPKM1       FROM PRESENT DISTANCE
0196  00463 064013B       LDB XFULL
0197  00464 044024B       ADB XPKM1
0198  00465 016624R       JSB DPSUM     NORMALISE RESULT
0199  00466 016474R       JSB DOPXY     GET 24 BIT BINARY RESULT
0200  00467 170025B       STA DOPAD,I     AND STORE IN BUFFER
0201  00470 034025B       ISZ DOPAD
0202  00471 174025B       STB DOPAD,I
0203  00472 036043R EXDOP ISZ DOP00     BUMP RETURN ADDRESS
0204  00473 126043R       JMP DOP00,I
```

```
0001***
0002****** THE FOLLOWING SUBROUTINES ARE USED BY THE DOPPLER PROGRAM ***
0003***
0004*** DOPXY FORMATS THE DOPPLER COORDS FOR HT OUTPUT, THE RESULT IS A
0005*** 24 BIT BINARY NUMBER WITH BITS 0-19 FORMING A SIGNED QUANTITY IN
0006*** TWOS COMPLEMENT MODE, BITS 20-23 ARE ALWAYS ZERO; WHEN
0007*** PROCESSING IN LARGE COMPUTER NEGATIVE NUMBERS ARE EXTRACTED
0008*** USING THE RELATION IF(N.GT.524287)N=N-1048576
0009***
0010  00474 000000  DOPXY NOP
0011  00475 070031B       STA DTMP1      PART KM
0012  00476 074033B       STB DTMP3      KM
0013  00477 006400        CLB
0014  00500 002020        SSA
0015  00501 007000        CMB
0016  00502 016001X       DIV SCL02      DIVIDE BY SCALE FACTOR TO GET
      00503 000046B
0017  00504 070031B       STA DTMP1        0.01 S OF KM
0018  00505 006400        CLB            CONVERT TO DOUBLE PRECISION
0019  00506 002020        SSA
0020  00507 007000        CMB
0021  00510 074032B       STB DTMP2
0022 00511 060033B       LDA DTMP3      CONVERT KM TO DOUBLE PRECISION
0023  00512 006400        CLB
0024  00513 002020        SSA
0025  00514 007000        CMB
0026  00515 016541R       JSB DMY10      DOUBLE PRECISION MPY BY 100
0027  00516 016541R       JSB DMY10
0028  00517 000040        CLE            ADD ON 0.01 S OF KM
0029  00520 040031B       ADA DTMP1
0030  00521 002040        SEZ
0031  00522 006004        INB
0032  00523 044032B       ADB DTMP2       32 BIT RESULT IN BA
0033  00524 070031B       STA DTMP1
0034  00525 012717R       AND =B7777     ISOLATE LOWER 12 BITS
0035  00526 070032B       STA DTMP2        AND SAVE
0036  00527 060031B       LDA DTMP1
0037  00530 001700        ALF
0038  00531 012722R       AND =B17       ISOLATE BITS 12-15
0039  00532 070033B       STA DTMP3        AND SAVE
0040  00533 062723R       LDA =B360
0041  00534 005700        BLF            SHIFT B 4 PLACES LEFT
0042  00535 010001        AND 1
0043  00536 030033B       IOR DTMP3      MERGE IN BITS 12-15
0044  00537 064032B       LDB DTMP2
0045  00540 126474R       JMP DOPXY,I    24 BIT RESULT IN AB
```

```
0048***
0049  00541 000000  DMY10 NOP            DOUBLE PRECISION MPY BY 10
0050  00542 000066        CLE,ELA
0051  00543 005600        ELB
0052  00544 070034B       STA DTMP4
0053  00545 074035B       STB DTMP5
0054  00546 000066        CLE,ELA
0055  00547 005600        ELB
0056  00550 000066        CLE,ELA
0057  00551 005600        ELB
0058  00552 000040        CLE
0059  00553 040034B       ADA DTMP4
0060  00554 002040        SEZ
0061  00555 006004        INB
0062  00556 044035B       ADB DTMP5
0063  00557 126541R       JMP DMY10,I

0065***
0066*** THIS SUBROUTINE CONVERTS AN INTEGER QUANTITY IN THE RANGE
0067*** 0 TO 9999 TO 8-4-2-1 BCD
0068***
0069  00560 000000  ENCOD NOP            RESULT RETURNED IN AB
0070  00561 070001        STA 1
0071  00562 006020        SSB            CHECK IF NEGATIVE
0072  00563 026621R       JMP TOBIG      REJECT
0073  00564 046724R       ADB =D-10000
0074  00565 006021        SSB,RSS        CHECK IF TOO LARGE
0075  00566 026621R       JMP TOBIG      REJECT
0076  00567 006400        CLB
0077  00570 042725R       ADA =D-1000    GET 1000 S
0078  00571 002020        SSA
0079  00572 026575R       JMP *+3
0080  00573 006004        INB
0081  00574 026570R       JMP *-4
0082  00575 042726R       ADA =D1000
0083  00576 005727        BLF,BLF
0084  00577 042727R       ADA =D-100     GET 100 S
0085  00600 002020        SSA
0086  00601 026604R       JMP *+3
0087  00602 006004        INB
0088  00603 026577R       JMP *-4
0089  00604 042730R       ADA =D100
0090  00605 074035B       STB DTMP5
0091  00606 006400        CLB
0092  00607 042731R       ADA =D-10      GET 10 S
0093  00610 002020        SSA
0094  00611 026614R       JMP *+3
0095  00612 006004        INB
0096  00613 026607R       JMP *-4
0097  00614 042732R       ADA =D10
```

```
0100  00615 005727          BLF,BLF
0101  00616 044000          ADB 0          AND UNITS
0102  00617 060035B         LDA DTMP5
0103  00620 126560R         JMP ENCOD,I
0104  00621 002400  TOBIG   CLA            TOO BIG SO OUTPUT ZEROS
0105  00622 006400          CLB
0106  00623 126560R         JMP ENCOD,I
0107**
0108** THIS ROUTINE CHECKS FOR OVERFLOW OF THE PART KM COUNTER, IF THIS
0109** OCCURS THE WHOLE KM COUNTER IS INCREMENTED AND THE PART COUNTER
0110** SUITABLY REDUCED, THE SIGN OF BOTH PARTS IS ALWAYS KEPT THE SAME
0111**
0112  00624 000000  DPSUM NOP
0113  00625 070031B         STA DTMP1      FRACTION OF KM IN SYNCHRO UNITS
0114  00626 074032B         STB DTMP2      INTEGRAL KILOMETRES
0115  00627 002021          SSA,RSS        POSITIVE OR NEGATIVE?
0116  00630 026641R         JMP DOP41      POSITIVE
0117  00631 040047B         ADA SCL03      NEGATIVE - MORE THAN 1 KM?
0118  00632 002021          SSA,RSS
0119  00633 026647R         JMP DOP42      NO
0120  00634 002004          INA            YES - SAVE ASJUSTED PART KM
0121  00635 070031B         STA DTMP1        AND AJUST WHOLE KM
0122  00636 046733R         ADB =D-1
0123  00637 074032B         STB DTMP2
0124  00640 026647R         JMP DOP42
0125  00641 040050B DOP41   ADA SCL04      MORE THAN 1 KM?
0126  00642 002020          SSA
0127  00643 026647R         JMP DOP42      NO
0128  00644 070031B         STA DTMP1      YES - SAVE ADJUSTED PART KM
0129  00645 006004          INB            AND ADJUST WHOLE KM
0130  00646 074032B         STB DTMP2
0131  00647 060031B DOP42   LDA DTMP1      CHECK THE SIGNS AND MAKE THEM
0132  00650 064032B         LDB DTMP2          THE SAME
0133  00651 002003          SZA,RSS
0134  00652 026672R         JMP DOP46
0135  00653 002020          SSA
0136  00654 026664R         JMP DOP44
0137  00655 006003          SZB,RSS
0138  00656 026672R         JMP DOP46
0139  00657 006021          SSB,RSS
0140  00660 026672R         JMP DOP46
0141  00661 006004          INB
0142  00662 040050B         ADA SCL04
0143  00663 026672R         JMP DOP46
0144  00664 006003  DOP44   SZB,RSS
0145  00665 026672R         JMP DOP46
0146  00666 006020          SSB
0147  00667 026672R         JMP DOP46
0148  00670 046733R         ADB =D-1
0149  00671 040047B         ADA SCL03
0150  00672 126624R DOP46   JMP DPSUM,I
```

```
0153  00673 000000  ,DTA  NOP             D/A DRIVER FOR DOPPLER PROGRAM
0154  00674 001727        ALF,ALF        POSITION CHANNEL NUMBER
0155  00675 001700        ALF
0156  00676 030001        IOR 1          MERGE IN DATA
0157  00677 102612        OTA DASC2        AND OUTPUT
0158  00700 103712        STC DASC2,C
0159  00701 126673R       JMP ,DTA,I
0160  00012         DASC2 EQU 12B
0161***
0162****** CONSTANTS,SCALE FACTURS AND TEMPORARY STORAGE AREA ******
0163***
0164  00000                 ORB
0165  00000 000000  ISTUP  NOP
0166  00001 000000  ORIGN  NOP
0167  00002 000000  LSYN   NOP
0168  00003 000000  XSYN   NOP
0169  00004 000000  LSYN0  NOP
0170  00005 000000  XSYN0  NOP
0171  00006 000000  LSYN1  NOP
0172  00007 000000  XSYN1  NOP
0173  00010 000000  LPART  NOP
0174  00011 000000  LFULL  NOP
0175  00012 000000  XPART  NOP
0176  00013 000000  XFULL  NOP
0177  00014 000000  XPK10  NOP
0178  00015 000000  XFKM0  NOP
0179  00016 000000  LPKM0  NOP
0180  00017 000000  LFKM0  NOP
0181  00020 000000  ISTLN  NOP
0182  00021 000000  LPKM1  NOP
0183  00022 000000  LFKM1  NOP
0184  00023 000000  XP[illegible]1  NOP
0185  00024 000000  [illegible]1  NOP
0186  00025 000000  DOPAD  NOP
0187  00026 000000  LINE   NOP
0188  00027 000000  INPUT  NOP
0189  00030 000000  DK3    NOP
0190  00031 000000  DTMP1  NOP
0191  00032 000000  DTMP2  NOP
0192  00033 000000  DTMP3  NOP
0193  00034 000000  DTMP4  NOP
0194  00035 000000  DTMP5  NOP
0195  00036 000000  DSPRS  NOP
0196  00037 000000  DCNTR  NOP
0197  00040 000000  REG40  NOP
0198  00041 000000  DDATA  NOP
0199  00042 000000  ISTRS  NOP
```

```
0202********************* DOPPLER CONSTANTS*****************************
0203***                                                                  *
0204*** THE DOPPLER SCALE FACTOR IS SET BY SCL01-SCL04                   *
0205***                                                                  *
0206  00043 003000  MAXSP DEC 1536       MAX SPEED 200 KNOTS            *
0207  00044 003633  MINSP DEC 1947       MIN SPEED 40 KNOTS             *
0208  00045 002732  SCL01 DEC 1474       SYNCHRO UNITS PER 1/10 KM      *
0209  00046 000223  SCL02 DEC 147        SYNCHRO UNITS PER 1/100 KM     *
0210  00047 034616  SCL03 DEC 14734      SYNCHRO UNITS PER KILOMETER    *
0211  00050 143161  SCL04 DEC -14735                                    *
0212*                                                                    *
0213**********************************************************************
      00702 160300
      00703 140000
      00704 017500
      00705 040000
      00706 000006
      00707 003777
      00710 000011
      00711 000002
      00712 177773
      00713 023420
      00714 000010
      00715 174000
      00716 004000
      00717 007777
      00720 177716
      00721 000004
      00722 000017
      00723 000360
      00724 154360
      00725 176030
      00726 001750
      00727 177634
      00730 000144
      00731 177766
      00732 000012
      00733 177777
0214                        END
**  NO ERRORS*
```

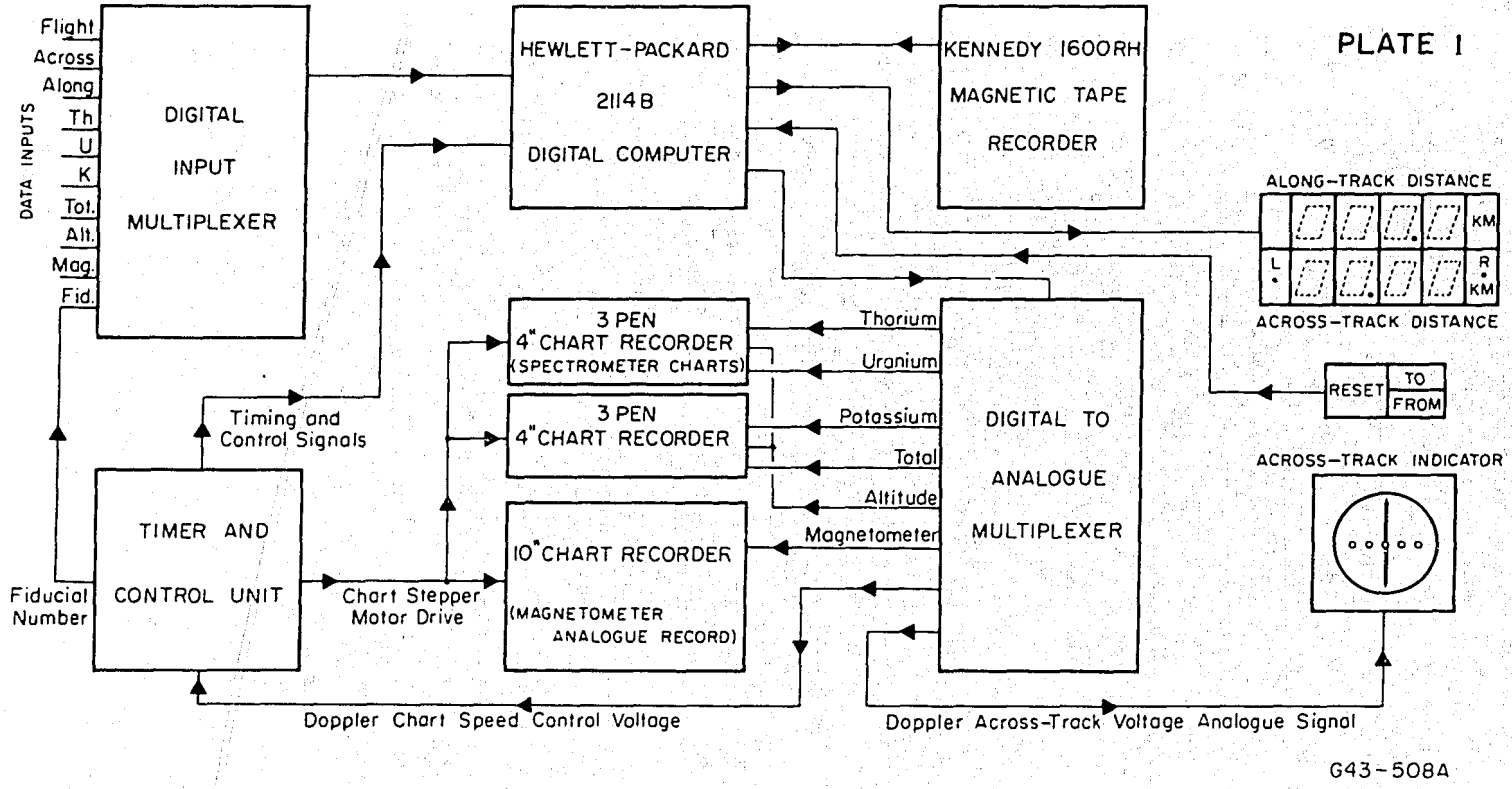
PLATE 1
DATA INPUTS
Flight
Across
Along
Th
U
K
Tot.
Alt.
Mag.
Fid.
DIGITAL INPUT MULTIPLEXER
HEWLETT-PACKARD 2114B DIGITAL COMPUTER
KENNEDY 1600RH MAGNETIC TAPE RECORDER
ALONG-TRACK DISTANCE
KM
L
R
KM
ACROSS-TRACK DISTANCE
RESET
TO
FROM
3 PEN 4" CHART RECORDER (SPECTROMETER CHARTS)
3 PEN 4" CHART RECORDER
10" CHART RECORDER (MAGNETOMETER ANALOGUE RECORD)
Thorium
Uranium
Potassium
Total
Altitude
Magnetometer
DIGITAL TO ANALOGUE MULTIPLEXER
ACROSS-TRACK INDICATOR
Timing and Control Signals
TIMER AND CONTROL UNIT
Fiducial Number
Chart Stepper Motor Drive
Doppler Chart Speed Control Voltage
Doppler Across-Track Voltage Analogue Signal
G43-508A

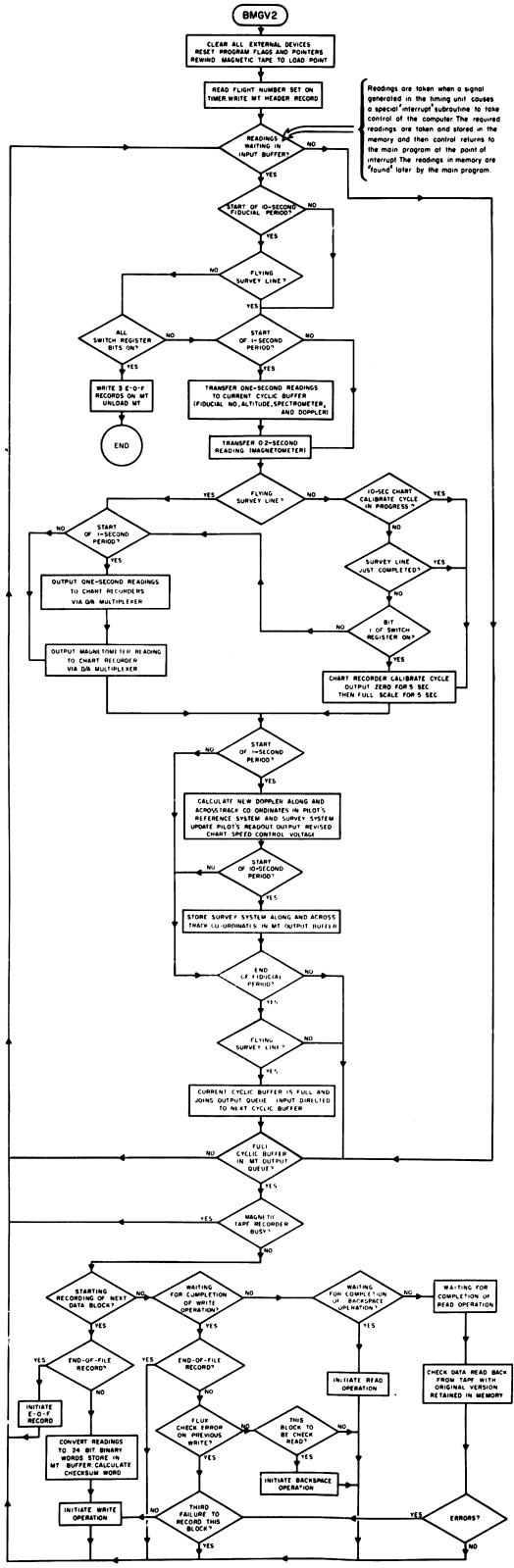

PLATE 2

643-509