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RADIO AND ELECTRICAL ENGINEERING DIVISION

USER'S MANUAL FOR THE DATA ACQUISITION SYSTEM AT THE ALGONQUIN RADIO OBSERVATORY

-J. WOLFE, D. BRADT AND T. G. O'NEILL-

OTTAWA

DECEMBER 1969

ANALYZED

ABSTRACT

A flexible data acquisition system based on a general purpose computer has been implemented on a 46-meter radio telescope. The user can specify what data will be sampled and how it will be processed and displayed before being recorded on magnetic tape. This report describes the data acquisition system to the user and shows him how to set it up and operate it.

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I. INTRODUCTION

The data acquisition system to be described was developed for the 46-meter radio telescope at the Algonquin Radio Observatory (ARO). It can be used by the astronomer to cause specified telescope, receiver, and related data to be sampled at pre-defined intervals and recorded on magnetic tape (ref. 1 & 2). Some degree of real-time processing of the data is possible and the resulting data are recorded along with the sampled data or displayed on a quick-look device. The format of the magnetic tape is self-defining and can be read into a computer for further analysis.

In order to provide a more palatable description of what the system does and how to use it, most of the details have been put in the appendices. Novice and infrequent users should find that the reading of sections 2 to 9 (with references to appendices B, F and H) will enable them to get started and that experience, with occasional reference to the rest of the manual, should fill in from there.

A brief description of the operating procedures is outlined in section 2. The operator will control data acquisition from the keyboard of a teletype unit by using the command language that is described in section 3. He must specify where the data are to be sampled (section 4) and what data are to be sampled (section 5).

A set of programs that will sample and process data can be put together by the operator with the aid of the system generator (section 6). Sections 7 and 8 outline the rules by which the operator can execute single or multiple scans. Sampling rates and filter delays are discussed in section 9.

Details of the system tape and the data tape are provided in sections 10 and 11, and techniques for processing

the data tapes on a SYSTEM/360 are described in section 12.

The core memory and the CPU time that are not required by the data acquisition programs are available to a second or background user. Rules for loading and executing background jobs which may be unrelated to data acquisition, are given in section 13.

The Glossary of Terms in Appendix A should reduce the terminology gap.

Additional information on the use and maintenance of the ARO data acquisition system is available from references 3 to 15.

Starting the Monitor

The basic data acquisition system is contained in 5 programs on the system tape (section 10). Each astronomer may have one or more system tapes that contain his custom data acquisition modules, or he may use one of the system tapes that is available to all users. This tape must be mounted on a tape drive and its unit number set to zero. The tape reel should have the write ring inserted. A bootstrap program that will load and start the monitor is executed as follows:

(i) Clear the CPU

(ii) Set the program counter to 3

(iii) Turn the program protect key off

(iv) Set console switches to re-assign command devices if desired (see Appendix D)

(v) Press start twice

(vi) When the monitor starts running (about 5 sec.) turn the program protect key on

Appendix C contains a starting procedure that can be used if the bootstrap program at location 3 has been destroyed.

Loading a Data Acquisition Module

The next step is to use one of two methods to load a set of programs into core which can perform the data acquisition job that is required. If such a set of programs has previously been generated and dumped on the system tape as an observer's module, it can be loaded with the LOAD command. If this module is not available, a new data acquisition module must be generated with the NEWS command by using the rules that are described in section 6 and Appendix H.

Running a Data Acquisition Module

The data tape must be mounted on the other tape drive and its unit number set to 4. Don't forget - no ring, no write! If the tape contains previously recorded data to which the operator wishes to add, he can position the tape with the POST command. When the data tape has been positioned beyond the last scan that was recorded, the message 'DT READY' will be typed.

If the operator wishes to observe quick-look data he may need to connect or adjust the quick-look device. The summary of computer hardware in Appendix D will assist in planning the observation and connecting peripheral devices.

Several modes of running a data acquisition module are available to the operator and are described in sections 7 and 8.

The status of conditions in the telescope, computer, and receiver systems are monitored every 250 ms. Pertinent parameters of the system are also displayed on the Command and Status Panel (see Fig. D.5). When an abnormal condition is detected an alarm message that describes the current error conditions is typed. Appendix F describes the status and alarm system and lists the alarm messages. Where possible, the system will continue operation and let the user take whatever action he deems necessary.

Shut Down

The operator may retrieve his data tape, and system tape if necessary, by using the rewind switch on the tape deck before removing the tape. On older systems the command

WEND must be used before rewinding to mark the position to which data have been recorded. Systems on or later than AUG 13/69 are automatically flagged so that the operator need use WEND only after the system has come to an unscheduled Halt and the operator wishes to remove the data tape.

The computer may be stopped with the halt switch on the CPU, but this is not necessary unless the operator is turning off the power or setting up to bootstrap a new program into core. Except for a hardware failure or a long interval without use, the CPU should not be turned off because the shut-down and start-up surges have a higher probability of causing a hardware failure than does continuous operation. If needed, a recommended shut-down sequence is posted on the inside cover of the breaker panel on the windowless wall beside the CPU.

Restarting the Monitor

If the computer is halted with the monitor program in memory, the operator can restart the monitor by pressing CLEAR once and START twice. By raising control switch no. 0 first, the event schedules, sample lists and the scan pattern will remain intact. When control switch 0 is off all lists are cleared and a new data acquisition module must be loaded.

3. COMMAND LANGUAGE

The command language program accepts instructions or commands from the operator and uses them to control the data acquisition process. It also lets the operator interrogate the system and informs him of various conditions in the data acquisition sequence. The inputs to, and the responses from, the command language will produce a log of the observing procedures that were used and the scan numbers that were assigned.

The operator can use the command language to set or update certain observing 'constants' such as meteorological data; observer, operator, or project numbers; the date; the name of the radio source; etc. These commands simply put the value in a pre-assigned location in the A directory (see Appendix F) which is then recorded on the data tape at the beginning and end of each scan. The specification of these constants is arbitrary. In fact, the astronomer can assign a new meaning to these locations, possibly for use in later stages of processing, and continue to input new values with the old commands.

All commands can be entered from the keyboard of the teletype unit that is assigned as the primary foreground device and all messages to the operator will be printed on this unit. Twenty-four of the most commonly used commands can also be entered through a Control and Status Panel (CASP) that is mounted above the chart recorder (see Fig. D.5). The format of the command language and a description of each command is outlined in Appendix B.

The basic observing unit during the acquisition, real-time processing, the recording, and the later processing phases will be the scan. Data within a scan will be sampled at a uniform interval along one of the telescope's coordinates. This pilot or P coordinate can be azimuth (AZ), zenith angle (ZA), declination (DEC), hour angle (HA), right ascension (RA), sidereal time (SID), solar time (SOL), or polarizer angle (PA). A scan is defined as the data that have been collected along the P coordinate from a starting position to a point where data acquisition was terminated.

Events can be programmed along the P coordinate by entering each event in a list of up to 8 elements that is called an event schedule. The four types of events that can be scheduled are:

(i) STRT - start sampling
(ii) STOP - stop sampling
(iii) CALN - turn the receiver calibration on
(iv) CALF - turn the receiver calibration off.

Only one start and one stop event can be used, and these define a segment of the P coordinate that is called the scan vector. The calibration-on and -off events can be used more than once, so that the 8 slots of one event schedule can be used to define the scan vector and 3 complete calibration sequences.

Before an event schedule is executed so as to produce a scan, its P coordinate must be defined by the P.C. command and the sample interval along the P coordinate must be specified in one of two ways. The command SI.X (X = 1, 2 or 3 depending on the sample list that is used) will define the sample interval directly, or the command SPBX will specify

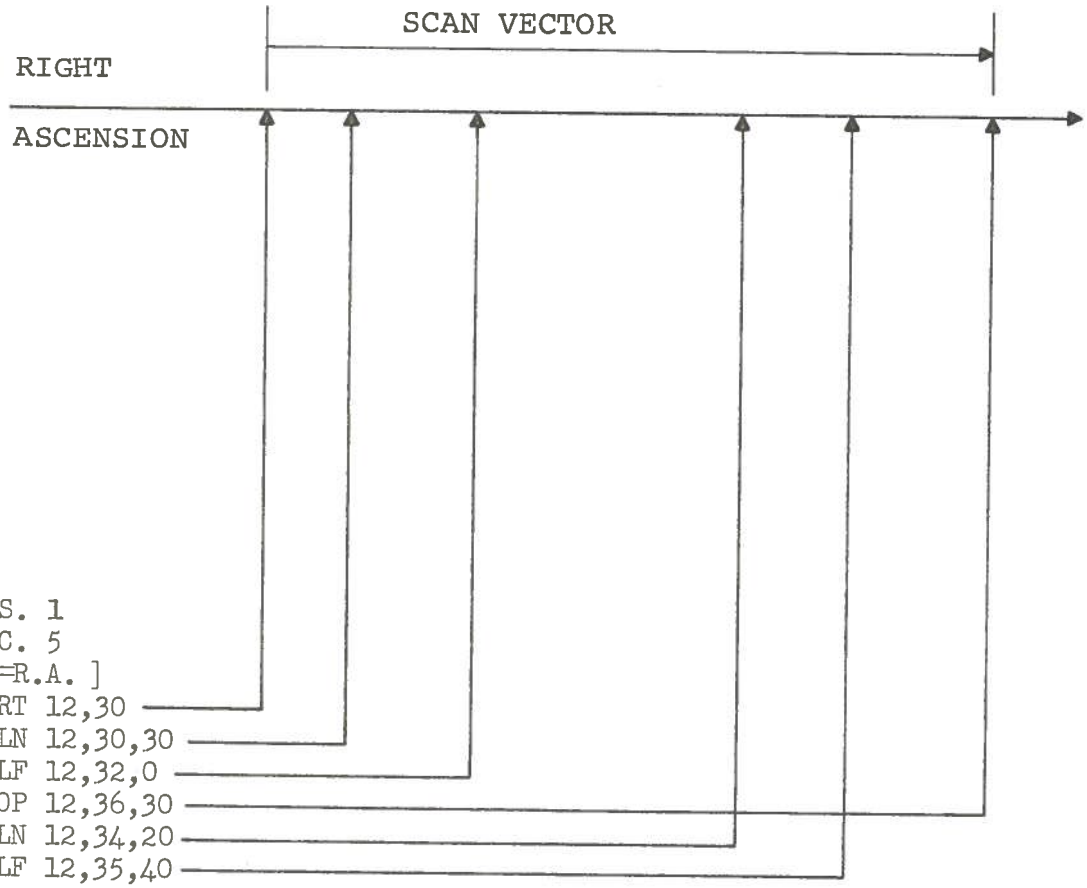
the number of samples per antenna beamwidth. With the latter command, the sample interval is calculated from the receiver frequency in terms of a P coordinate interval. At run time, HA and RA (AZ) scans will have this equatorial interval corrected by cos δ (sin ZA) so that the number of samples per beamwidth will remain constant (see section 9).

Figure 4(a) illustrates the procedures that can be used to schedule events along the P coordinate.* Note that the order within the event schedule is irrelevant because events are executed according to their position in the scan vector. The command CPES was used to copy the event schedule on the operator log as shown in figure 4(a). In this and other examples certain responses are enclosed in square brackets ([ ]) to indicate that they are optional and can be inhibited by putting Operator Switch No. 0 on (see Fig. D.5).

Several commands are available to the operator for changing an event schedule and these are illustrated in figure 4(b) where the event schedule that was defined in 4(a) is altered. Individual events can be deleted with the DELE command by specifying the event numbers as the arguments of the command. The RVES command reverses the schedule to run in the opposite direction by interchanging start and stop events and calibration-on and -off events. An event schedule can be moved to a new starting coordinate with the relative positions of all other events intact by using the command MESX.

Three independent event schedules can be formed and each is referred to by the digit 1, 2 or 3 which replaces the

* The format that is used to specify coordinate values in Astronomer's Units is described in Appendix B.




```
 /E.S. 1
 /P.C. 5
[PC =R.A. ]
 /STRT 12,30
 /CALN 12,30,30
 /CALF 12,32,0
 /STOP 12,36,30
 /CALN 12,34,20
 /CALF 12,35,40
 /SI.1 0 0 0.20
 /CPES
[#ES= -1   #PC=R.A.    #MODE = ABST  #S.VECTOR= POS  000  006  030  00 ]
  SI.1 =  000  000  000  19
   1    STRT AT P =  012  029  059  99
   2    CALN AT P =  012  030  030  00
   3    CALF AT P =  012  031  059  99
   4    STOP AT P =  012  036  029  99
   5    CALN AT P =  012  034  020  00
   6    CALF AT P =  012  035  040  00
```

Figure 4(a) Creating and listing an event schedule ([ ]-optional lines)

character X in some of the command names. Since scans must be executed sequentially, only one event schedule is in use or is active at a time. Therefore, when modifying an event schedule the operator must ensure that the schedule that he wishes to change is the active one. The command ES.X will activate event schedule X.

With multiple event schedules the operator can define independent scans which can be executed in a sequence to form a pattern. These event schedule sequences can be run manually as single scan units by the methods described in section 7. The full use of multiple event schedules is realized in the scan pattern mode where a series of event schedules is pre-defined and run automatically (see section 8).

```
 /DELE 2,3                          REMOVE FIRST CALIBRATION
 /CPES
[#ES= -1    #PC=R.A.    #MODE = ABST  #S.VECTOR= POS  000  006  030  00 ]
  SI.1 =   000  000  000  19
   1    STRT AT P =   012  029  059  99
   4    STOP AT P =   012  036  029  99
   5    CALN AT P =   012  034  020  00
   6    CALF AT P =   012  035  040  00

 /RVES                              REVERSE E.S.
 /CPES
[#ES= -1    #PC=R.A.    #MODE = ABST  #S.VECTOR= NEG  000  006  030  00 ]
  SI.1 =   000  000  000  19
   1    STOP AT P =   012  029  059  99
   4    STRT AT P =   012  036  029  99
   5    CALF AT P =   012  034  020  00
   6    CALN AT P =   012  035  040  00

 MES1 20,20,20                      MOVE E.S.
 /CPES
[#ES= -1    #PC=R.A.    #MODE = ABST  #S.VECTOR= NEG  000  006  030  00 ]
  SI.1 =   000  000  000  19
   1    STOP AT P =   020  013  049  99
   2    STRT AT P =   020  020  019  99
   5    CALF AT P =   020  018  010  00
   6    CALN AT P =   020  019  030  00

 /DELE                              REMOVE ALL EVENTS
 /CPES
[#ES= -1    #PC=R.A.    #MODE = ABST  #S.VECTOR= POS  006  000  000  00 ]
  SI.1 =   000  000  000  19
```

Figure 4(b) Examples of modifying an event schedule; [ ]-optional lines. (See 4a)

In defining a scan by an event schedule the operator has answered the question 'Where is data sampled?'. He must now specify what data must be sampled.

A list of potential information sources can be found in Appendix F. Each element of the list is referred to by its sequence number within the list and this number is called its sample index. The operator can select the data that will be taken at each sample point by creating a list of sample indices that is a subset of the list in Appendix F. (See also section 6). This list is called the sample list and is used to control the sampling, on-line processing, and formatting sequences. Sample lists of up to 8 elements can be specified through the system generator in which the operator defines each element by its sample index.

One of the most powerful features of the system is the ability to have the sampled data (defined by the sample indices in the sample list) processed and put on the data tape or displayed immediately. This real-time processing is done by subroutines which the operator must specify and load during system generation. When a certain processing function is needed, the appropriate subroutine must be loaded either from one of the libraries on the system tape or from the paper tape reader. All processing subroutines fall into two types. If the output from the processing routine is merged with the sampled data and recorded on the data tape it must be specified by a separate entry in the sample list. This type of routine is called an AA subroutine because the first two characters of its six-character name must begin with AA. When results from a processing routine are used for display purposes only, a QL subroutine is used and no additional slot

in the sample list is required. Instead, the QL subroutine is appended to the element of the sample list whose value is to be processed and displayed. Only one QL subroutine can be used with each entry of the sample list.

As sampling proceeds, the data that the acquisition programs collect or calculate at each sample point, according to the specifications of the sample list, are put in consecutive memory locations of an output formatting area. When all of the processed data are added to the sampled data for one sample point, the result is called a sample set. When the output area has enough sample sets to form one data block, its contents are dumped onto the data tape in a format that is described in section 11.

The flow of information and data from the operator's specification for the sample list through to the recording of data on magnetic tape is illustrated in figure 5(a). When the data blocks are read back into another computer and packed together, the result will be a string of sample sets that comprise a scan. This means that the user can treat the scan as the basic unit of data for both the acquisition phase and for later stages of processing. Data that have been generated by one sample list are called a data stream.

When the system generator translates the data indices into the internal coding for the sample list it distinguishes between discrete and analog data sources. Discrete signals such as coordinate values or the receiver status are always available so that when the P coordinate for the next sample is reached the data for all discrete elements in the sample list are sampled immediately. The analog signals, however, must propagate through the pre-sampling filters before their corresponding values are available. Therefore, the sampling

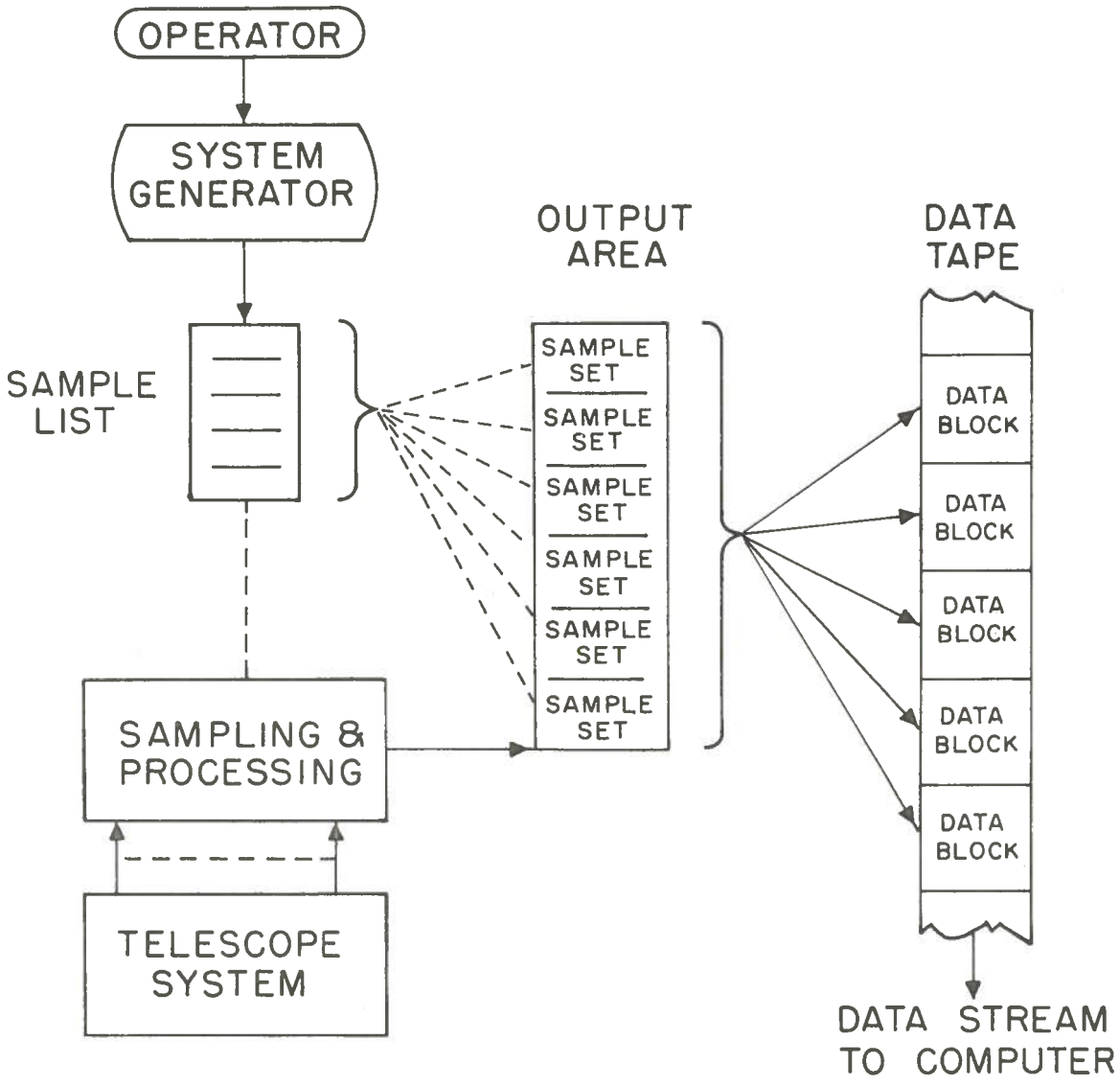


Figure 5 (a) Sample list to control sampling and processing

of all analog signals for one sample list is retarded by the delay time of the pre-sampling filter that is used on the output of the receiver, (section 10). In this way, all the samples in one sample set correspond to the values that existed when the P coordinate reached the sample point. When a sample list specifies more than one analog source the operator should use filters on each signal that are similar to the receiver filter so that the sampled data can be aligned correctly by the common delay time.

The operator can examine a sample list and the effective delay of the filter with the CPSL command.

Up to three sample lists can be set up and run simultaneously by one event schedule so as to produce a corresponding number of data streams. This provides the facility for sampling signals at rates that are appropriate to their information bandwidths. Although the sampling interval for each stream is independent, samples must be taken along the scan vector that is defined by the active event schedule. In order to connect a sample list to an event schedule the operator must use the SPBX or SI.X commands, where X (= 1, 2 or 3) specifies the sample list.

Data blocks from each sample list are interleaved on the data tape and separated upon reading by a data stream code that is written in each data block header.

At least one sample list must be declared by each event schedule. If the operator violates this rule the error message 'NO S.I.' will be typed when the event schedule is enabled. Similarly the error message 'NO S.L.' is typed when the system tries to use a sample list that has not been defined at generation time, i.e., there is no list.

The command NEWS initiates a two-stage sequence by which the operator can generate a new observer's module. In the first stage the system generator is loaded from the system tape and executed. This program then assists the operator in setting up the parameters and lists that define a working data acquisition system or observer's module. The degree of assistance that the operator receives can be controlled by operator switch No. 0. Experienced users can put this switch on to reduce the generation time by eliminating some of the instructions that are typed out (see Fig. 6(c)). A detailed description and some examples of how to use the generator can be found in Appendix H and in figures 6(a), (b) and (c). Figure 7(a) also illustrates the use of the system generator.

Briefly, the operator and the system generator set up the sample lists first by using the sample indices to specify the sampled data and the AA or QL subroutines to specify the data processing procedures. The next phase simply consists of instructions that show the operator how to use the command language to set up the event schedules. This phase can be skipped during generation by specifying no event schedules, and completed later since all the commands that are needed to create the event schedules are available at any time.

Next, the operator is asked to define the start mode as absolute or relative. One line of comments that describe anything at all about the module can be appended. These comments stay with the module during LOAD-DUMP operations and can be listed with the command COMM. When the first phase of system generation is finished the operator can choose to abort the generation or continue with the loading stage.

By putting operator switch (OPSW) no. 1 on, the experienced user can cause a modified loader to be used in which the messages to the operator have been shortened in order to free about '140 locations for AA or QL subroutines.

During loading, the system tape is searched for the subroutines that are required in the module which the operator defined in stage 1. This includes the AA and QL processing subroutines. Those programs that are found on the systems tape (section 10) are loaded automatically and the rest must be entered either with the high-speed paper tape reader or by searching the system tape libraries again. When all the necessary subroutines have been loaded, system generation will be complete and the operator will have the data acquisition programs in the core memory. If necessary, the command language may be used to make last minute changes before the module is executed. The operator may also preserve the module for future use by dumping it on the systems tape. The DUMP command first asks the operator to assign a 4-character name to the module which will be used to locate and read it back into core memory with the LOAD command.

```
 /NEWS
 ENTER # OF DATA STREAMS-2
[******* SET UP DATA STREAM #  1 ]
[ENTER SAMPLE INDICES ]
   1 -- 13
   2 -- 41
   3 -- 67
   4 --
[ENTER AA SUBS-AAXXXX,ARG(N)]
   4  AAFILT,1
   5  AAFIT ,4
   6  AA
[ENTER QL SUBS-QLXXXX,ARG(N)]
   QLLOOK,4
   QL
[******* SET UP DATA STREAM #  2 ]
[ENTER SAMPLE INDICES ]
   1 --
   1 -- 40
   2 -- 99
 NO!!
   2 -- 9
   3 --
[ENTER AA SUBS-AAXXXX,ARG(N)]
   3  AA1234,5
 NO!!
   3  AA1234,2
   4  AA
[ENTER QL SUBS-QLXXXX,ARG(N)]
   QL___,7
 NO!!
   QL___,1
   QL
 ENTER # EVENT SCHEDULES-2
[**********SET UP E.S.#  1 ]
 TYPE /ES.1--/ES.1
[#ES= -1    #PC=DEC.    #MODE = RLST  #S.VECTOR= POS  090  000  000  00]

 TYPE /P.C.X.-/P.C.3
[PC =DEC. ]

 CONNECT SAMPLE LISTS
 TYPE /SI.1 XX XX XX.XX OR /SPB1 XX -/SI.1 0 0 1

 TYPE /SI.2 XX XX XX.XX OR /SPB2 XX -/SI.2 0 0 25

 FILL IN EVENTS AS REQUIRED:
 /STRT 22 30 40
 /STOP 22 32 0

 **********SET UP E.S.#  2
 TYPE /ES.2--/ES.2
[#ES= -2    #PC=SOL.    #MODE = RLST  #S.VECTOR= POS  006  000  000  00 ]

 TYPE /P.C.X-/P.C.7
[PC =SOL. ]
```

Figure 6(a) An example of system generation. The operator inputs are *underscored* and the lines enclosed in brackets are responses that can be suppressed by OPERATOR SWITCH No. 0

```
CONNECT SAMPLE LISTS
TYPE /SI.1 XX XX XX.XX OR /SPB1 XX -/SI.1 0 0 10

TYPE /SI.2 XX XX XX.XX OR /SPB2 XX -/SPB2 12
NO! TIME PC
/SI.2 0 0 50

FILL IN EVENTS AS REQUIRED:
/STRT 0 0 0
/CALN 0 1 0
/CALF 0 2 0
/STOP 0 3 0

SET START MODE BY /ABST OR /RLST -- /RLST

ENTER COMMENTS- THIS IS A DESCRIPTIVE GENERATION ONLY
GENERATION COMPLETE , CONTINUE?-
NOT FOUND!
  AAFILT
  AAFIT
  QLLOOK
  AA1234
  QL
LOAD LIBRARY ON READER.
EXIT
NEWS ABORTED
/CPSL 1
DELAY =   04810
  1.     13
  2.     41
  3.     67
  4.    -01  QL
  5.    -04
/CPSL 2
DELAY =   04810
  1.     40  QL
  2.     09
  3.    -02
/ES.1
[#ES= -1    #PC=DEC.    #MODE = RLST  #S.VECTOR= POS  000  001  020  03 ]
/CPES
[#ES= -1    #PC=DEC.    #MODE = RLST  #S.VECTOR= POS  000  001  020  03 ]
 SI.1 =   000  000  000  93
 SI.2 =   000  000  024  72
  1    STRT AT P =   022  030  039  86
  2    STOP AT P =   022  031  059  89
/ES.2
[#ES= -2    #PC=SOL.    #MODE = RLST  #S.VECTOR= POS  000  003  000  00 ]
/CPES
[#ES= -2    #PC=SOL.    #MODE = RLST  #S.VECTOR= POS  000  003  000  00 ]
 SI.1 =   000  000  009  99
 SI.2 =   000  000  049  99
  1    STRT AT P =   000  000  000  00
  2    CALN AT P =   000  001  000  00
  3    CALF AT P =   000  001  059  99
  4    STOP AT P =   000  003  000  00
```

Figure 6(b) The system generation example continued

```
/NEWS
ENTER # OF DATA STREAMS-1
  1 -- 10
  2 -- 13
  3 -- 44
  4 -- 42
  5 --
  5  AASCAV,2
  6  AAPANG,3
  7  AA
  QLRCVR,1
  QLPSC8,4
  QLBEAM,5
  QL
ENTER # EVENT SCHEDULES-1
**********SET UP E.S.#  1
TYPE /ES.1--/ES.3
/P.C. 6

TYPE /P.C.X-
CONNECT SAMPLE LISTS
TYPE /SI.1 XX XX XX.XX OR /SPB1 XX -/SI.1 0 0 3.10

FILL IN EVENTS AS REQUIRED:
/STRT
/CALN 0 1 0 0
/CALF 0 2 20.0
/STOP 0 3 40.0

SET START MODE BY /ABST OR /RLST -- /RLST

ENTER COMMENTS- SCAN AVERAGE,10 SAMP./BW,0.16 FILT.,ES1=RA,ES2=DEC,ES3=CAL
GENERATION COMPLETE , CONTINUE?-
NOT FOUND!
LIBE

DONE
NEW SYSTEM READY,   HI=  27056
POST D.TAPE?
/DUMP
ENTER NAME--SCAN
NOT FOUND!
SCAN COMPLETED , HI= 27056
POST D.TAPE?
```

Figure 6(c) An example of the use of the system generator and loader with Operator Switches No. 0 and No. 1 on

7. EXECUTING A SCAN

Data acquisition will not begin until two conditions are satisfied. First, the system must be enabled, which causes the next event in the active event schedule to be checked each time that a new P coordinate is received from the raksyn system. Secondly, the P coordinate must cross the coordinate of the start event in the same direction that the scan has been defined. That is, the telescope must be driven so that the value of the P coordinate is less than the start value for positive scan vectors and greater than the start value for negative scan vectors. Executing a start sequence is much like firing a revolver, in that one chamber is activated with the ES.X command, the safety latch is removed by the NABL command and the trigger is pulled by the start event.

Pertinent event schedule data will be logged when the system is enabled (if OPSW No. 0 is off) and the message 'SCAN XXXX STARTED' will be typed when the start event has initiated sampling. Data acquisition will proceed at a time rate that is determined by the sample interval(s) and the scan rate. Each event in the active event schedule will be executed and set complete when the P coordinate reaches the value that is specified for that event. When the coordinate of the stop event is reached, the last data block is padded out with zeros, the scan trailer block is written, the system is disabled, and the message 'SCAN XXXX FINISHED' is typed. If the operator wishes to take the scan again he may do so by using the command BACK to scan in the reverse direction, or he may use NABL to repeat the scan in the original direction.

The operator may put events in the active event

schedule while the system is enabled. The event commands (STRT, STOP, etc.) are treated in the same way as before except that those commands which have a zero P value argument are interpreted as requests for immediate execution. Therefore, the current value of the P coordinate is entered in the event schedule and the event is executed immediately. This applies to all events that are entered when the system is enabled. Thus the operator need not define a scan with preset events, but rather, he can create or add to a scan while it is being taken. This is illustrated in figure 7(a) where the operator uses the command CLAN to clear and then enable an event schedule. When he decides to start sampling, possibly by watching a chart record or the polarizer angle, he types /STRT (CR). As the P coordinate moves along, he adds events as required until the STOP command is entered to terminate the scan.

When the event schedule is copied it contains the "immediate" events with their corresponding P coordinates. Figure 7(a) also goes on to illustrate that the event schedule generated in this way can be reapplied to succeeding scans, first by the BACK command and then by using MESX to move the event schedule to a new part of the sky. The use of the commands FLAG, DRTY, TEMP, DATE, and SCAN are also demonstrated. Notice that comments can be logged by using the dummy command **** or by appending the message to other commands after all the arguments have been specified.

When an event schedule that has no start or stop event is enabled the scan is said to be open, since the scan vector and therefore the direction is not defined. When the system is enabled the absence of a start or stop event is brought to

```
 /SCAN 1000              SET SCAN NUMBER
 /P.C. 3
[PC =DEC. ]
 /CLAN 2
[SCAN NABLED,SN =  0001000   PC = DEC. ES=  2 ]
 NO STRT
 NO STOP
 /STRT
 SCAN 0001000  STARTED
 /******  DATA ACQUISITION STARTED ON SCAN 1000
 /CALN
 /CALF
 /STOP
 SCAN 0001000  FINISHED
 /CPES                    THE RESULTING E.S. IS:
[#ES= -2    #PC=DEC.    #MODE = ABST  #S.VECTOR= POS  090  000  000  00 ]
  SI.1 =   000  000  000  93
   1  C STRT AT P =   042  051  022  50
   2  C CALN AT P =   042  053  028  57
   3  C CALF AT P =   042  054  032  84
   4  C STOP AT P  =  042  056  032  73

 /DATE 010169                  CHANGE DATE
 /DRTY 1                       CHECK DATE
   0010169
 /TEMP -33                     UPDATE TEMPERATURE
 /DRTY 60                      CHECK TEMPERATURE
  -0000033
 /BACL↑
 /BACK                         REPEAT LAST SCAN IN OPPOSITE DIRECTION
[SCAN NABLED,SN =  0001001   PC = DEC. ES=  2 ]
 SCAN 0001001  STARTED
 /FLAG 77777                   FLAG DATA FROM HERE ON
 FLAG SET ,P=  042  055  022  43
 /DRTY 41,2                    GET CURRENT ZA
   355  057  005  054
 /FLAG                         RESET FLAG TO ZERO
 FLAG SET ,P=  042  053  023  78
 SCAN 0001001  FINISHED
 /CPES
[#ES= -2    #PC=DEC.    #MODE = ABST  #S.VECTOR= NEG  000  005  010  23]
  SI.1 =   000  000  000  93
   1  C STOP AT P =   042  051  022  50
   2  C CALF AT P =   042  053  028  57
   3  C CALN AT P =   042  054  032  84
   4  C STRT AT P =   042  056  032  73
```

Figure 7(a) An example of the execution of an open scan with 'immediate' event commands and the application of the resulting event schedule to the next scan. ([ ]-optional lines)

the attention of the operator (figure 7(a)). However, a scan direction must be specified before enabling in order that the system may resolve ambiguities that can arise in the direction of crossing the start event and in projecting the sample points along the P coordinate. In the example shown in figure 7(a) the operator had previously defined all open scan directions as positive with the command POSS. Notice that the scan vector that was picked up at enable time was +90 degrees. If he had wished to take the original scan in the negative direction, the command NEGS would have been used and the scan vector would have been -90 degrees. When scan 1001 was enabled the STRT and STOP events allowed the scan vector to be calculated and its sign superseded any direction that a previous POSS or NEGS had specified.

Time scans are treated somewhat differently than scans in spatial coordinates. All negative time scans are reversed and made positive when they are enabled. Also, it is difficult for the operator to schedule time scans because he cannot predict ahead of time when the scan can be started. For this reason a relative start mode was added. If the system is operating in this mode, the message MAN.STRT.REQ will be typed and sampling will be held back when a time scan is enabled. When the operator types /STRT (CR), <u>all</u> events in the event schedule will be updated such that the start event is scheduled for the present value of the P coordinate and sampling will begin at once. A time scan is set up and executed in the relative start mode in figure 7(b). The commands that put the system in the relative start mode and take it out (absolute start mode) are RLST and ABST respectively. The method that is used to implement relative

starts is to prevent the scheduling program from finding a start event by setting this event as having been completed before the system is enabled. Thus, when the second (negative) scan in figure 7(b) was enabled, the scan vector was reversed to a positive direction again and the start event was listed as being completed although sampling did not begin until the immediate start command was issued.

Two commands allow the operator to terminate a scan in an abnormal manner. If the current scan has been ruined, say by interference, and should be done again the command REDO can be used to terminate the scan, and enable the same event schedule for another try. If the scan has already been started (i.e., sampling has begun) a terminate block is written on the data tape and the scan number is incremented before re-enabling. If sampling has not started, no record of the aborted scan will be on the data tape so that the terminate record is not issued and the scan number is not incremented.

When the operator wants to abort the current scan without re-enabling it, he can use the command ABRT. The system must be enabled in order to accept this command. If sampling has started, the trailer block will be coded to indicate an ABRT termination and the scan number will be incremented.

AA and QL processing subroutines have separate entry points that are used when starting, stopping, aborting, and re-doing a scan. In some cases these subroutines require additional data from the operator during one or more of the above phases. Figure 7(c) illustrates the generation and execution of an observer's module in which a processing subroutine calculates the system temperature from a

calibration sequence that was controlled by 'immediate' event commands. When the scan was completed the final result (which was corrupted by interference) was not calculated until the operator entered values for 3 parameters with the keyboard of the command device.

At certain stages of operation some AA and QL subroutines (e.g. AANGRT) request a series of values from the keyboard, and a series of messages (one for each value) to this effect is listed. The operator must enter these values in the same sequence in which the requests are listed.

A second, and in many cases a more convenient, communication channel between the operator and the processing subroutines is the set of twelve operator switches (OPSW No. 12 to 23).

Since AQ subroutines have access to values in the A-directory a third means of control is to use the FLAG command to set location 67.

```
 /ES.1
 /P.C. 7
[PC =SOL. ]
 /STRT
 /CALN 0 0 30
 /CALF 0 1 0
 /STOP 0 1 30
 /RLST
 /NABL
[SCAN NABLED,SN =  0000001   PC = SOL. ES=  1 ]
 MAN.STRT.REQ
 /STRT
 SCAN  0000001  STARTED
 SCAN  0000001  FINISHED
 /CPES
[#ES= -1   #PC=SOL.    #MODE = RLST    #S.VECTOR= POS  000  001  030  00]
  SI.1 =  000  000  000  93
   1  C STRT AT P =  016  004  027  49
   2  C CALN AT P =  016  004  057  48
   3  C CALF AT P =  016  005  027  49
   4  C STOP AT P =  016  005  057  49

 /RVES
 /CPES
[#ES= -1    #PC=SOL.    #MODE = RLST   #S.VECTOR= NEG  000  001  030  00]
  SI.1 =   000  000  000  93
   1    STOP AT P =   016  004  027  49
   2    CALF AT P =   016  004  057  48
   3    CALN AT P =   016  005  027  49
   4    STRT AT P =   016  005  057  49

 /NABL
[SCAN NABLED,SN =  0000002   PC = SOL. ES= 1 ]
 MAN.STRT.REQ
 /CPES
[#ES=  1   #PC=SOL.    #MODE = RLST  #S.VECTOR= POS  000  001  030  00 ]
  SI.1 =  000  000  000  93
   1  C STRT AT P =  016  004  027  49
   2    CALN AT P =  016  004  057  48
   3    CALF AT P =  016  005  027  49
   4    STOP AT P =  016  005  057  49

 /STRT
 SCAN  0000002  STARTED
 SCAN  0000002  FINISHED
 /CPES
[#ES= -1    #PC=SOL.   #MODE = RLST  #S.VECTOR= POS  000  001  030  00 ]
  SI.1 =   000  000  000  93
   1  C STRT AT P =   016  007  050  27
   2  C CALN AT P =   016  008  020  06
   3  C CALF AT P =   016  008  050  27
   4  C STOP AT P =   016  009  020  27
```

Figure 7(b) An example of executing a time scan in the relative start mode. ([ ]-optional lines)

```
 /NEWS
 ENTER # OF DATA STREAMS-1
[******* SET UP DATA STREAM #  1]
[ENTER DATA INDICES- ]
   1 -- 13
   2 -- 44
   3 --
[ENTER AA SUBS-AAXXXX,ARG(N)]
   3  AA
[ENTER QL SUBS-QLXXXX,ARG(N)]
   QLLIN2,1
   QLNOIS,2
   QL
 ENTER # EVENT SCHEDULES-
 ENTER COMMENTS- NO COMMENT!

 GENERATION COMPLETE , CONTINUE--
 DONE
 NEW SYSTEM READY,    HI=  25511
 /ES.1
 /P.C.6
[PC =SID. ]
 /SI.1 0 0 0 50
 /CLAN
[SCAN NABLED,SN =  0000001    PC = SID. ES=  1 ]
 NO STRT
 NO STOP
 /STRT
 SCAN  0000001  STARTED
 /CALN
 /CALF
 /STOP
 SCAN  0000001  FINISHED
   INITIAL SIDEREAL TIME      17  44  34  NO. SAMPLES  0000639
   BASELINE  0000352    CALIB.     0000138
   CAL. STEP     0000180.303669    S.D.    0000003.942421
       BASELINE LEVEL    0000482.203220
   SLOPE    -0000000.078711     R.M.S. DEV.    0000039.162167

 ENTER CAL TEMP IN DEG    (XXX.X) 8.9

 ENTER FILTER BWIN HZ(X.XXX).250↑
 0.250
 ENTER RF BW OF FRONT END OF RCVR IN MHZ 475
 T(RMS),T(SYS)=    00001.93309    23459.22913
```

Figure 7(c) The generation and execution of an observer's module in which the operator communicates directly with the processing subroutines. ([ ]-optional lines)

Multiple event schedules can be used to define multiple scans, although only one schedule can be run at a time. The operator can sequentially select and run single scans by using the procedures described in section 7. However, a series of scans or a scan pattern can be prepared and executed automatically by simply driving the telescope along the vector of each scan in the sequence. This scan pattern consists of from 1 to 8 single scans (scan elements) and is defined by the S.P. command. The first argument of this command specifies the number of patterns (M) that are to be run while the rest of the arguments specify the pattern (i.e. the scan elements) in terms of the event schedules that are to be used. Each element of the pattern is specified by a sign to represent the direction of the scan and a digit to indicate which event schedule will control the scan. After the scan pattern has been defined the command NABL (or RESP) will initiate its execution by enabling the event schedule that is specified by the first pattern element. If the pattern count M is zero the system will revert to the single scan mode of operation when it is enabled. The command RESP will ensure the pattern mode of operation by setting $M \geq 1$.

As each element of the pattern is enabled, the system will force the scan vector of the specified event schedule to the direction that is stipulated by the sign of that element. This is accomplished by automatically reversing the event schedule if necessary. Thus the 3 event schedules can define 3 positive and 3 negative scans when run as part of a scan pattern. Each scan in the pattern is executed in the same manner as a single scan, so that time scans are forced into a positive direction and may be operated in the relative start mode.

The examples in figure 8(a) and (b) show how a pattern consisting of the elements (1, -1, 1, -1, 2) can be defined and executed twice. As each element of each pattern is enabled the element and pattern number are logged. However, the operator can suppress these statements by putting operator switch No. 0 on.

The first element of the next pattern is enabled automatically as soon as the current pattern is complete and the value of M is decremented by 1. This process continues until M is zero and the ALL PATTERNS DONE message is typed. The operator may not know beforehand how many scans will be required. He can specify a large number, such as M = 99 in figure 8, and cut this number down when he has a sufficient number of patterns. This can be done with the S.P. command which, if entered when the system is enabled, will set M = 1 so that when the current pattern is completed the sampling will stop.

In some cases the operator may wish to use the pattern once per source and then move to a new source with the same pattern. To effect this type of observation the operator can specify a pattern count of M = 1 and when the ALL PATTERNS DONE message is typed he can move the event schedules separately to their new positions with the MESX command. The pattern count can be refreshed by typing /S.P. 1 (CR) and the next pattern can be started with the NABL command.

An easier method of repeating a scan pattern is to use the command RESP which refreshes the pattern count M and also enables the system. Multiple patterns can be specified because M is set to the value of the argument of RESP, except when less than 1, in which case M is set equal to 1.

```
 /ES.1
 /P.C.5
[PC =R.A. ]
 /SI.1 0,0,1,0
 /STRT 20,30,00
 /STOP 20,31,00


 /ES.2
 /P.C.7
[PC = SOL. ]
 /SI.1 0,0,1,0
 /STRT
 /CALN 0,0,20
 /CALF 0,0,40
 /STOP 0,1,0
 /RLST
 /S.P.2   1,-1,1,-1,2
 /CPSP
 SP =  0002  1 -1  1 -1  2  0  0  0
 /NABL
[PATTERN   001  001 NABLED,SN =  0000001   PC = R.A. ES=   1]
 SCAN  0000001  STARTED
 SCAN  0000001  FINISHED
[PATTERN   001  002 NABLED,SN =  0000002   PC = R.A. ES=   1]
 SCAN  0000002  STARTED
 SCAN  0000002  FINISHED
[PATTERN   001  003 NABLED,SN =  0000003   PC = R.A. ES=   1]
 SCAN  0000003  STARTED
 SCAN  0000003  FINISHED
[PATTERN   001  004 NABLED,SN =  0000004   PC = R.A. ES=   1]
 SCAN  0000004  STARTED
 SCAN  0000004  FINISHED
[PATTERN   001  005 NABLED,SN =  0000005   PC = SOL. ES=   2]
 MAN.STRT.REQ
 /STRT
 SCAN  0000005  STARTED
 SCAN  0000005  FINISHED
[PATTERN   001   DONE ]
```

FIGURE 8(a)

An example of generating and executing a scan pattern

([ ]-optional lines, removed by OPSW#0)

```
[PATTERN   002  001 NABLED,SN =  0000006   PC = R.A. ES=   1]
 /CPSP
 SP =  0001  1 -1  1 -1  2  0  0  0
 SCAN  0000006  STARTED
 SCAN  0000006  FINISHED
[PATTERN   002  002 NABLED,SN =  0000007   PC = R.A. ES=   1]
 SCAN  0000007  STARTED
 SCAN  0000007  FINISHED
[PATTERN   002  003 NABLED,SN =  0000008   PC = R.A. ES=   1]
 SCAN  0000008  STARTED
 SCAN  0000008  FINISHED
[PATTERN   002  004 NABLED,SN =  0000009   PC = R.A. ES=   1]
 SCAN  0000009  STARTED
 SCAN  0000009  FINISHED
[PATTERN   002  005 NABLED,SN =  0000010   PC = SOL. ES=   2]
 MAN.STRT.REQ
 /STRT
 SCAN  0000010  STARTED
 SCAN  0000010  FINISHED
[PATTERN   002   DONE ]
 ALL PATTERNS DONE

 /CPSP
 SP =  0000  1 -1  1 -1  2  0  0  0
 /S.P.99
 /CPSP
 SP =  0099  1 -1  1 -1  2  0  0  0
```

FIGURE 8(b)

The continuation of the scan pattern example in 8(a)

At enable time, the criterion that is used to differentiate a single scan from a scan pattern is the pattern count M. If M is not zero a pattern of 1 to 8 elements is assumed and it will be executed accordingly. If M is zero, the single scan mode is used, which in effect causes the active event schedule to be executed as a scan pattern of one element with a pattern count of M = 1. Therefore, the operator can get out of the pattern mode by clearing the scan pattern with an S.P. command that has no arguments.

Any scan element either in the pattern or single scan mode can be taken again by typing

/REDO (CR)

before that scan has finished. When the new scan is completed the pattern will continue as before. In some cases the operator is unable to use REDO soon enough because the next scan (say N + 1) in the pattern is enabled before he realizes that scan N was faulty. When this occurs he should type

/REDO D1 (CR)

which will cause the pattern sequence to be stepped back one position to scan N providing that:

(a) the system is still enabled (i.e., scan N was not the last element of the last pattern)

(b) the currently active scan element (N + 1) has not executed a start event

(c) argument D1 is not equal to zero.

With the command ABRT the pattern sequence is terminated and must be reset by an NABL or RESP command if the operator wishes to use the pattern again.

This section contains a brief discussion on the interdependence of the receiver frequency, the antenna scan rate, the sampling interval and the filter setting, and is intended as a guide to assist the operator in choosing values for these parameters. Since the scans on the data tape are readily digestible (by a computer), the astronomer may try data processing methods that he had not planned for when the data were taken. Therefore, care should be taken when specifying the data acquisition parameters to make sure that all the signal information is retained and that it is not contaminated by the sampling process.

Figure 9(a) illustrates the shape of the signal spectrum and the maximum signal frequency is given by

$$F_o = \frac{R\ D}{\lambda} \quad \text{(Hz)}$$

where R is the scan rate in radians per sec

D is the antenna diameter

λ is the observing wavelength.

A more useful relation for the 46-meter telescope is

$$F_o = 1.33\ \frac{r}{\lambda} \quad \text{(Hz)}$$

where r is the scan rate in degrees per minute

and λ is in centimeters.

Scans in HA, RA or AZ also require a cosine correction that can be applied automatically by using the SPBX instruction that is described elsewhere in this section.

Prior to recording, the signal and the much wider bandwidth noise are passed through a filter whose cut-off frequency (F_c) would be set near F_o in order to yield the

maximum signal-to-noise ratio. The exact filter setting will depend on a number of factors.

For weak signals the tendency in some applications such as search scans, where only one scan is displayed, might be to narrow the filter in order to emphasize the lower part of the band where the signal is stronger than the noise. This technique is not recommended when the data are recorded on magnetic tape because further processing may require all of the energy in the signal band. For example, the point by point integration of scans can bring the higher signal frequencies out of the noise if this energy has not previously been removed by the filter. Therefore, the first rule should be:

$$F_c \geq F_o \qquad (1)$$

Most astronomers will not be cramped by this rule because F_c is normally increased to from 2 to 5 times F_o in order to separate impulse noise from true sources. In sampled data systems there is a danger in opening the pre-sampling filter too much because the energy that it passes (base band) is mixed with the sampling frequency and its harmonics. The energy that is aliased back into the base band is illustrated in figure 9(a) and it cannot be removed by further processing. With an ideal filter the sampling rate should be at least twice the filter cut-off frequency. For the 5-pole filters that are used at ARO this ratio must be increased to the point where the aliased energy is not a significant part of the base band energy. In order to reduce the aliased energy at F_o by 20 db (> 20 db at lower frequencies) a ratio of $F_s/F_c = 3.5$ can be derived from the

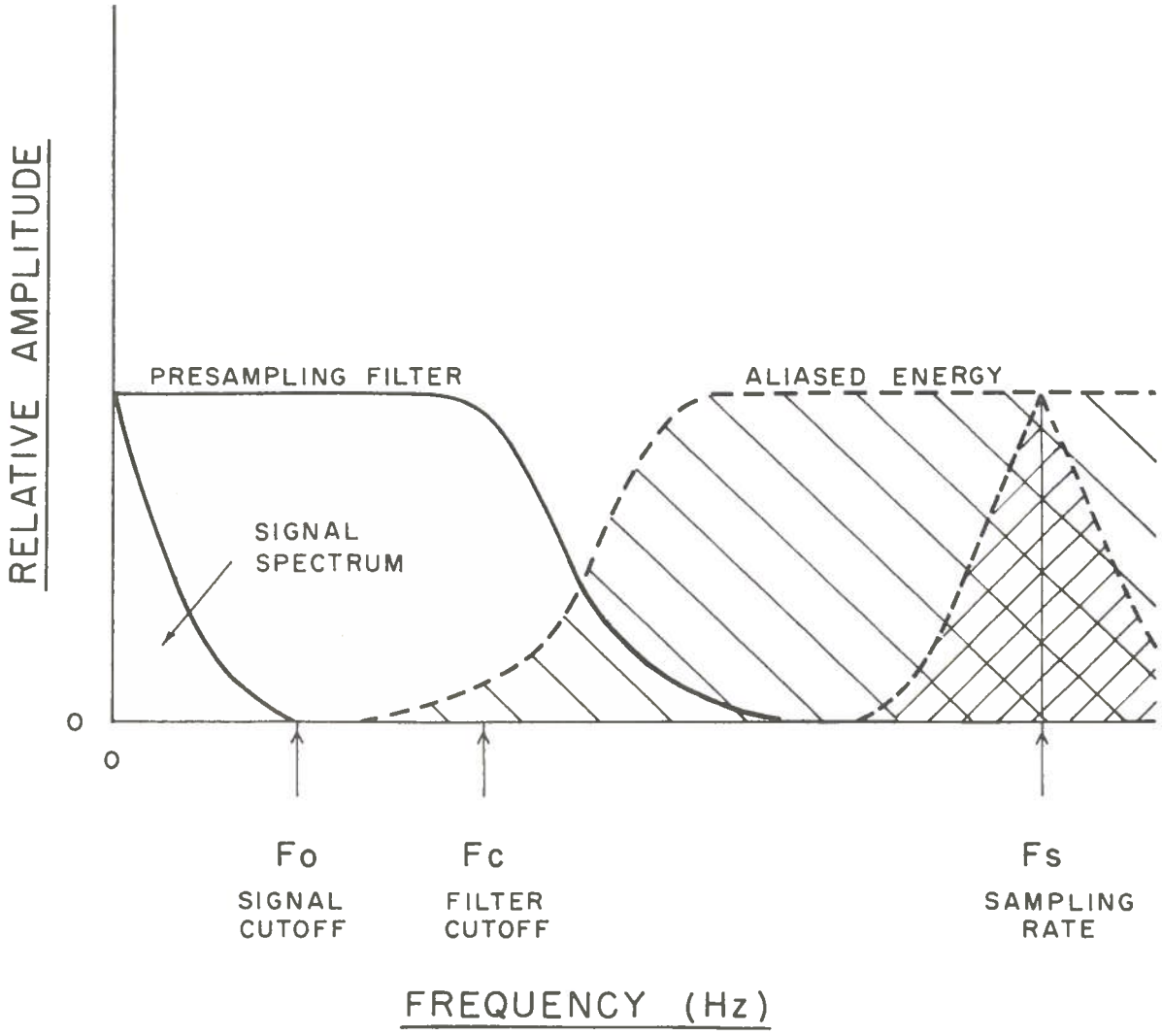


Figure 9 (a) Signal, filter and sampling frequencies

filter characteristics in Appendix I. Therefore, the second sampling rule should be

$$F_s \geq 3.5\ F_c. \qquad (2)$$

The sequence that the operator usually follows when specifying the sampling parameters begins with the sample interval. If the command SI.X is used the sample interval will be an increment of the P coordinate and will not change during acquisition. The SPBX command, however, will generate a sample interval in terms of the antenna beamwidth in a great circle plane of the P coordinate. When the scan is enabled all SPBX-generated sample intervals are divided by cos δ for HA and RA scans (sin ZA for AZ scans) in order to keep the samples per beamwidth constant. The value of declination (ZA) at the time of enabling each scan is used in these corrections.

Next, the operator will choose a scan rate. This value is not normally entered into the computer since the sampling algorithm of the data acquisition phase (Appendix M) is independent of the control mode and is based primarily on position data and not velocities.

The command RATE, however, will allow the operator to input to the computer the proposed rate in order to see what the acceptable filter range would be if the active event schedule was enabled. From the scan rate that is specified in the argument of RATE (millidegrees per minute), from the first sample interval that is found in the active event schedule, and from the current coordinate values if necessary (SPB-defined sample intervals), the computer calculates the minimum and maximum filter cut-off frequencies based on

sampling rules (1) and (2). In order to calculate F_o, the computer relates the maximum sampling interval to the beam-width by a factor of 2.5. This ratio was found to range from 2.1 at 9.4 cm to 2.6 at 2.8 cm.

If the calculated filter range is positive the operator can select the appropriate filter setting within this range (see Appendix I). If the acceptable filter range is negative, the operator should decrease the sample interval (i.e., increase F_s) until $F_s \geq 3.5\ F_o$. Note that changing the scan rate will not effect a positive filter range because F_s and F_o will be scaled in the same ratio.

When the sampling rate is much higher than it needs to be, according to the pre-sampling filter bandwidth, the capacity of the monitor program that handles the delay in sampling the analog sources is exceeded (see Appendix M). The result will be the loss of one or more samples and the alarm message 'TIMQFUL' will be typed. For realistic ratios of F_s/F_o (eg. 2-20) this problem should not arise.

These procedures and the use of RATE are only meant as guides to assist the operator. Each astronomer can do his own thing to arrive at values for these sample parameters, but for reasons already given he should try to satisfy the two sampling rules that are stated in this section.

The magnetic tape that is mounted on tape drive no. 0 is called the system tape because it contains the programs that constitute the basic data acquisition system. The system tape can also be used to store subroutine libraries and the observer's modules.

Each program on the system tape is identified by a four-letter name that is written in a preceding identification block. The system programs are of three types:

(1) System programs (absolute)

(2) Observer's modules (absolute)

(3) Subroutine libraries (relocatable)

Five system programs are located at the beginning of each tape (i.e., after the load point marker) and are in the following order:

SMON - the monitor program

SGEN - the system generator

SREL - the relocatable loader

SLDR - the modified loader

SMAP - a memory map (for reference only)

When the bootstrap loader is executed it rewinds tape drive no. 0, loads the first program (SMON) and starts it running. In the two-stage process of system generation, the programs SGEN and SREL (or SLDR) are loaded and executed in sequence.

Each system tape will contain four subroutine libraries in the following order:

(1) LIBA - data acquisition programs for 1, 2, and 3 data streams

(2) LIBB - scan averaging programs AANGRT and QLNGRT (by D. Bradt)

(3) LIBC - AA and QL subroutines (by L. Higgs)

(4) LIBD - Fortran and machine-coded libraries (SEL modified) plus various utility programs.

The contents of each library are listed in table 10.1.

The last entry on each system tape must be an identification record with the name NOMO which is used to indicate that there are no more programs on the tape. Subroutine libraries and observer's modules are added by writing over this identification record and then appending it to the end. Therefore, when the system tape programs are listed by the command PRGS the format should be:

```
SMON
SGEN
SREL
SLDR
SMAP
LIBA
LIBB
LIBC
LIBD
 .          Observer's modules
 .               and
 .          Subroutine libraries
 .
NOMO
```

In the first stage of system generation (see section 6) the operator causes requests to be placed for the data acquisition programs and the AA and QL subroutines. These programs must be in one of the relocatable libraries on the systems tape or available for entry from the paper tape reader during the loading stage. Programs from the libraries (LIBX) are found and loaded automatically if they have been requested. In order to locate the libraries on the system

tape each must be given a name that begins with LIB. Since system tapes are generated that contain all the data acquisition programs for all data streams in a library called LIBA that is located after SREL, the operator is usually unaware of the requests for, and the loading of these programs.

Frequently used processing subroutines in addition to those found in LIBC can be added together to form a new relocatable library (LIBE for example) which will relieve the operator of loading the paper tape versions each time that a new system is generated. A procedure for creating a relocatable library on the system tape by using the SEL executive is outlined in Appendix N.

An observer's module can be added to the system tape by using the DUMP command after a system has been generated. First, the computer will check all the identification blocks on the system tape to see if the name that the operator has assigned to the new module has already been used. This means that the name given to an observer's module cannot be:

(a) one of the system names

(b) a name beginning with LIB

(c) NOMO

(d) one of the names given to a previous module.

If the new name meets these requirements, the module will be dumped by writing over NOMO and a new NOMO record will be put at the end.

All observer's modules and libraries beyond any point on the system tape can be deleted by moving the NOMO identification record ahead to this position. The sequence of SEL executive command that should be used to move NOMO is listed in Appendix N.

10-4.0 THE SYSTEM TAPE

Each user will work with libraries and observer's modules that suit his own needs or the needs of the observing program that he is associated with. Therefore, the best approach to system tape distribution would be to assign to a user (or an observing program) a virgin system tape on which he can build a set of observer's modules. The AA and QL subroutines that are written by various users are documented and made available in the AQ library. Individual programs from this library can be distributed as paper tape object programs which the user can load at generation time or put into a relocatable library on his system tape.

The process of creating a system tape from a master library tape is called monitor generation and is described in a separate report (8). A new system tape can be generated by the computer personnel at ARO in a few minutes.

LIBA

DSP1	DSP2	DSP3
ASP1	ASP2	ASP3

LIBB

AANGRT	QLAVG7	AAAVG4
QLNGRT	AAAVG5	QLAVG4
AAAVG7	QLAVG5	AAAVG3

LIBC

QLPOLA	AAPANG	QLNOIS	RXNUMB
QLPOLR	QLLYNC	QLONF1	RXMODE
AASCVM	QLLYNE	RMSOF	RXFILT
AASCAV	QLFSET	QLONOF	QLRADW
QLSPCQ	QLBEAM	QLPOSN	QLRCRD
QLSPCR	QLPEAK	QLPSC8	QLPTCH
QLDLYC	QLDCTB	QLPTSC	PATCH
RMSLN	QLRATB	QLRCVR	AAPASS

TABLE 10.1

THE CONTENTS OF SYSTEM LIBRARIES LIBA, LIBB and LIBC

LIBD

DSQRT	CONJG	SIGN	COLREP
E$61	A$52	DIM	LSMATR
E$26	S$52	FLOAT	MATRIX
E$62	M$52	E$11	FPIN
E$66	D$52	IABS	FPOP
DCOX	C$25	MOD	PTEN
DSIN	CMPLX	ISIGN	SBDTA
DATAN2	A$55	IDINT	SQRT
DATAN	S$55	IDIM	C$12
DLOG10	M$55	MAXO	A$22
DLOG	D$55	MAX1	S$22
DLOG2	N$55	MINO	M$22
DEXP	AIMAG	MIN1	D$22
DMAX1	E$21	IFIX	C$21
DMIN1	E$22	C$61	L$22
DMOD	TANH	INT	H$22
DINT	COS	I$WT	N$22
DABS	SIN	CVRA2E	F$ER
DSIGN	ATAN2	CVRE2A	ARG$
A$62	ATAN	CAA2EQ	RTN1
S$62	ALOG10	CEQ2AA	F$PA
M$62	ALOG	ATANFX	D$WR
D$62	ALOG2	DEC2BF	O$WR
DBLE	EXP	DF2DEC	SBDTA
C$26	AMAX0	DROOT	FASTFT
E$51	AMAX1	DEC2BF	INVSFT
CCOS	AMINO	BF2DEC	INITFT
CSIN	AMIN1	LSM4X4	DINR
CLOG	AMOD	DET4X4	DOTP
CEXP	AINT	INTCOL	DOPT
CSQRT	ABS	INTROW	DROOT
CABS			

TABLE 10.2

THE CONTENTS OF SYSTEM LIBRARY LIBD

General

Data acquired by the ARO data acquisition system will be recorded on seven-track magnetic tape in IBM compatible format. The digital tape is currently being recorded at low density* (200 characters per inch), odd parity, and with 4 characters on tape representing one 24-bit computer word.

Each scan will begin with a scan header block. Data blocks will be written when a fixed number of data samples has been acquired. Each scan will be terminated by a scan trailer block, and an end-of-file mark. Each data tape is terminated with an end-of-tape block. (See fig. 11a.)

File Organization

Each file on magnetic tape consists of one scan. Each scan or file consists of:

a) One scan header block

b) A number of data blocks

c) A scan trailer block

d) An end-of-file mark

Each block on magnetic tape consists of a ten-word block header followed by the DIRECTORY in the case of the scan header and trailer blocks, and by the sampled data in the case of the data blocks. This first word of every block

* Future systems will generate medium density (556 BPI) data tapes if the error rate in reading these tapes proves to be sufficiently low. This will result in better tape utilization, by a factor of 2 to 1, and in less computer time to read the data for subsequent processing.

header is an identification code that is set as follows:

= -1 end-of-tape block

= 0 data block

= 1 scan header block

= 2 scan trailer block

a) SCAN HEADER BLOCK

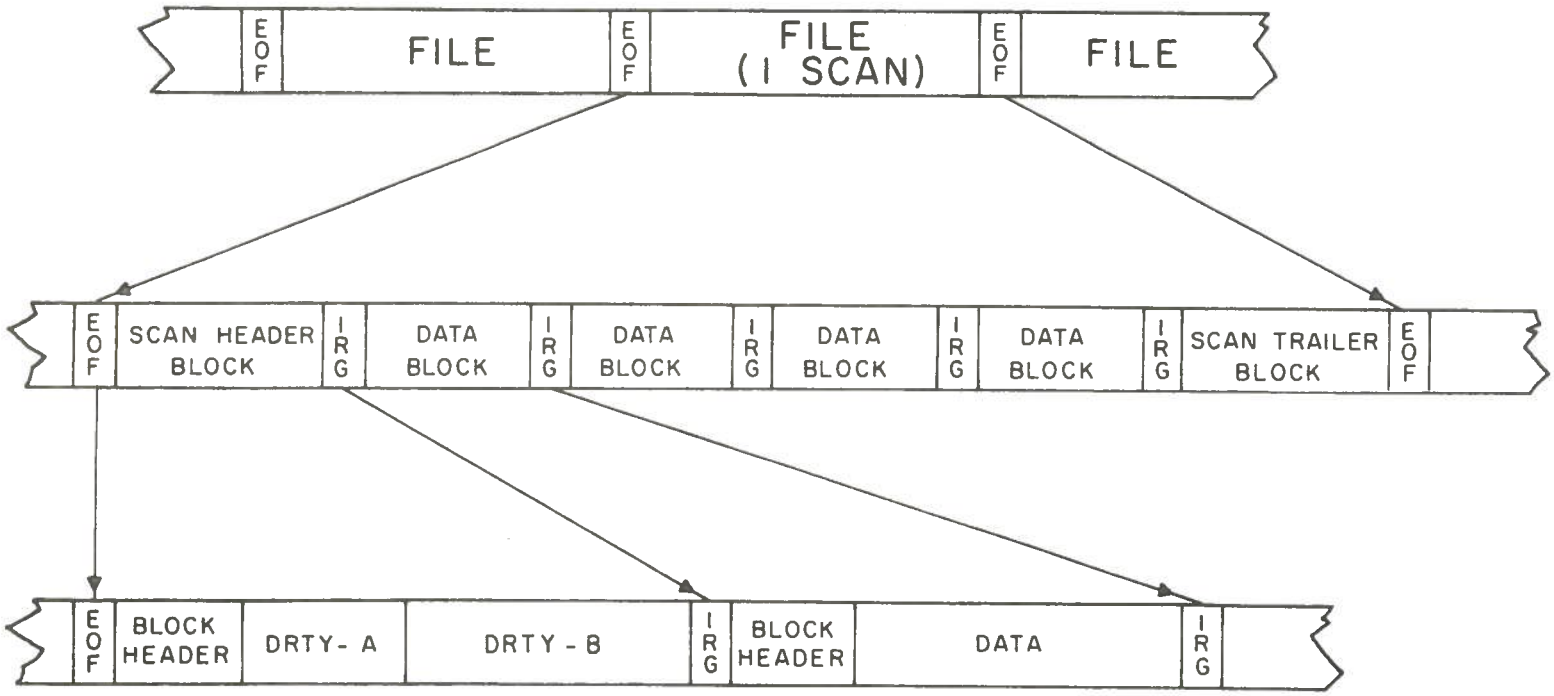
The scan header block, although one physical block on the tape, is composed of:

1) a block header
2) the DIRECTORY (A-DIRECTORY)
3) the Sample Lists (B-DIRECTORY)

Only the first word of the 10-word block header is used in the scan header block. It is a block identification code, and has the value of 1 for a scan header block.

The DIRECTORY is a list of all values which may be sampled by the data acquisition system. It contains codes that specify the astronomer, the project, the driver, the scan number, etc. More important, it contains the Q-values (the seven coordinates displayed on the console) as they were at the beginning of the scan. It also contains the values of the meteorological data which have been typed in. A complete list of the directory constants can be found in Appendix F.

The B-DIRECTORY contains mostly data relevant to the internal machinery of the data acquisition system. It does contain the sample lists, however, and the sample lists contain an entry specifying what is being sampled. The entries of the B-directory are given in Appendix K. Bits 1-8 (the 24-bit words are numbered from bit 0 to bit 23, left to right) contain an index to the DIRECTORY(part A), and therefore indicate what is being sampled. If all of the bits are on, (377_8) the



EOF - END-OF-FILE MARK

IRG - INTER-RECORD GAP

DRTY - A - THE DIRECTORY, PART A

DRTY - B - THE DIRECTORY, PART C

Figure 11 (a) The data tape format

quantity is a value calculated by an AA Subroutine.

b) DATA BLOCK

Each data block consists of a block header, and as many sample sets (data) as it takes to fill the fixed length block. The block header is ten words long, and the length of each sample set is determined by the length of the sample list (the number of variables being sampled).

i) Block Header

WORD 1 Block code. A word identifying the type of block following.
= -1 for tape end block
= 0 for data block
= 1 for scan header block
= 2 for scan trailer block

WORD 2 Data stream number. Data blocks are written on tape as soon as the data area is full. Each data stream has its own sample interval, and data area. This word (= 1, 2 or 3) gives the data stream to which this block belongs.

WORD 3 Block number. The block or record number of this data block. Each data stream maintains a separate block count.

WORD 4 The system status word, as it was at the end of this data block. See Appendix E for a description of the system status word.

WORD 5 The operator flag word as it was at the end of this data block.

WORD 6 The block length in words. (Includes the 10 words for the block header).

WORD 7 Sample set for calibration ON

WORD 8 Sample set for calibration UP

WORD 9 Sample set for calibration OFF

WORD 10 Sample set for calibration DOWN

Words 7-10 give the sample set number of any calibration events which took place during the creation of the data block.

ii) Sample Sets

At each sample interval, all variables present in the sample list are sampled and placed in the data area. When the data area has been filled, the data are output as one data block. If there are 3 variables being sampled (α β γ) then the data on tape will be:

$\alpha_1 \beta_1 \gamma_1 \alpha_2 \beta_2 \gamma_2 \alpha_3 \beta_3 \gamma_3 \cdots \alpha_i \beta_i \gamma_i \cdots$,

where each element of the list will be 1 word, or 4 characters (bytes) on magnetic tape.

c) SCAN TRAILER BLOCK

The format of the Scan Trailer Block is identical to the format of the Scan Header Block. The identification word is set equal to two, and DIRECTORY entries contain the Q values as they were at the end of the scan.

The second word of the scan trailer block contains the scan termination code:

0 - normal termination

1 - a REDO termination

2 - an ABRT termination

d) END-OF-TAPE BLOCK

This is a short 3-word block consisting of -1, -1, -1 (all bits on), and signifies the last block on the magnetic tape.

Data Word Format

Variables which are being sampled at regular intervals, or variables present in the DIRECTORIES have a format unsuitable for floating point calculations. Some type of conversion must be done. (See the section on Processing ARO tapes on the /360). All values are in the form of 2's complement integers. Analog inputs are right justified, 12 bits in significance, with the sign bit propagated through bits 0 to 11 to ensure 2's complement form. The Q-values are in the form of a binary fraction of a circle scaled to the right of the sign bit. Solar Time, Sidereal time, Right Ascension, Declination, and Hour Angle have 20-bit significance. Azimuth and zenith angle have 18-bit significance. Values calculated by AA subroutines will usually be in the same 24-bit 2's complement notation.

Recording Format

The data are recorded on IBM compatible, 7-track tape at low density, and odd parity. The blocks are variable in length, and as such are UNDEFINED. Each scan on magnetic tape is one file long consisting of a scan header block, data blocks, a scan trailer block, and an end-of-file mark. See the section "Data Tape Format" for more detailed information.

Re-formatting the data words

The primary reformatting problem is caused by the difference in word length between the two computers. The SEL 840A has a word length of 24 bits, and the IBM 360 has a word length of 32 bits. Fortunately, both computers use 2's complement integer notation. By inhibiting the BCD translator, and the byte converter during input to the IBM /360, the 24-bit words may be expanded to 32 bits, with the insertion of leading zeros in each byte. These zeros may then be shifted out. See Fig. 12a.

The conversion from Format 1 to Format 2 is accomplished by the hardware of the IBM /360 magnetic tape control unit. The conversion from Format 2 to Format 3 is accomplished by a Fortran compatible function INTCVT written in OS/360 assembly language.

Calling sequence

a) `X = INTCVT(J)` to convert J to REAL

b) `I = INTCVT(J)` to convert J to INTEGER

If (b) is used, the resultant integer may be converted to hours, degrees, or radians by means of other conversion routines. (See section "Conversion of Data" within this chapter).

Complete Scan Input Routine: (GETSCN)

An input routine has been written for the IBM /360 for the input of files or scans. This routine is composed of a number of Fortran and OS/360 assembly language subroutines. Each time this routine is invoked, an entire scan will be input and formatted for the Fortran programmer. The data are returned to the calling program through subroutine arguments, and through labeled common.

The following variables must be declared in the user's Fortran program.

```
 INTEGER  A(80,2),B(160,2)
 INTEGER  T1(3,1000),T2(500),T3(500)
 INTEGER  STIND1,STIND2,STIND3,
1         CLPTR1,CLPTR2,CLPTR3,
2         FLGPT1,FLGPT2,FLGPT3,
3         SYPTR1,SYPTR2,SYPTR3
 INTEGER  CLEVT1(2,10),CLEVT2(2,10),CLEVT3(2,10),
1         OPFLG1(2,10),OPFLG2(2,10),OPFLG3(2,10),
2         SYSST1(2,10),SYSST2(2,10),SYSST3(2,10),
3         SLTDS1(10),  SLTDS2(10),  SLTDS3(10)
 INTEGER  Z(120)
 COMMON   /STATUS/CLEVT1,CLEVT2,CLEVT3,
1         OPFLG1,OPFLG2,OPFLG3,
2         SYSST1,SYSST2,SYSST3,
3         SLTDS1,SLTDS2,SLTDS3
```

1.	SEL 840A	SXXXXX XXXXXX XXXXXX XXXXXX	24 bits
2.	AFTER INPUT TO /360	OOSXXXXX OOXXXXXX OOXXXXXX OOXXXXXX	32 bits
3.	DESIRED FORMAT IN /360	SSSSSSSS SXXXXXXX XXXXXXXX XXXXXXXX	32 bits

FIGURE 12 (a)

CONVERSION OF ONE WORD FROM SEL 840A

2's COMPLEMENT, TO SYSTEM/360 2's COMPLEMENT

```
 COMMON   /FLAGS/Z
 EQUIVALENCE (Z(1), ERROR),(Z(2),WARN),(Z(3),ABRTCD),
1            (Z(4),STIND1),(Z(5),STIND2),(Z(6),STIND3),
2            (Z(7),CLPTR1),(Z(8),CLPTR2),(Z(9),CLPTR3),
3            (Z(10),FLGPT1),(Z(11),FLGPT2),(Z(12),FLGPT3),
4            (Z(16),SYPTR1),(Z(17),SYPTR2),(Z(18),SYPTR3),
5            (Z(22),NPPDS1),(Z(23),NPPDS2),(Z(24),NPPDS3),
6            (Z(25),MODE),
7            (Z(31),MXDIM1),(Z(32),MXDIM2),(Z(33),MXDIM3)
 MXDIM1 = 3000
 MXDIM2 = 500
 MXDIM3 = 500
 ERROR = 0
 WARN = 0
 ABRTCD = 0
    .
    .
    .
 CALL GETSCN (A,B,T1,T2,T3)
    .
    .
    .
 END
```

For explanation of data in labeled common - see Appendix L.

The parameters returned in the parameter list are:

A The DIRECTORY (part A). A list of variables which may be sampled by the data acquisition system. See Appendix F.

A(i,1) contains information from the scan header block.

A(i,2) contains information from the scan trailer block.

eg. A(42,1) is the Zenith Angle at the start of the scan.

A(42,2) is the Zenith Angle at the end of the scan.

B The DIRECTORY (part B). The event schedules and sample lists are in part B of the directory. The Fortran programmer will probably not need this information. See Appendix K for a detailed description.

T1 The data array from data stream 1. If three variables were sampled, T1 should be dimensioned (3,n) where n is the maximum number of sample sets. MXDIM1 should be set to 3*n before GETSCN is called.

If the three sampled values are α, β and γ, the samples are arranged in T1:

$$\alpha_1\ \beta_1\ \gamma_1\ \alpha_2\ \beta_2\ \gamma_2 \cdots \alpha_i\ \beta_i\ \gamma_i \cdots$$

$T(1,i) = \alpha_i$

$T(2,i) = \beta_i$

$T(3,i) = \gamma_i$

T2 and T3 will contain the sampled values from stream 2 and stream 3, respectively, if they are present.

All variables are in /360 INTEGER format, 32 bits in length.

DD CARD

The DD card necessary for this routine is:

```
//GO.INPUTAPE DD UNIT=TAPE7,LABEL=(,NL),          X
//              DISP=(OLD,KEEP),DCB=(DEN=0),      X
//              VOLUME=SER=ARXXXX
```

HEADR1

A subprogram to collect and reformat scan parameters.

A subroutine has been coded in Fortran to collect and reformat the scan parameters returned by GETSCN. The combination of GETSCN and HEADR1 is easy to use and requires a minimum of variable declaration on the part of the user. All scan parameters are returned to a 100-word array HDR. This same array has three names; the name that is used depends upon the type of parameter being fetched, i.e., INTEGER*2, INTEGER*4, or REAL*4.

The coding for this subroutine has been appended to Appendix L as an example of how to use the parameters returned by GETSCN. The comments at the beginning of the listing give the parameter layout in the 100-word array. The array should be referenced:

HDR if the parameter is REAL

IDR if the parameter is INTEGER

JDR if the parameter is INTEGER*2

The following program will input the first 400 scans on a data tape.

```
      INTEGER*2  JDR(200)
      INTEGER*4  IDR(100)
      REAL  HDR(100)
      EQUIVALENCE(HDR(1),IDR(1),JDR(1))
      INTEGER T1(3,1000),T2(2),T3(2)
      INTEGER  Z(120),A(80,2),B(160,2)
      COMMON/FLAGS/Z
      Z(31)=3000
      Z(32)=2
      Z(33)=2
      DO  200  I=1,400
      CALL GETSCN(A,B,T1,T2,T3)
      IF(Z(2).EQ.3) CALL EXIT
      CALL HEADR1(HDR,IDR,JDR,A,B)
            user's scan

            processing

            statements
200   CONTINUE
      CALL EXIT
      END
```

Conversion of the Data

After the subroutine GETSCN has been invoked, the data are available to the Fortran programmer in /360 INTEGER format.

Radiometer Data Range is ± 2048

Convert this to floating point (REAL)

by: X = T(1,i)

Q-values Range is 0 to 2^{23}

Convert to time by:

X = BFTIME(A(45,1)) for the initial right ascension in hours.

Convert to degrees by:

X = BFSPAT(A(43,2)) for the final declination in degrees.

Convert to radians by:

X = BFRADN(A(42,1)) for the initial zenith angle in radians.

The peak demand on the ARO computer occurs when its environment requests simultaneous attention on all interrupt lines. Although this condition rarely occurs, the computer must have the capacity to service these demands within a specified time. Over long periods the average drain on the computer is about 15% of its capacity for most data acquisition jobs. Additional computer time will be needed when processing subroutines are included but the total time is not likely to exceed 30%. The unused CPU time is spent in an idling loop which checks all memory locations for a parity error and also, with the aid of the sidereal clock, calculates the fraction of CPU time that is used by the data acquisition job. During this program the memory addresses that are being tested can be seen to ripple through the T and A registers at several cycles per second.

In order to put the free CPU time to better use, a background facility was built into the monitor by which a second operator can load, dump, and execute programs in the core memory not used by the data acquisition system (foreground program). These background programs can be used to:

(1) process some of the data from previous scans
(2) assist the foreground operator in such areas as coordinate conversion or pointing error corrections
(3) develop foreground or background programs
(4) monitor the foreground system.

One of the teletype units (keyboard and printer) is assigned as the background command device and is the means by which the operator communicates with the background system. The high-speed paper-tape unit (punch and reader) is also

available but it must be shared with the foreground user during the second stage of system generation, and possibly when certain AA or QL subroutines are used. The background system will also be capable of using the I/O features such as discrete and analog inputs and outputs (see appendix D) that are not assigned to the foreground user.

Hardware options in the CPU and some associated monitor programs prevent the background program and operator from interfering with the execution of the foreground job. The background user may request and get the portion of the core memory that the foreground does not require. From 0 to 6000_8 memory locations will be available depending on the number of data streams and the processing programs that are used in the data acquisition job.

Fourteen commands are available to the background operator and these are listed in section (B) of Appendix B. The format rules that apply to these commands are the same as those of the foreground command language, with the exception that all arguments are interpreted as octal and not decimal numbers. Before loading a background program the operator must request the core that he wishes to use by the CORE command. If the foreground programs exceed the address that is specified the reply 'CORE USED TO XXXXX' will be typed to indicate where the foreground limit is, and that his request for core has been denied. If, during the loading or generation of a foreground system, the core memory that has been assigned to the background user has been expropriated, the message 'FGD. USED TO YYYYY' will be typed and any background program that was running will be terminated.

The background memory can be loaded from the keyboard

with KEIN and a program or a data tape that was dumped in the SEL absolute format can be loaded from the high-speed reader with the LOAD command. Relocatable object tapes that the assembler or compiler generate must be entered by first loading and executing a version of the relocatable loader that has been adapted for use in the background area.

Each time that the computer services all the current demands of the foreground job, control returns to one of the following programs:

(1) the idle loop

(2) the background program

(3) a foreground program that runs as a background job in order to execute a series of tape commands (LOAD, DUMP, NEWS, PRGS)

The background operator can select modes (1) or (2) but he has no control over (3), the highest priority mode. When the foreground substitutes one of its tape subroutines (3) in place of the background job, the operator is warned with the message 'BGD.HOLD'. In this condition a background program cannot be executed but the other commands such as LIST are available. The message 'BG.ACTIV' is typed when mode (3) terminates and control is returned to either (1) or (2) at the point at which it was suspended.

A background program is started (mode (1) to (2)) with a GOTO command in which the arguments specify the starting address and the contents of the registers prior to the execution of the first instruction. The command PAUS will terminate a background program (mode (2) to (1)) but the contents of the registers (status) are saved and the program can be re-started at the same point with CONT. When the

background program tries to execute an instruction that will interfere with the foreground programs it is aborted by switching to the idle loop and the status of the background program at the time of the violation is listed for the operator.

The contents of any contiguous memory locations (except 0) can be listed on the background device in octal by LIST and in decimal by LISD. A zero argument in these commands will cause the current status of a running, suspended (PAUS), or an aborted background program to be listed. Long listings can be terminated prematurely with the command QUIT. The command DUMP will put the contents of the memory locations that are defined by arguments 1 and 2 onto paper tape in the absolute format that LOAD or the SEL executive can use.

An intentional exit from the background program, which causes the status of the program to be typed, is called a breakpoint and can be inserted with the BKPT command. The previous instruction at the address defined by the argument is saved and a new instruction (CALL CHECK) is inserted. Only one breakpoint is available but the repeated use of BKPT will move it around and also restore the original instruction at the previous breakpoint address. The original instruction at the last breakpoint can also be restored with the RSBP command.

The command CMAP is used to get the core map of certain monitor programs plus all of the programs that comprise the currently resident observer's module. TINT is used to initialize all teletype and paper tape devices so that they may be turned on and used while the computer is running.

The following foreground utility subroutines are also available to the background program:

(1) IOCS (305) - Input/output control system (for background devices only)

(2) CHECK (362)- Checkpoint (to terminate a background job)

(3) BGNDIO(363)- Analog and discrete I/O (for background facilities only)

(4) SINFX (367)- Fixed point sine

(5) COSFX (370)- Fixed point cosine

(6) AU2BIN (372) - A.U. to binary conversion (Table B.1)

(7) BIN2AU (371) - Binary to A.U. conversion (Table B.1)

The ARO program library will contain descriptions and listings for these programs. The octal addresses in parentheses indicate the memory location at which the background program can pick up the SPB instruction (see assembler manual) that will link each utility subroutine. These instructions must be brought into the background program and executed by a sequence similar to:

```
      LAA   '367
      STA   SINX+1
            .
            .
            .
      SPB   SINX
            .
            .
            .
            .
            .
SINX  ZZZ   **
      ZZZ   **
      BRU*  SINX
```

Even with these utility subroutines the amount of core that is available will probably limit the background user to short programs. For example, in order to load a relocatable object tape 1300_8 words must be available for the relocatable loader alone. The probability of being able to assemble a program (about 4400_8 locations) is just about nil, and the compiler cannot be used at all unless additional memory is acquired. If full control is implemented the background area will disappear and the AA and QL processing subroutines will be limited to a few short programs.

The background user can access data from the foreground directories by using the A-directory address that is contained in location '373.

A complete description of the background facilities and some utility programs will be issued in a separate report, (Ref. 7).

14. ACKNOWLEDGEMENTS

This report describes one phase in the procurement of the hardware and software systems for data acquisition and control of the radio telescope. The authors received valuable assistance from Mr. S.G. Jones of the Data Systems Section who supervised the overall project. We are also indebted to Dr. L. Higgs of the Radio Astronomy Section for his suggestions concerning the operating procedures and for his work on the Glossary of Common Terms.

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8. ARO/Data Acquisition Monitor Maintenance Manual (NRC/ERB-817)

9. ARO/Input/Output Control System Maintenance Manual (NRC/ERB-812)

10. ARO/DATAC System Maintenance Manual (NRC/ERB-818)

11. ARO/Command Language Maintenance Manual (NRC/ERB-819)

12. ARO/Input/Output Control System Users Manual (NRC/ERB-813)

13. ARO/System Generator and Loader Maintenance Manual (NRC/ERB-820)

14. SEL Fortran Compiler (Modified) ARO Program Library # ARO-033

15. ARO/SEL Executive System (Version B) to be documented.

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17. A Program for Magnetic Tape Input and Control on the IBM 360 (NRC/ERB 811)

GLOSSARY OF COMMON TERMS

A-DIRECTORY: A table listing all possible inputs the astronomer may request to be sampled. The elements of the table are referenced by their sequence number or sample index (see Appendix F).

ABORT: To abnormally terminate a scan or an observing sequence.

ABSOLUTE MODULE: A complete section of coding or data, that, when loaded into the computer, must start at a fixed address.

ABSOLUTE START: The normal start mode in which data acquisition will begin when the P coordinate reaches the start position defined by the event schedule.

ACCUMULATOR: A hardware register in the computer used for arithmetic operations. It consists of two 24-bit registers (A and B).

ALARM: A warning to the operator that one or more of a group of status conditions that are tested periodically has been found in an abnormal condition (see Appendix E).

ALARM STATUS: The computer word defining the current result of all the alarm tests. This word is available to the data logging system (see Appendix F).

ANALOG INPUT: A facility which allows analog information to be input to the computer. The analog signal is sampled by an analog-to-digital

converter and the information is read in to the computer in digital form.

ANALOG OUTPUT: A facility which allows digital information in the computer to be output in analog form. This is accomplished by a digital-to-analog converter.

ANALOG SAMPLE: This is a sample (see sample) of an analog signal which is external to the computer.

ASSEMBLER: An SEL system program which accepts nmemonic coding and produces a relocatable object tape. There is a one-to-one correspondence between mnemonic assembler instructions and machine language instructions.

ASTRONOMER'S UNITS: Either the units of angle (degrees, minutes, seconds) or time (hours, minutes, seconds) which are used by the astronomer. The computer will use the shaft encoder units, i.e., binary fraction of circle, and where necessary the computer will convert between the two systems. (See Binary Fraction of a Circle.)

B-DIRECTORY: A common data area that contains all event schedules, sample lists, and the scan pattern.

BACKGROUND: The job to which the computer can be applied after it services all demands of the data acquisition program. It cannot be a real-time job.

BACKGROUND COMMAND: An input via the background command device which allows the background operator to

load, execute, and terminate background programs.

BACKGROUND COMMAND DEVICE: The teletype at which commands may be typed in the background command language, and which may be assigned at start-up via the CPU console switches.

BACKGROUND LOGGING DEVICE: The teletype at which all messages to the background user are logged.

BINARY FRACTION OF CIRCLE: An angular representation in binary form where 1.000 (base 2) = 360^{o}. In the data acquisition system this representation is used in words of length 12, 18, or 20 bits. In the 20-bit representation, the smallest angular increment is $2^{-20} \times 360^{o}$.

BLOCK: A specified number of successive computer words. This can be in memory or any other storage device and is frequently used when describing information transfers. (see data block)

BLOCK HEADER: A specified number of successive computer words which usually precedes (in serial situations) a block and which contains information pertinent to handling of the block (e.g., block length).

BOOTSTRAP LOADER: A small, simple program which will input (in absolute form) a larger, more complex program, and begin execution of the program once loaded. The ARO bootstrap is contained within the MONITOR and will load itself and

the monitor. The SEL bootstrap can also be used (see Appendix C).

BREAK POINT: The location of a command that has been inserted in a program that is being debugged, which will cause the status of the CPU at that point to be listed.

C-DIRECTORY: A common data area used to pass control and status information to the various programs.

CALCULATION SUBROUTINE: A subroutine tailored for a specific observing program which operates in an on-line manner on the sampled data (e.g., scan averaging). The output from the subroutine is stored on magnetic tape in the sample set.

CALIBRATION ON: One of the events in an event schedule. This refers to the automatic turning-on of a receiver calibration by the computer.

CALIBRATION OFF: As above but refers to the automatic turning-off of a receiver calibration.

CALIBRATION PHASES: There are four phases which comprise a calibration: Phase 1 begins when the calibration-on event is executed, Phase 2 begins when the desired calibration level has been reached, Phase 3 begins when the calibration-off event is executed, Phase 4 begins when the signal is back to its baseline level.

CALLING SEQUENCE: A description of the method in which parameters (arguments) and control are passed to, and returned from a subroutine. Control is passed to an ENTRY POINT of the subroutine.

CHECKSUM: A simple redundancy check that is transferred with data. For example, programs that are on paper tape in either the relocatable or absolute format contain checksums at regular intervals which are tested during loading.

CLOCK: Periodic pulses from an external source used by the computer to regulate programs; possibly by integration to form an internal time function. In the data acquisition system, 1-kHz pulses from the sidereal oscillator chain are used to regulate time dependent functions to within 1 ms.

COMMAND AND STATUS PANEL: A panel that is mounted above the chart recorder (fig. D.5) that can be used by the operator as an alternate command device. Twenty-four of the most frequently used commands can be initiated by push buttons on the panel. The status of the system is also displayed on lamp indicators.

COMMAND DEVICE: The input device that the operator uses to communicate with the computer.

COMMAND LANGUAGE: The set of instructions that the operator can use to control either the foreground or background job.

COMPILER: An SEL system program which will input Fortran language (one instruction in the language will usually generate more than one machine language instruction) and output a relocatable binary tape containing the machine language instructions.

GLOSSARY

CORE MAP: A list of subroutine names and the addresses at which the routines have been loaded in the core memory.

CPU: The central processing unit, or the computer itself.

CR: Carriage return

CUSTOM BUFFER: The custom hardware which serves as the interface between the computer and the real world. It contains the analog input/output and digital input/output hardware.

DATA BLOCK: A block composed of a number of sample sets (see sample sets) which is recorded on magnetic tape.

DATA INDEX: See Sample Index

DATA STREAM: The data acquisition system allows the sampling and recording of three different sample lists with different sample intervals, during a given scan. The sequence of data corresponding to each sample list is referred to as a data stream. This facility permits sampling of various quantities to proceed at different sampling rates.

DATA TAPE: The magnetic tape on which the sampled data are stored.

DATAC PROGRAMS: The programs which perform the data sampling and storage on magnetic tape and which also control the data processing (AA or QL) subroutines.

DELAY (CALCULATION SUBROUTINES): The delay, expressed as a number of samples, between the input argument

and output argument for a calculation subroutine. In general if the i^{th} sample is the input to the calculation subroutine, the immediate output will be the calculated argument corresponding to the $(i-n)^{th}$ input sample. The calculation subroutine delay is then n samples. Calculation subroutine delays will most often be found in digital filtering and similar applications. (See also FILTER DELAY.)

DENSITY: The number of characters per inch written on magnetic tape. Three densities are available:

1) LOW (200 char/inch)
2) MEDIUM (556 char/inch)
3) HIGH (800 char/inch)

The normal density for data tapes will be low.

DIRECTORY: A memory table by which data are passed between programs. (See also A-DIRECTORY, B-DIRECTORY, C-DIRECTORY.)

DISCRETE EXTERNAL SAMPLE: A sample (see sample) of a digital signal which is external to the computer.

DISCRETE INPUT: A facility which allows external signals in digital form to be input to the computer.

DISCRETE INTERNAL SAMPLE: A sample of the contents of any memory location in the computer.

DISCRETE OUTPUT: A facility for transferring signals in digital form from the computer to the outside world.

GLOSSARY

ENABLE: To initialize the data acquisition system and to start it searching the active event schedule for jobs to execute. Sampling does not begin until the enabled system executes a start event or gets an immediate start command.

END-OF-FILE (TAPE MARK): A special record written on magnetic tape to separate groups of records. This facilitates rapid searching of magnetic tapes.

END OF TAPE MARKER: A strip of aluminum foil fastened fourteen feet from the end of a reel of magnetic tape. This allows the computer to detect the end of a magnetic tape without running the tape off the reel.

ENTRY POINT: The instruction or address of a sub-program at which execution of the sub-program will begin.

EVENT: A special function which is performed or is to be performed by the data acquisition system at a predefined P coordinate. The events the system recognizes are: start, stop, calibration-on, and calibration-off.

EVENT SCHEDULE: A list of events which are to be executed during a scan. Each event is defined by a mnemonic and the P coordinate at which the event is to be executed.

EXECUTIVE: The SEL EXECUTIVE is an SEL system program which will load and execute the Fortran compiler, the assembler, the loader, and other

SEL system programs. It is not compatible with, and cannot be used at the same time as, the data acquisition software.

FILE: A file on magnetic tape is that information between two consecutive end-of-file marks, or in the case of the first file, the information between the load point and the first end-of-file mark.

FILTER DELAY: This is the time delay in an analog signal due to the pre-sampling filter between the receiver and the computer. (See Appendix I)

FLAG: A coded message that can be tested by another program or part of the system. The "operator's flag" can be used to note on the data tape that a certain event has been detected in much the same way as the astronomer writes on a strip-chart record.

FOREGROUND: The prime function of the system (i.e., data acquisition) which is given priority over the background.

FOREGROUND COMMAND: An input via the foreground command device which allows the operator to control the data acquisition system.

FOREGROUND COMMAND DEVICE: The teletype unit at which foreground commands may be typed, and which may be assigned at start-up via the CPU console switches.

HEADER: A specified number of successive units of data on a storage medium that precede a group of words, a table or list which contains parameters pertaining to the data that follows.

IDENTIFICATION BLOCK: A header of ten words plus the contents of the A and B directories, which is written on the data tape at the beginning of every scan.

INDEX REGISTER: A hardware feature in the CPU used for address modification and counting purposes.

INITIALIZE: Presetting a program (data areas or constants, etc.) to a condition from which the program may begin operation.

INSTRUCTION TRAP: A hardware feature in the CPU which will inhibit the execution of certain instructions by the unprotected (background) user which could disrupt the foreground job.

INTERRUPT: See PRIORITY INTERRUPT

IOCS: Input/output control system. A group of routines which schedule and supervise all I/O operations to and from the standard peripheral units.

LIBRARY: One or more relocatable (object) binary tapes grouped together as one paper tape, or one file on the system tape.

LIST LENGTH: The number of quantities in a sample list.

LOAD POINT: A small piece of aluminum foil about 12 feet from the beginning of a reel of magnetic tape. It is sensed by a photocell during rewind and backspace operations and marks the beginning of the usable portion of tapes.

LOGGING DEVICE: The printer unit of one of the teletype devices that is used to generate a hard copy of commands and replies.

MEMORY MAP: A memory map or core map is a list of sub-routines which have been loaded, followed by the entry point address of each routine.

MEMORY PARITY: Each computer word is 26 bits long. The 25th bit is the logical single-bit sum of the first 24 bits. Each time a word is referenced, this sum is computed and checked with the parity bit there. If it differs there is an error, and the memory parity interrupt is raised.

MEMORY PROTECT: The 26th bit of each computer word determines whether or not this is a protected location. When memory protect is turned on, it is impossible to execute or modify protected locations. Thus the background user can be prevented from modifying foreground programs.

MNEMONIC: An alphabetic symbol for a numeric code or operation. A mnemonic is usually easier to recognize and use than a numeric code.

MONITOR: The set of programs that provide the basic services for the foreground and background

jobs, such as IOCS, command language, foreground and background status, clocks, etc.

NON-RESIDENT: A program that is not in the core memory.

OBJECT MODULE: A program or group of programs in relocatable binary format. (The output from the assembler or Fortran compiler.)

OBSERVER'S MODULE: The set of programs that have been generated to perform a specific data acquisition and processing function. Each is assigned a unique name and can be stored onto and loaded from the system tape.

OCTAL NUMBER: A number to the base 8. The 24-bit contents of any memory location in the SEL 840A may be represented by an eight-digit octal number.

OPEN SCAN: A scan whose vector cannot be calculated because of the absence of a STRT or STOP event.

OPERATOR FLAG: An entry in the A-DIRECTORY the contents of which can be sampled and put on the data tape. The operator can set the flag to any number to notify later stages of processing that a particular event or condition was observed.

OPERATOR'S SWITCHES (OPSW): A set of 24 toggle switches that the operator can use to control various functions (see Appendix D).

OUTPUT AREA: A predefined area in memory which is used to accumulate the sampled data in block form prior to recording on the data tape.

OVERLAY: A program or subroutine not resident in core, but read in from the system tape (or elsewhere) when needed. It overwrites an existing program. The System Generator, and System Loader are overlays.

P-COORDINATE: The Q value in terms of which the data sampling is defined and events are scheduled.

PARITY: A redundant bit of information used to detect errors in the reading and writing of binary data.

PHYSICAL UNIT NUMBER: A fixed number by which the CPU designates a given peripheral device.

POWER FAIL: An option on the computer which warns the program when the power has started to fail, and allows the status to be saved before the memory is shut off.

PRIORITY INTERRUPT: The hardware that permits an internal or external signal to interrupt the current computer program (if it is of lower priority) and cause another program to be executed. The new program "services" the interrupt request, turns it off when completed and returns control to the previous job.

PROCESSOR: (a) Hardware - the main part of the computer, (b) a program dedicated to executing one function such as servicing an interrupt request.

PROGRAM COUNTER: A register in the CPU which points to the memory address from which the next instruction will be taken and executed.

Q VALUE: A coordinate quantity from the telescope raksyn hardware or the feed angle encoder. The eight Q values are Polarizer Angle, Zenith Angle, Azimuth, Declination, Hour Angle, Right Ascension, Sidereal Time, and Solar Time.

QUEUE: A list of events or requests awaiting action. Computer programs work on these events or requests either sequentially, or according to some priority determined by the parameters of the job waiting in the queue.

QUICK-LOOK DEVICE: A device used for outputting or displaying quick-look data (the output from a quick-look subroutine).

QUICK-LOOK SUBROUTINE: A subroutine tailored to a specific observing program which operates in an on-line manner on the sampled data. The output from this subroutine is available in printed, punched or graphical form but is not recorded on the data tape.

READER: A device for inputting paper tape. Usually refers to the high-speed photoelectric reader (300 ch/sec) as opposed to the mechanical readers (10 ch/sec) on the teletype units.

RECEIVER STATUS: A 24-bit word that indicates the current receiver conditions, e.g., receiver number, filter number, any malfunctions, etc.

RECORD: On magnetic tape, the information between two consecutive inter-record gaps. Information on magnetic tape is written and read in records or blocks. The inter-record gap is 3/4 inch of blank tape to allow for acceleration and deceleration of the tape.

RELATIVE START: A mode in which the start event in the event schedule is not executed when its corresponding P coordinate is reached if the P coordinate is one of the time values. This permits the whole event schedule to be relocated to the current time by entering a "start now" command via command language.

RELOCATABLE LIBRARY: One or more relocatable object tapes combined to form a single paper tape, or a file on magnetic tape.

RELOCATABLE LOADER: A program which will input the relocatable object tape produced by the assembler or Fortran compiler and create an executable program in core.

RESIDENT: Refers to a program that is currently in the core memory.

SAMPLE: A computer word of data which results from a sampling operation and which is to be stored on the data tape.

SAMPLE INDEX: The number by which the operator/astronomer specifies an element of the A directory. This index system is used to set up or generate a data acquisition job and is used later when processing the data tapes.

SAMPLE INTERVAL: The separation in terms of the P coordinate between successive sample sets. This determines the P coordinates at which sample sets are to be taken.

SAMPLE LIST: A list defining the quantities which the observer wishes to sample and store on magnetic tape. The four possible types of quantities are analog, discrete internal, discrete external, and calculated.

SAMPLE SET: The set of data which results from sampling each of the quantities in the sample list once. There will be one sample set at the beginning of each sample interval.

SCAN: A general observation that is defined by a STRT and STOP event in an event schedule. Thus an integration at a fixed celestial position is a "scan".

SCAN NUMBER: A number in the A-DIRECTORY identifying the current scan. It is automatically incremented after each scan and can be preset to any value.

SCAN PATTERN: A sequence of up to 8 scans that are executed sequentially. The elements of the pattern must be selected from three basic scans (possibly in different P coordinates),

defined by the three event schedules, and their corresponding reverse scans. The computer will execute each scan automatically as the telescope is driven through the patterns.

STALL ALARM: A hardware device to pull the computer out of a stalled condition. A stalled condition exists when the program counter does not advance in 32 memory cycles.

START: The event in an event schedule which defines the P coordinate value at which sampling is to commence.

START TIME: The Eastern Standard Time at which the scan commenced.

STOP: The event in an event schedule which defines the P coordinate value at which sampling is to stop.

SUBROUTINE: A sub-program written in assembly language or in Fortran which can be used by some other program.

SYSTEM: Will usually mean the data acquisition hardware and programs, unless referred to as SEL system. In this case, it refers to the SEL software package used in program development.

SYSTEM GENERATOR: A program that will assist the operator in defining the inputs that the data acquisition system is to sample and the processing that is to be done before recording the data on the data tape.

GLOSSARY

SYSTEM LOADER: One of two relocatable loaders which loads the data acquisition and processing programs from the libraries on the system tape or from the paper tape reader.

SYSTEM STATUS: A computer word (24 bits) that has individual bits set or reset according to the current status of strategic hardware and software conditions.

SYSTEM TAPE: A magnetic tape containing the monitor and data acquisition routines, any overlay programs needed by the monitor, relocatable libraries, and observer's modules.

TAPE PARITY: Seven-track magnetic tape consists of 6 information bits, and 1 parity bit across the width of the tape. The lateral parity bit is the single-bit logical sum for even parity units, the complement of the sum for odd-parity units. In addition, each of the seven tracks has a longitudinal parity bit, which is formed in the same manner.

TRAILER BLOCK: A block consisting of a ten-word header plus the contents of the A and B DIRECTORIES. It is written on the data tape at the end of every scan.

UNIT: Usually refers to an I/O device.

UNIT NUMBER: A number by which an I/O device is referenced.

USER'S MODULE: A collection of acquisition and possibly processing programs that have been put together by the system generator and that can be saved on the system tape, reloaded, and run.

WATCH-DOG TIMER: An external timer which raises a CPU interrupt after a specified time interval has elapsed unless reset by a computer command.

WORD: Usually refers to a computer word which in this case is 24 bits (8 octal digits).

WRITE RING: A plastic ring which fits into the underside of a reel of magnetic tape. When removed, it is physically impossible for the computer to write on, or alter the tape.

COMMAND LANGUAGE

Commands are entered via the keyboard of the command device using the following sequence:

(a) / - a slash code to indicate the beginning of a command sequence

(b) cccc - a four-character code that defines the command

(c) D1, D2--D9 - optional parameters or arguments that convey additional data. These arguments are read as decimal* numbers in the range ± 8,388,607 and are separated by inserting a non-numeric character between the string of digits. Blanks, periods, and commas are frequently used separators. Unspecified arguments are given the value of zero.

Some commands (RATE, SI.X, MESX---) require arguments that represent decimal fractions. Since all arguments are read as integers, the trailing zeros must be inserted. For example the command /SI.1 1, 2, 3, 4 will set the first sample interval to

1 degree (or hour)

2 minutes

* These arguments are taken as octal numbers for the background commands unless the # specification is used to switch to decimal values.

and 3.04 seconds (not 3.4 sec) because D4 is taken as an integer between 0 and 99 that defines hundredths of a second.

(d) Carriage return - this signals the end of the command and initiates its execution.

The command and status panel can be used to initiate 24 commands that are used frequently and that require all arguments to equal 0.

Special Characters

The following characters can be used to perform special functions. Each can be used as a non-numeric terminator with the first 4 having special significance when used as the first character of the argument.

+ - sets the argument positive. It is also treated as a positive number without the + sign.

- - sets the argument negative.

- sets the input mode so that all following arguments are treated as decimal numbers. This mode is the normal one (for the foreground user) so that the # character need not be used unless returning from the octal mode.

' (single quote) - sets the input mode so that all following arguments are treated as octal numbers.

↑ - deletes all previous input from the current line and returns the carriage.

Astronomer's Units (AU)

The computer receives coordinate data from the raksyn system in units which divide the circle into 2^n equal parts, that is, as a binary fraction of a circle. This representation is used in the computer when storing and manipulating events. The command language interfaces the operator to this internal format by converting to and from the normal astronomer's units, that is, degrees (hours), minutes and seconds. Astronomer's units are specified by 3 arguments in the command. A fourth argument has been added to make use of the 23-bit (0.15 arc second) accuracy of the computer. When used, this last argument is a one- or two-digit integer that defines the hundredth of a second of angle or time.

Table B.1 illustrates the conversion from the binary fraction of a circle to astronomer's units for both time and angular coordinates.

ANGULAR CONVERSIONS

BINARY FRACTION (BIN2AU INPUT)	DEGS	MINS	SECS	/100	BINARY FRACTION (AU2BIN OUTPUT)
00000000	000	000	000	00	00000000
20000000	180	000	000	00	20000000
10000000	090	000	000	00	10000000
04000000	045	000	000	00	04000000
02000000	022	030	000	00	02000000
01000000	011	015	000	00	01000000
00400000	005	037	030	00	00400000
00200000	002	048	045	00	00200000
00100000	001	024	022	50	00077777
00040000	000	042	011	25	00037777
00020000	000	021	005	63	00020000
00010000	000	010	032	81	00007777
00004000	000	005	016	41	00004000
00002000	000	002	038	20	00001777
00001000	000	001	019	10	00000777
00000400	000	000	039	55	00000377
00000200	000	000	019	78	00000200
00000100	000	000	009	89	00000100
00000040	000	000	004	94	00000037
00000020	000	000	002	47	00000017
00000010	000	000	001	24	00000010
00000004	000	000	000	62	00000004
00000002	000	000	000	31	00000002
00000001	000	000	000	15	00000000

TABLE B.1

TABLE OF CONVERSIONS -- FROM BINARY FRACTION OF A CIRCLE TO ASTRONOMER'S UNITS (AND BACK)

BINARY FRACTION (BIN2AU INPUT)	ASTRONOMER'S UNITS				BINARY FRACTION (AU2BIN OUTPUT)
	HRS	MINS	SECS	/100	
20000000	012	000	000	00	20000000
10000000	006	000	000	00	10000000
04000000	003	000	000	00	04000000
02000000	001	030	000	00	02000000
01000000	000	045	000	00	01000000
00400000	000	022	030	00	00400000
00200000	000	011	015	00	00200000
00100000	000	005	037	50	00077777
00040000	000	002	048	75	00037777
00020000	000	001	024	38	00020000
00010000	000	000	042	19	00010000
00004000	000	000	021	09	00003777
00002000	000	000	010	55	00002000
00001000	000	000	005	27	00000777
00000400	000	000	002	64	00000400
00000200	000	000	001	32	00000200
00000100	000	000	000	66	00000100
00000040	000	000	000	33	00000040
00000020	000	000	000	16	00000017
00000010	000	000	000	08	00000007
00000004	000	000	000	04	00000003
00000002	000	000	000	02	00000001
00000001	000	000	000	01	00000000

TABLE B.1 (cont'd)

TABLE OF CONVERSIONS -- FROM BINARY FRACTION OF A CIRCLE TO ASTRONOMER'S UNITS (AND BACK)

B-6.0 (a) FOREGROUND COMMANDS

The commands that can be initiated from the command and status panel are marked by an asterisk.

ABRT* ABRT*

The current scan will be terminated immediately and the scan pattern reset to the beginning. If sampling has started the last data block will be dumped, followed by the scan trailer block, otherwise the trailer block is omitted.

This command is rejected when the system is not enabled.

ABST* ABST*

The system will be set to the absolute start mode in which all starts are treated as absolute values of the P coordinate. This command is rejected when the system is enabled.

BACK* BACK*

This command is a combination of the commands RVES and NABL, and will cause the previous scan to be re-started and run in the reverse direction.

CALF D1, D2, D3, D4 * CALF*

A calibration-off event will be scheduled in the active ES at a position defined by D1 to D4 (in astronomer's units).

If the system is enabled and D1 to D4 are zero, the current value of the P coordinate is used; i.e., the calibration signal is turned off immediately.

CALN D1, D2, D3, D4 * CALN*

A calibration-on event will be scheduled in the active ES at the position defined by D1 to D4 (in astronomer's units).

If the system is enabled and D1 to D4 are zero, the current value of the P coordinate is used; i.e., the calibration signal is turned on immediately.

CALS D1 CALS

The calibration setting that is used on the balance control panel is stored in location 11 of the A directory.

CLAN D1* CLAN*

This command clears and enables the event schedule D1 and also sets the scan pattern count to zero so that the single scan mode of operation is used. If D1 = 0 the currently active event schedule is used. The result is identical with the command sequence:

/ES.X
/S.P.
/DELE
/NABL

COMM COMM

When a system module is generated the operator can include one line of comments that describe the module. These comments stay with the module during DUMP and LOAD operations. This command will list the comments of the module currently in core.

CPES* CPES*

The event schedule that is active will be listed. Events that have been completed will be preceded by "C". If the system is enabled the event schedule number will be positive. The sample intervals that connect the event schedule to the sample lists are listed in a format that indicates whether it has been set by an SI.X or an SPBX command.

CPSL D1* CPSL*

Sample list D1 will be typed as follows:

DELAY	YYYYY
1.	X1
2.	X2
3.	X3
.	.
.	.
.	.

where YYYYY is the nominal delay of the pre-sampling filter (see Appendix I) and the values X1, X2 .... are the sample indices that indicate the quantity being sampled. If Xn is negative (say = -M) an AA subroutine is indicated which uses the M^{th} element of the list as input data. Entries that are also displayed by QL subroutines have QL listed after the sample index.

CPSP* CPSP*

The scan pattern and the remaining number of times that it is to be executed will be listed on the log sheet.

DATE D1 DATE

The current date is coded into one argument and put in location 1 of the A directory. Three pairs of decimal digits representing the day, month, and year can be arranged into one six-digit argument.

DELE D1, D2 --- D8 * DELE*

The entries in the event schedule that are selected (numbered sequentially) by the arguments D1, D2--- will be removed. If the arguments are zero all events in the active ES are deleted.

DRTY D1, D2 DRTY

The current value of directory location D1 will be listed on the command device in a format defined by D2. The formats that are available are:

D2 = 0 decimal

D2 = 1 octal

D2 = 2 angular AU (deg, min, sec, sec x 100)

D2 = 3 temporal AU (hr, min, sec, sec x 100)

For example /DRTY41,2(CR) will list the current value of ZA (in deg, min, sec, sec x 100).

DUMP DUMP

The data acquisition programs and the directories that are currently in core will be dumped as an observer's module on the system tape. The operator must first enter a 4-letter name for the module and the system tape will be checked to make sure that this name has not been used already. The restrictions on the assignment of names to observer's modules

are listed in section 10. All characters except ↑ may be used in the name.

ES.X* ES.X*

The event schedule defined by X (1, 2, or 3) will be activated if the system is not enabled. This command is rejected if the system is enabled.

FLAG D1 FLAG

This command sets the operator's flag (location 67 of the A directory) to the value of D1. This value is recorded in each scan header block and in the header of each data block. In addition, any sample list that was generated with a sample index of 67 in it will cause this value to be recorded in the corresponding data stream.

The current value of the P coordinate is typed on the log sheet when this command is executed.

LOAD LOAD

When the operator types a 4-letter name the system tape is searched for an observer's module of that name. If it is found, the module is loaded and is ready for execution (or modification). If the module cannot be found a message to this effect will be typed.

LOG. D1 LOG.

Argument D1 is the driver's log number and is put in location 5 of the A directory.

MESX D1, D2, D3, D4 MESX

All entries in event schedule X will be displaced by a value that will make the new starting position equal to D1 to D4 (in astronomer's units). The system must not be enabled, and there must be a start event in the ES. This command does not enable the system.

NABL* D1 NABL*

This command will enable the data acquisition program to proceed as the telescope is driven along the P coordinate. If a scan pattern has been defined the complete pattern will be executed as many times as are specified by the pattern count. If no pattern has been specified the system will execute the scan that is defined by the currently active event schedule, if D1 = 0, or by the event schedule that is specified by D1.

NEGS* NEGS*

This command is similar to POSS except that it specifies a negative direction along the P coordinate for single, open scans (see POSS).

NEWS NEWS

This command starts the two-stage system generation sequence by loading and executing first the generator (SGEN) and then the loader (SREL or SLDR).

The system must not be enabled. During generation and loading the command language is available, but the data acquisition system should not be enabled until all elements of the new system have been loaded.

OBSE D1 OBSE

Argument D1 is the observer's number and is put in location 3 of the A directory.

OPER D1 OPER

Argument D1 is the operator's/driver's number and is put in location 4 of the A directory.

P.C. D1 P.C.

The P coordinate of the currently active ES will be set to that defined by the digit D1 as follows:

D1	P Coordinate
0	PA
1	AZ
2	ZA
3	DEC
4	HA
5	RA
6	SID
7	SOL

This command is rejected if the system is enabled.

POSS* POSS*

The direction of each scan must be known when it is enabled. When executing a scan pattern the direction of each scan is given by the pattern definition. Single scans, however, must rely on the scan vector to determine the scan direction. This vector cannot be calculated for open scans (no STRT and/or STOP events). The command POSS is used to set a back-up scan vector to + 90^{o} (+ 6 hours) and this

value will be used whenever a single open scan is enabled.

The back-up vector will remain positive until changed by a NEGS command.

POST POST

The data tape will be searched in the forward direction until the unique end label written by WEND is found. The tape is positioned ahead of this label so that subsequent data will be recorded over the label.

PRES D1 PRES

Argument D1 is the atmospheric pressure reading and is put in index 61 of the directory.

PRGS PRGS

The names of all the modules on the system tape will be listed. All the programs will be observer's modules except for the libraries (LIBX) and the system modules SMON, SGEN, SREL, SLDR and SMAP.

This command can be executed any time except during system generation, or during a LOAD/DUMP operation.

PROG D1 PROG

Argument D1 is the program number and is put in index 2 of the directory.

PROJ D1 PROJ

Argument D1 is the project number and is put in index 0 of the directory.

QUIT* QUIT*

This command will cause a premature termination of listings on the foreground device which may have been started by such commands as CPES, CPSL --- etc.

RATE D1 RATE

This command will guide the operator in selecting a setting for the pre-sampling filter. The anticipated scan rate D1 (in milli-degrees per minute) is used to calculate an acceptable filter range. The minimum filter setting is calculated as the signal bandwidth of the antenna system. The maximum suggested setting is calculated from the sample interval such that the noise power reflected into the signal band by the sampling process will be at least 20db below the signal level. A cos δ (sin ZA) factor is applied where necessary by using the current value of DEC (AZ). The filter settings are given in milli-hertz.

REDO D1* REDO*

The current scan is terminated and then re-enabled again so that it may be redone immediately. The last data block and scan trailer are dumped on the data tape if data acquisition had already begun. The scan pattern will remain intact but the scan number will be advanced for the new scan. If argument D1 $\neq$ 0 the scan pattern is backed up to the previous scan element providing that the current scan has not started.

This command is rejected when the system is not enabled.

RESP D1* RESP

The current scan pattern will be executed D1 times by setting the pattern count to D1 and enabling the system. If D1 < 1 the pattern count is set to 1.

R.H. D1 R.H.

The argument D1 is stored as the relative humidity in index 62 of the directory.

RLST* RLST

The system will be set to the relative start mode which will cause a manual start to be needed when scanning in one of the time coordinates. The command /STRT will update the active ES to the current time.

This command is rejected when the system is enabled.

RVES* RVES*

The events in the active ES will be interchanged (STRT's & STOP's; CALN's & CALF's) so that the same scan is defined in the reverse direction.

The system must not be enabled.

SCAN D1 SCAN

The scan number (index 6 in the directory) will be set to D1. This number will be incremented automatically as each scan is enabled. It can be reset to any value by this command whenever the system is not enabled.

SI.X D1, D2, D3, D4 SI.X

The sample list (X = 1, 2 or 3) will be linked to the active ES such that samples will be taken along the P coordi-

SI.X SI.X

nate at intervals defined by D1 to D4 (in astronomer's units). The previous sample interval will be replaced by the new value. If no arguments are specified (i.e., D1 to D4 are zero) sample list X will be disconnected from the active ES.

S.P. D1, D2 --- S.P.

This command will define a scan pattern and set the number of times that it is to be executed equal to D1. The pattern itself is defined by D2, D3--- up to D9. Each argument in the pattern definition consists of

(a) a sign to specify the direction of the scan (+ signs can be omitted)

(b) a digit to specify which ES is to be used to control the scan.

e.g., /S.P. 10, 1, -1 will set up 10 complete patterns consisting of a positive and negative scan along the path defined by ES1.

A new scan pattern is enabled when the previous one has finished until D1 patterns have been completed.

When the number of scan patterns to be executed reaches zero, it may be refreshed again by typing /S.P. D1 (or /RESP D1).

For D1 = 0 this command sets the pattern count to 1 when the system is enabled, and clears the pattern (and count) when the system is disabled. The latter case is the means by which the operator switches from the pattern to the single scan mode of operation.

SORC SORC

This command allows the operator to enter a 12-character source name which is put into directory locations 76 to 78 inclusive.

SPBX D1 SPBX

This command will set the sample interval such that the number of samples per antenna beamwidth will be D1. The sample interval in the equatorial plane is calculated and put in the active event schedule just as if the command /SI.X were used. However, when this event schedule is enabled the sample intervals that have been entered by an SPB command will be modified by cos δ or sin ZA if necessary so that the samples per beamwidth will remain at the value D1.

STOP D1, D2, D3, D4 STOP

A stop event will be entered in the active ES at the position defined by D1 - D4 (in astronomer's units). Previous STOP codes will be deleted.

If the system is enabled and the arguments D1 to D4 are zero, an immediate stop is effected by placing the current value of the P coordinate in the event schedule that is active.

STRT D1, D2, D3, D4* STRT

This command will put a start code in the active event schedule at the coordinate given by D1 to D4 (in astronomer's units). Previous start codes are deleted.

A "start now" command is implemented when the system is enabled and arguments D1 to D4 are zero (the current value

STRT STRT

of the P coordinate is put in the ES). In addition, the whole event schedule will be updated to the new starting point if the P coordinate is one of the time functions and the system is in the relative start mode.

If data acquisition has already begun, the message "TOO LATE" will be typed.

TEMP D1 TEMP

The argument D1 is stored as the temperature in index 60 of the directory.

TINT TINT

The input and output programs and the interrupts for all teletype units and the high-speed paper-tape system will be re-initialized.

WEND WEND

This command will put a unique end label on the data tape to mark the position to which data have been recorded. After each programmed termination of a scan (i.e., STOP, ABRT, or REDO) the data tape is flagged automatically by effecting a WEND command and then positioning the data tape to the beginning of this flag. If more scans follow, this flag is simply overwritten. After the last scan the operator may try to append a second flag by using the WEND command as before but it is not necessary. (If the user does use WEND the tape must be rewound and the command POST must be completed before recording any more data.) He must, however, use WEND to locate the end of data when acquisition is terminated by

WEND WEND

an abnormal stoppage such as a power failure or a program error and no more data are to be recorded.

The command is rejected when the system is enabled.

XTND* XTND

This command will remove the stop code from the active ES. The operator can thereby extend a scan indefinitely during execution.

**** (alpha-numeric) ****

This command will let the operator enter one line of comments on the log without having ILLEGAL! typed back.

Arguments in the background commands are interpreted as octal; i.e., only the digits 0 to 7 are legal and the rest are terminators. Decimal values can be input by using the # character.

BKPT D1 BKPT

This command inserts a breakpoint at location D1. The previous breakpoint is restored and the instruction at D1 is saved and typed out before inserting the new breakpoint instruction.

When executed, the breakpoint instruction will cause the background status to be typed and the idle loop to be run instead of the background program.

CMAP D1 CMAP

The core map for the system programs will be listed on the background device. If D1 = 0 the variable call table will be listed. If D1 is not 0 the permanent call table will also be included.

CONT CONT

This command causes the background program to continue by using the status that remained from a PAUS command or a breakpoint entry.

CORE D1 CORE

The operator uses this command to request core memory from location D1 up to the highest possible location. If D1 is above the resident foreground module, his request is granted and he may load and run a job in this area. If D1 is

CORE CORE

below the resident foreground module, his request is denied and the message

FGND USED TO YYYYY

is typed.

DUMP D1, D2 DUMP

This command causes the core from address D1 to D2 to be dumped onto paper tape in the standard SEL absolute format.

GOTO D1, D2, D3, D4, D5, D6 GOTO

This command starts executing a background program at the location D1 with the A, B, X1, X2, and X3 registers containing D2---D6, respectively.

KEIN D1, D2 --- KEIN

This command allows the operator to key into the background memory. The contents D2 are put into the address D1, D3 into D1 + 1, etc., until all arguments have been placed.

LISD D1, D2 LISD

The decimal equivalent of the contents of locations D1 through to D2 will be listed on the background device. If D2 is zero or less than D1 the contents of D1 to D1 + 5 will be listed.

If D1 = 0 the current status of a running or paused background program is listed in decimal.

LIST D1, D2 LIST

This command is similar to LISD except that the contents are listed in octal.

LOAD

This command will load background programs from the high-speed paper-tape reader. Loading will not start unless all of the program will fit into the background memory. Before using LOAD the background user should check to make sure that the foreground operator does not need the reader.

PAUS

This command causes a pause in the execution of a background program. The status is preserved and control is switched to the idle loop.

QUIT

This command terminates multiple line listings on the background device that are generated by commands such as LIST or CMAP. Listings that background programs generate must be halted with the PAUS command.

RSBP

This command restores the original instruction in the current breakpoint address.

TINT

This command initializes IOCS and the interrupts for the teletype and HSPT units.

APPENDIX C

LOADING PROCEDURE

This appendix details the technique used to reload the system following complete destruction of the contents of memory. The routine for loading programs into memory is resident in core and if it is accidentally destroyed, no means exists in core for loading the memory. It is necessary then to have a very short machine language program which the operator can key into the core memory via the console switches and use as a starting point for loading his programs. The small keyed-in program is called a bootstrap and hence the terminology "bootstrapping" or "bootstrapping into core" is used in referring to this elementary loading technique. Since most operators will be concerned primarily with programs stored on magnetic tape we shall consider only magnetic tape bootstraps here. There are two magnetic tape bootstraps at ARO, one is a simple version called the SEL magnetic tape bootstrap and the other is more sophisticated and is identified as the ARO magnetic tape bootstrap (SUPERBOOT). The ARO bootstrap is a general purpose one and should always be used to load the monitor or the SEL Executive, (see Section 2.1, Chapter 2 for user instructions) provided it is resident in core. The ARO bootstrap is long (locations '3 to '32), and should it be destroyed, the SEL bootstrap should be used as follows:

1) Use the CPU console switches to enter the SEL bootstrap as follows:

C-2.0 LOADING PROCEDURE

1)

LOCATION	CONTENTS
'60	00000000*
'61	00020000
'62	01310006
'63	01000100
'64	01310006
'65	42200000
'66	01310006
'67	42200000
'70	00000000
'71	41100060

*USE 00025745 when bootstrapping the SEL EXECUTIVE, SYSTEM B (for SYSTEM A.2 use 26541).

2) Put the SYSTEM tape on tape unit #0.

3) Set the program counter to '62.

4) Press start twice.

5) When the monitor is running (about 5 sec) turn the protect key on. If this step is omitted the data acquisition phase will not be protected from the background user.

The ARO bootstrap should now be in core since it is part of the monitor, and it can be used for subsequent bootstrap operations.

COMPUTER SYSTEM HARDWARE

The hardware for the computer system, including the analog and digital interface, is illustrated in figure D.1. Each I/O device is assigned a unit number by which programs in the CPU control that device. Figure D.4 contains a list of the unit number assignments for the analog and digital I/O units in the custom buffer interface unit.

(a) Central Processor Unit

The central processor unit (CPU) contains two 24-bit accumulators (A and B registers) and three 15-bit index registers. The execution times for fixed point add, multiply, and divide are 3.5, 10.5, and 26.2 μs, respectively. Memory protection (on individual words), an instruction trap, stall alarm, additional interrupts, power-fail and auto restart are options that have been added to the standard CPU. The control panel that the operator uses to start and stop the computer is illustrated in figure D.2. Once the data acquisition system is running an operator communicates through the foreground (or background) command device and does not need this panel except possibly to monitor the integrity of the CPU by observing the register patterns. Users requiring more information should consult references 3, 4, and 5.

The CPU has a total of 31 interrupts which are used primarily by system programs, such as IOCS, and are allocated according to figure D3. Each interrupt gives an external signal the ability to turn on a corresponding program. This service program is started within 3.5 μs if there are no jobs of higher priority being executed. The spare interrupts were acquired for future equipment, such as an operator's

console, and until control is implemented these interrupts can be made available to user's equipment providing that hardware and software compatibility are retained.

(b) Analog Inputs

The 16 analog inputs in the custom buffer can be sampled randomly at rates up to 20,000 samples per second. The analog converter is accurate to 12 bits and its output is read as a 24-bit, 2's complement integer where the least significant bit represents 2 mV. Analog signals should be confined to the prescribed range of ± 4.096 volts, although the operator should try to provide an analog level to the computer that is large enough to swamp out any noise on the analog lines. A voltmeter has been put across the output of the pre-sampling filter and should be used to monitor the analog level to the computer.

Analog signals from additional user's equipment can also be sampled and put on the data tape. These signals must have an output impedance that is low enough to drive a twisted pair of conductors with an over-all shield.

(c) Digital Inputs

The discrete inputs are read into the computer as full words, that is, 24 bits at a time. Each of the 12 words of discrete input is addressed by a separate unit number as indicated in figure D.4. Connections to the individual units are made with 50-pin Cannon subminiature connectors. Each signal must be driven through a twisted pair of conductors that are terminated with 100 ohms at the custom interface. The input levels are compatible with SEL logic modules, that

is, + 3 volts for logical 1 and 0 volts for logical 0.

(d) Digital Outputs

Most of the 96 discrete outputs were obtained for control purposes and so are available for other uses until control is implemented. These signals are binary voltages (+3V or 0V) and are arranged in 6 groups of 16. Each group is normally available on a 37-pin Cannon connector with twisted pairs being used to cable individual signals.

(e) Analog Outputs

Ten analog outputs in the range 0 to -11V were purchased to drive the velodynes of the telescope. Three additional analog outputs in the range ± 4.096V are available for quick-look outputs or user's equipment.

Users wishing to build or use special equipment that requires the interrupt or custom interface facilities can obtain further details from the SEL technical manual on the custom interface, from the ARO computer personnel, or from the Radio Astronomy Section in Ottawa. Such users should also consult the ARO computer group beforehand to ensure that the necessary facilities will be available and connected during the required observing period.

In cases such as LBI observations, line receiver work, or the rapid sampling of special sources, the use of the general purpose acquisition system that is described in this manual may not be advisable because of core memory or speed limitations. To overcome these difficulties, users may wish to write their own acquisition program, in which case all the computer facilities will be at their disposal.

(f) Command Devices

The computer system contains 3 teletype keyboard-printers (two ASR 35's and one ASR 33 on the CPU console) that may be used as command devices for either foreground or background. The standard assignment is to use ASR 35 unit no. '15 for the foreground, the console teletype for background commands and ASR 35 unit no. '10 for any quick-look output. However, during start-up these devices can be re-assigned by setting console control switches 18, 19, and 20 to specify the background device and 21, 22, and 23 to specify the foreground device. Each device is specified as follows.

0 - standard assignment
1 - input and output on console teletype (ASR 33)
2 - input and output on ASR 35 (unit no. '10)
3 - input and output on ASR 35 (unit no. '15)
4 - input on the console teletype, output on the high-speed punch
5 - input on ASR 35 ('10), output on the high-speed punch.

(g) Command and Status Panel (CASP)

An alternate means of implementing certain commands is available in the command and status panel. The 24 commands that are available through this device are illustrated in figure D.5. Status conditions such as the P coordinate, the active event schedule, scan direction, etc., are displayed on lamp indicators. Figure D.4 also illustrates the 24 operator switches that are mounted above the CASP.

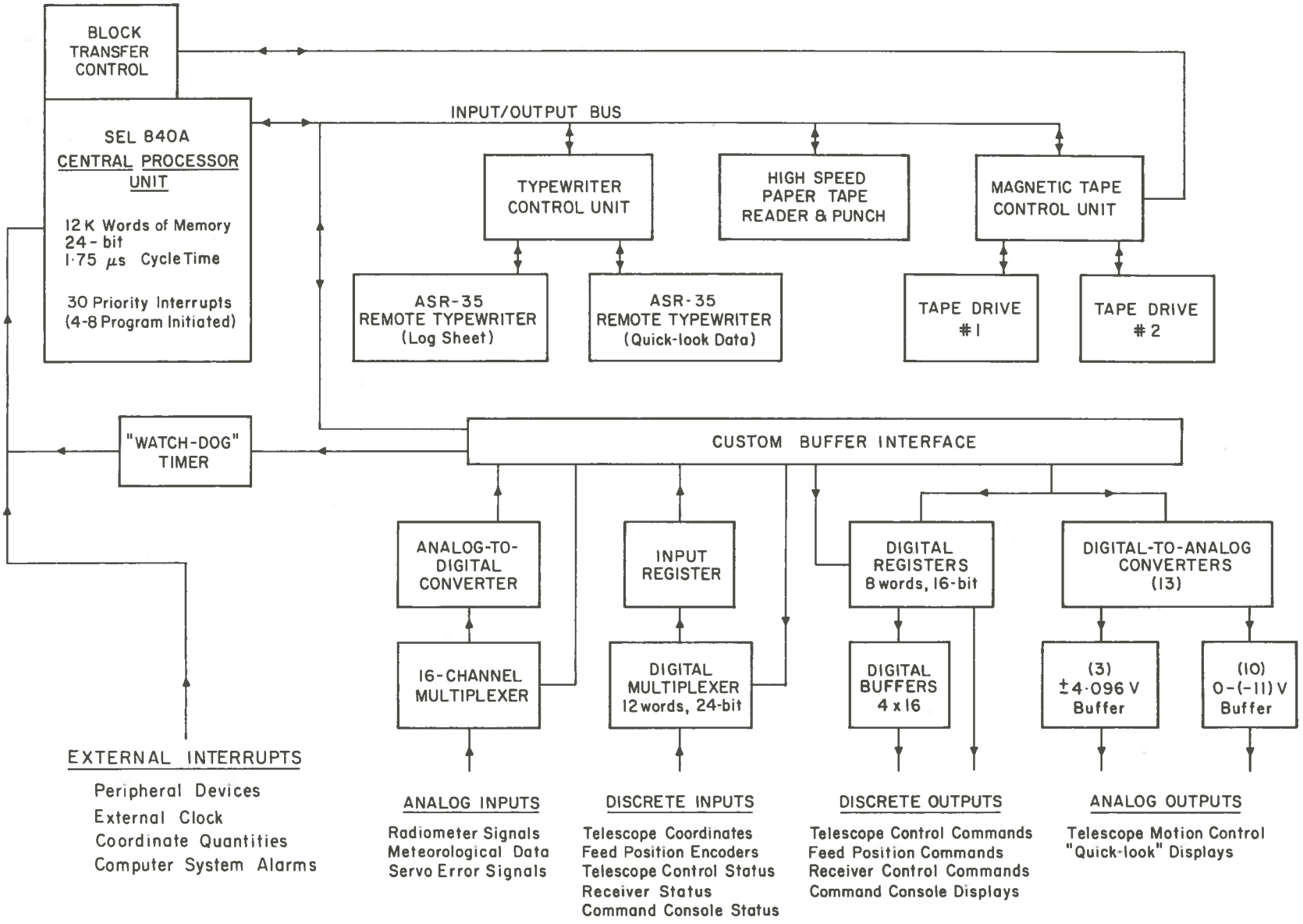


FIGURE D.1 COMPUTER SYSTEM HARDWARE

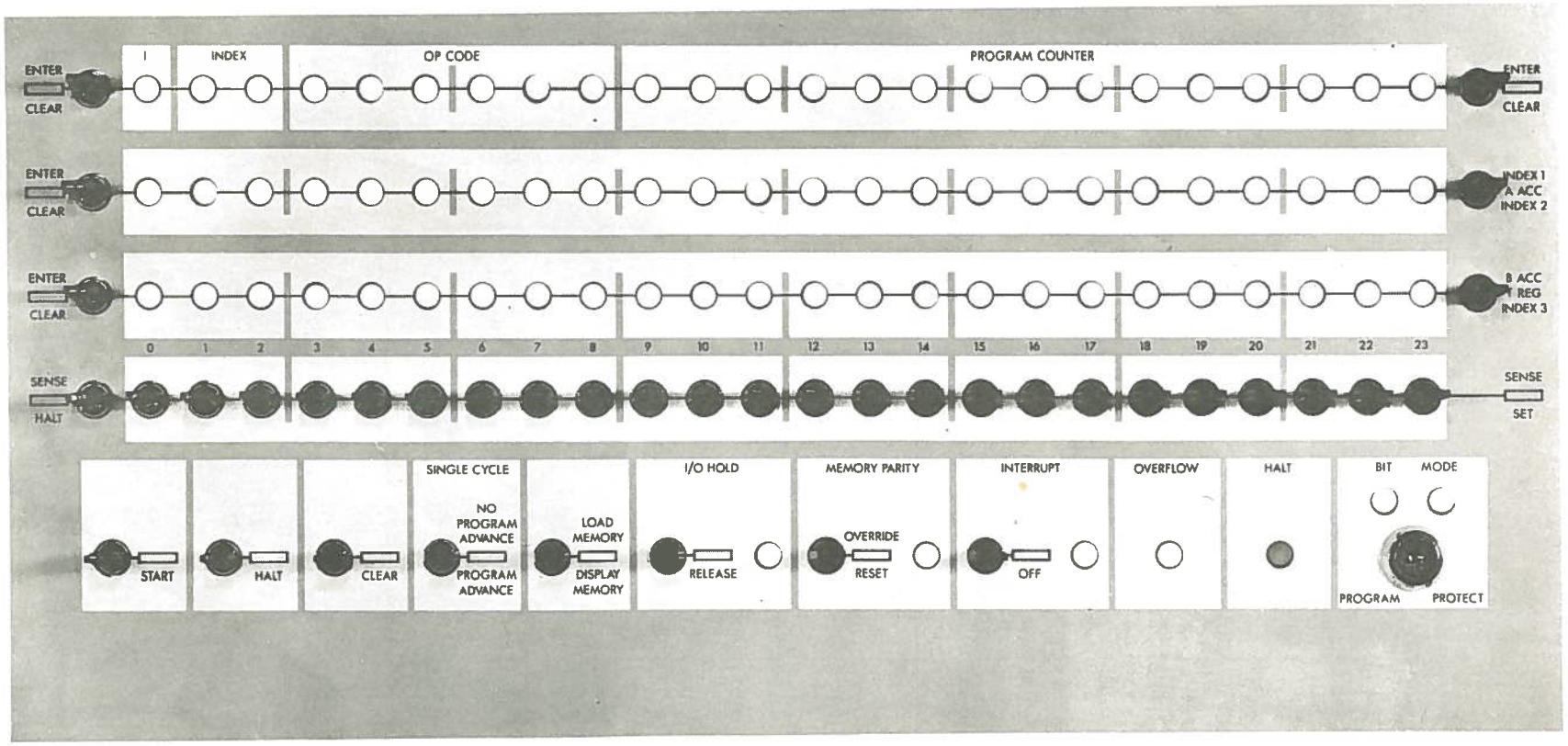


FIGURE D.2 The Control Console of the A.R.O. Computer (S.E.L. 840A)

Group	Level	Use	Address (Octal)
0	0	Power Fail	100
	1	Stall Alarm	101
	2	Block Transfer	102
	3	Watch Dog Timer	103
	4	HYUP	104
	5	Analog Converter	105
	6	Sidereal Clock (IMS)	106
	7	Coordinate Values	107
	8	Memory Protect	110
	9	Instruction Trap	111
	10	ASR 33 Teletype (Output)	112
	11	ASR 33 Teletype (Input)	113
	12	Memory Parity	114
	13	Mag. Tape Free	115
	14	Standard/Spare	116
	15	Standard/Spare	117
1	1	ASR 35 TTY #10 (Output)	121
	2	ASR 35 TTY #10 (Input)	122
	3	ASR 35 TTY #15 (Output)	123
	4	ASR 35 TTY #15 (Input)	124
	5	High-speed Punch	125
	6	High-speed Reader	126
	7	Discrete Sample Processor no. 1	127
	8	Analog Sample Processor no. 1	130
	9	Discrete Sample Processor no. 2	131
	10	Analog Sample Processor no. 2	132
	11	Discrete Sample Processor no. 3	133
	12	Analog Sample Processor no. 3	134
	13	Spare	135
	14	Solar Clock (IMS) - LBI	136
	15	Command Language	137

Figure D.3 ARO interrupt assignments

UNIT NO.	TYPE OF I/O	CHANNEL NO.	ALLOCATION
'60	DI	-	Raksyn Coordinates
'61	DI	-	Receiver Status
'62	DI	-	Operator Switches
'63	DI	-	Command Panel
'64	DI	-	System Status
'65	DI	-	Polarizer/Focus
'66-'73	DI	-	Future Control/User's choice
'74	DO	0	Control Desk
		1	Receiver Control
		2	CASP
		3-7	Future control/User's choice
'75	AO	0-9	(0-11V) Velodyne control
		10	(± 4V) Chart Recorder
		11	(± 4V) Marker Pulse (added to ch #10)
		12	User's choice
'76	AI	1	Receiver Output
		2-16	User's choice

FIGURE D.4

ALLOCATION OF DIGITAL AND ANALOG I/O UNITS

IN THE CUSTOM BUFFER INTERFACE

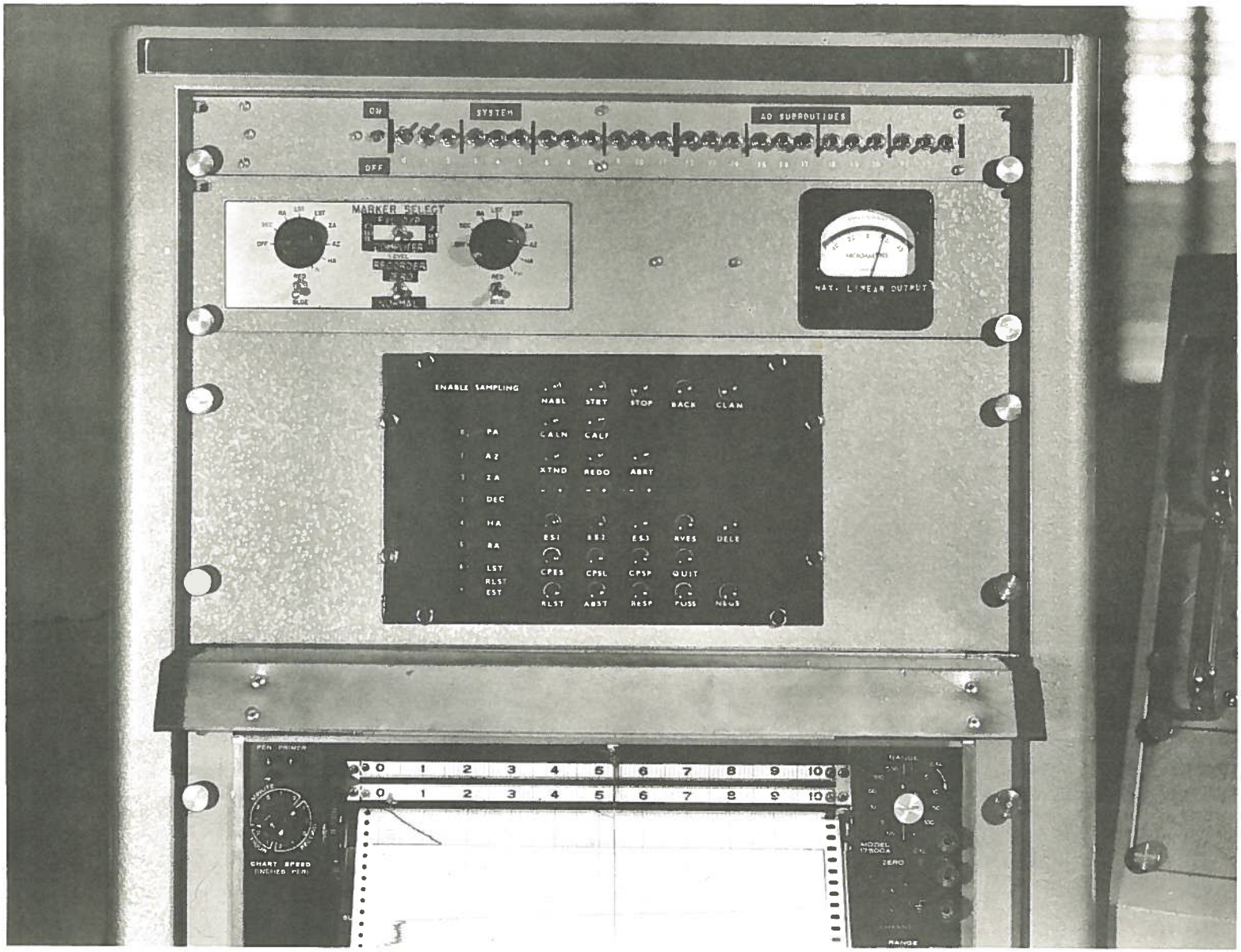


Figure D.5 The control and status panel with the operator switches mounted above

APPENDIX E

ALARM AND STATUS CONDITIONS

A system status word and an alarm word are formed by sampling certain internal CPU and external telescope functions every 1/4 of a second. The new system status and alarm status words are put in directory locations 8 and 9, respectively, after being formatted so that each of the 24 bits in these words corresponds to the conditions that are listed in tables E.1 and E.2. Bits for the monitoring of certain control functions have been assigned and probably will not be connected until computer control is implemented. The blank entries in tables E.1 and E.2 are spares which can be assigned and connected to functions that the users find worth monitoring.

An alarm is an adverse status condition which is important enough to be brought to the operator's attention. Whenever the alarm word changes, a message that identifies the current alarm conditions will be typed. The alarm messages are listed in table E.2 along with some of the possible reasons for the alarm condition. When all the alarm conditions are reset the all clear signal is typed.

The condition of the receiver system is also checked every 1/4 of a second and a receiver status word is stored in location 10 of the A directory with the bits assigned as follows:

E-2.0 ALARM AND STATUS CONDITIONS

RECEIVER STATUS WORD

BITS		FUNCTION
0	-	Any receiver malfunction. Tests for conditions are combined within the receiver.
1	-	The calibration temperature has been fully removed.
2	-	The receiver has reached the injected calibration temperature
3 - 6	-	The setting of the pre-sampling filter.
7 - 10	-	The receiver identification number.
11 - 23	-	The positions of the switches that are used to set the mode of operation.

The four bits (7-10) that contain the receiver number are capable of specifying 15 different receivers (no. 0 is illegal and is used to indicate that the receiver is not connected or is not turned on). The currently available receivers have been assigned the following octal numbers:

2.8 cm - 7
4.55 cm - 3
9.4 cm - 13

In addition, allowance has been made in the programs for the following receivers:

1.4 cm - 1
4.6 cm (at focus) - 4
2.8 cm (paramp) - 6
2.2 cm - 11
9.4 cm (maser) - 14
21.0 cm - 16

FORMAT OF THE SYSTEM STATUS WORD

BIT	FUNCTION TESTED
0	Any alarm condition
1	Sampled data are unreasonable
2	P coordinate value unreasonable
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	Telescope under computer control
13	Computer control mode (AA or ME)
14	Wind over 45 mph
15	Error detector in use
16	
17	
18	
19	
20	
21	
22	
23	

TABLE E.1

E-4.0 FORMAT OF ALARM STATUS WORD

BIT	OPERATOR MESSAGE	FUNCTION
0	RXEROR	A receiver hardware malfunction.
1	SYS2SLO	The computer has not completed a job.
2	MGTQFUL	The magnetic tape queue in IOCS has overflowed, probably because the sampling rate is too great.
3	TIMQFUL	The time processor queue (WHEN) has overflowed, probably because of too many samples in the filter delay time.
5	WDQEROR	The Q value processor has not checked in (possibly the raksyn is not on).
6	WDCEROR	The antenna control program has not checked in.
7		
8		
9		
10	QVL2SLO	The Q value processor did not sample a new coordinate value fast enough.
11	LNKQFUL	The LINKIO queue overflowed, probably due to calls from AA and QL subroutines
12		
13	INTRLOK	One of the telescopes interlock keys has been removed.
14	WIND2HY	The wind has exceeded 55 mph.
15	MACHSET	The machine sets are not on.
16	VENTLUB	The ventilation and lubrication system is not 100%
17	400CYCL	The 400 cycle power is off.
18	AA LMIT	The telescope is in an AA limit.
19	ME LMIT	The ME is at a limit
20	ZA RATE	The zenith angle rate is too high
21	COCOLMT	The coordinate converter is at a limit.
22		
23		

TABLE E.2

APPENDIX F

THE A DIRECTORY

The directory is a set of core memory locations in the monitor that is used as a common area by which information can be passed among programs. The A directory is the first part of this area that is also used to pass information between the computer and the operator. Each element in the A directory is referred to by its index within the directory as shown in table F.1.

To the operator the A directory is a list that can be used in the following ways:

(a) The group of potential sources of sampled data is a subset of the A directory. During system generation the operator can select which of these sources will be sampled in each data stream by placing its index in the corresponding sample list. Those elements which can be used in this way have an A or U code in Table F.1. If the operator tries to specify any other element in a sample list the system generator will reject it and type the reply NO!! .

(b) Variable constants such as temperature, radio source name, project number, etc., are locations in the A directory that can be updated by the operator with the command language. Since the A directory is part of the scan header and trailer blocks these entries will make current conditions and operating procedures available during subsequent stages of data processing.

(c) Certain elements of the A directory contain the values of system parameters that are updated periodically by the monitor programs. The coordinate data, including polarizer angle, and the status words fall into this

category. The current value of one of these or any other elements in the A directory can be examined by the operator with the DRTY command.

CODE DEFINITION

A and U	-	can be sampled (specified in a sample list) and put on the data tape
A	-	can be set directly by the astronomer
U	-	is used and set by the system programs
N, F and X	-	cannot be sampled
F	-	reserved for future expansion
X	-	spares
N	-	set and used by system

INDEX	CODE	DATA	
0	A	Project Number	
1	A	Date	
2	A	Program (Observing)	
3	A	Observer	
4	A	Operator	
5	A	Log. number (operators)	
6	A	Scan number	
7	U	Start time of scan (E.S.T.)	
8	U	System Status	
9	U	Alarm Status	
10	U	Receiver Status)	
11	A	Calibration Setting)	
12	F	Load Temp.)	
13	U	Analog Output 1)	
14	U	Analog Output 2)	
15	X	)	Receiver Oriented Data
16	U	Polarizer angle/focus position)	
17	X	)	
18	X	)	
19	X	)	
20-35	N	Observer's module comments -filled during generation and listed by /COMM	
36	X		
37	X		
38	X		

TABLE F.1

INDEX	CODE	DATA	
39	F	Polarizer Angle)	
40	U	Azimuth)	
41	U	Zenith Angle)	Coordinates that can
42	U	Declination)	be used as the P-
43	U	Hour Angle)	coordinate in a scan
44	U	Right Ascension)	
45	U	Sidereal Time)	
46	U	Solar Time)	
47	U	Computer Time (minutes)	
48	U	Computer Time (ms)	
49	U	P coordinate Address	
50	X		
51	X		
52	X		
53	X		
54	X		
55	X		
56	X		
57	X		
58	X		
59	U	Computer use (% of time)	
60	A	Temperature	
61	A	Pressure	
62	A	Relative Humidity	
63	F	Wind	
64	F	Compensation (ME)	
65	F	AZ. Sin (ZA) error	
66	F	ZA Error	
67	A	Operator Flag	
68	N	No. of sample streams	
69	X		
70	N	No. of words in A directory	
71	N	No. of words in B directory	
72	N	No. of words in C directory	
73	N	P coordinate Index (0-7)	
74	N	System tape label	
75	N	Name of observer's module	
76	F)		
77	F)	Name of the radio source (12 characters)	
78	F)		
79			

TABLE F.1 (cont'd)

OPERATOR MESSAGES

This section contains an alphabetical list of operator messages along with the conditions that triggered the message and the action that the monitor has taken. Requests for operator input by the system generator (Appendix H) and the alarm messages (Appendix E) are not included. Also missing from the list are the responses to the listing commands CPES, CPSL, CPSP and COMM.

All error and status messages from IOCS are in the form:

IO XX explanation.

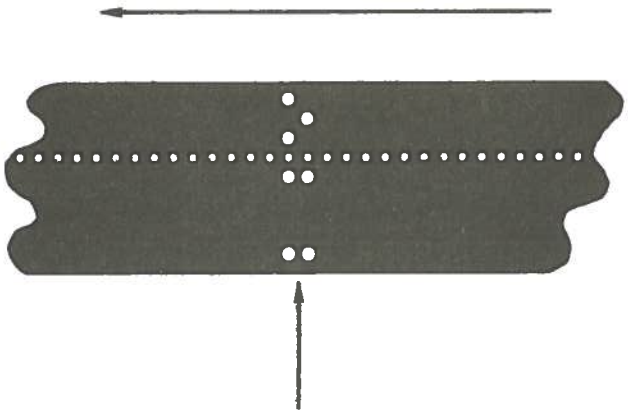
The IO prefix is a code unique to IOCS. The number XX identifies the message for easy reference, and the explanation attempts to explain the message in as few characters as possible.

ALL PATTERNS DONE ALL PATTERNS DONE

All the patterns that were specified by the first argument of S.P. have been completed.

BACKSPACE PAPER TAPE 1 RECORD BACKSPACE PAPER TAPE 1 RECORD

This message occurs during the loading phase of system generation after REREAD has been typed, and the input unit being used is the paper tape reader. Put a mark on the tape at the last character read. Remove any loose chad adhering to the tape, backspace the tape sixteen inches, and position it between the two characters that are shown in the following diagram.



CHECKSUM ERROR CHECKSUM ERROR

This message may occur during the loading phase of system generation. There is little that can be done if this error occurs on magnetic tape, but it can usually be corrected if paper tape is being used. The error indicates either an improperly punched, or an incorrectly read paper tape. Type

REREAD to read the paper tape once more, or type EXIT to abort the system generation.

CKSM - See CHECKSUM ERROR

CORE - See CORE EXCEEDED

CORE EXCEEDED CORE EXCEEDED

This message may occur during the loading phase of system generation. The programs being loaded will not fit in available core storage.

DONE DONE

This message occurs at the successful completion of the loading phase of system generation.

DT READY DT READY

The data tape is ready to be removed (after a WEND command) or to be written on (after a POST command).

ENTER NAME ENTER NAME

The operator is requested to enter a 4-character name to specify an observer's module or a 12-character name to specify a radio source.

ESALTRD ESALTRD

The event schedule was full and one entry had to be deleted to make room for an ABRT, REDO or a STOP event.

ILLEGAL ILLEGAL

The previous command is illegal and no action was taken.

IO 01 MGTP INPUT IO 01 MGTP INPUT

A block has just been read from magnetic tape which contains a parity error. The parity error has persisted for five re-read attempts. This message is displayed on the foreground logging device.

IO 02 MGTP OUTPUT IO 02 MGTP OUTPUT

A block has just been written onto magnetic tape with a permanent parity error. The parity error has persisted after five re-write attempts. This message is displayed on the foreground logging device.

IO 04 END-OF-TAPE IO 04 END-OF-TAPE

The reflective strip marking the end of tape area has just been sensed on magnetic tape. This message is displayed on the foreground logging device.

IO 06 MGTP NO-RING IO 06 MGTP NO-RING

An erase gap, write, or write end-of-file has been attempted on a protected tape. This message is displayed on the foreground logging device.

IO 07 BKWRD MOTION NHBITED IO 07 BKWRD MOTION NHBITED

An attempt has been made to rewind, backspace file, or backspace more than one record on a magnetic tape unit that has the backspace inhibit option enabled. This message is displayed on the foreground logging device.

IO 08 ILEG OPRTN

An IOT for magnetic tape specifies an illegal operation. (Basic magnetic tape handler only.) This message is displayed on the foreground logging device.

IO 14 WRDCNT XXXXX

A paper tape or teletype IOT has specified a word count greater than 50. This error message replaces the output on the device selected.

ITS USED

The name that was to be given to the observer's module has already been used on this system tape.

LIBE

See LOAD LIBRARY ON READER.

LOAD LIBRARY ON READER

This message may occur during the loading phase of system generation. All the programs that are required to create a user's module could not be located on the system tape during the last pass. These routines can be put in the paper tape reader and loaded from there by typing CONT(CR). At this point the operator can also cause the libraries on the system tape to be searched again by typing SYSTEM(CR).

MAN. STRT. REQ

This current scan has been enabled, but since the start mode is relative and the P coordinate is time the operator must enter a STRT command.

MEM. PAR. ERR MEM. PAR. ERR

A memory parity error was detected (probably by the idle loop) at the address given by the program counter PC in the status conditions that are listed. The system may be functioning properly, depending on the position of the error word, and it is up to the operator to abort further execution.

A recurrent parity error in one location will produce no additional message. However two or more memory parity errors should cause this message to be repeated until the operator halts the CPU.

MON. ABORTED MON. ABORTED

The preceding error condition precluded further foreground operation so that the monitor aborted the data acquisition phase and then re-initialized itself.

NEWS ABORTED NEWS ABORTED

System generation has been aborted and the operator must use the command NEWS to re-enter this phase.

NEW SYSTEM READY, HI = ZZZZZ NEW SYSTEM READY, HI = ZZZZZ

The generation of a new data acquisition system or the loading of an observer's module has been completed and it uses core memory up to location 'ZZZZZ.

NO!! NO!!

The system generator has detected an illegal data index specification or an illegal AA or QL argument specification.

NO, ALT. MODE NO, ALT. MODE

The system was in the alternate mode (NEWS, LOAD, DUMP, or PRGS) and could not execute the procedure that was specified.

NO - DISABLED NO - DISABLED

The system was disabled and was therefore unable to execute the procedure that was requested.

NO - ENABLED NO - ENABLED

The system was enabled and was therefore unable to execute the procedure that was requested.

NO, E.S. FULL NO, E.S. FULL

Another entry could not be made in the event schedule because it was full.

NO, ILLG. ARG NO, ILLG. ARG

The operator specified an illegal argument and command language refused to execute the procedure.

NO S.I. NO S.I.

A scan could not be enabled because its event schedule did not specify a sample interval, or the result of an SPB command was a sample interval of zero.

NO S.L. NO S.L.

When the system tried to enable a scan it found that one of the sample lists that was specified by the active event schedule had a length of zero. As a result the scan was not enabled.

NO STOP NO STOP

This message is to make the operator aware of the fact that a scan has been enabled which has no STOP in its event schedule.

NO STRT NO STRT

This message is to make the operator aware of the fact that a scan has been enabled which has no STRT in its event schedule.

NO, TIME PC NO, TIME PC

The SPB command cannot be used to generate a sample interval when the P coordinate is time.

NOT FOUND NOT FOUND

(1) The computer searched the system tape for a particular name and was unable to find it. When dumping a new module, the search sequence is used and this message must be written before the dump can proceed.

(2) During the loading phase of system generation the following routines were not loaded.

P = ----- P = -----

The computer is verifying that the operator's flag has been set by the FLAG command and is logging the value of the P coordinate.

PATTERN XXX DONE PATTERN XXX DONE

The last scan element in the XXXth pattern has been completed.

PATTERN XXX YYY ENABLED PATTERN XXX YYY ENABLED

Scan element YYY in the XXXth pattern has been enabled.

PC = ----- PC = -----

The pilot coordinate has been set by the P.C. command to the indicated coordinate.

PC, A, B, X1, X2, X3 PC, A, B, X1, X2, X3

The contents of the 6 registers that define the CPU status when an error condition was detected are listed after this message.

P. CORD P. CORD

The value of the P coordinate when an error condition was detected is listed after this message.

POST D. TAPE? POST D. TAPE?

A new data acquisition system has been generated or loaded and the operator is reminded that he may wish to use POST to position the data tape.

POWER OFF POWER OFF

If the power fails while the CPU is running this message is typed when power is re-applied. The monitor system will be running but all data acquisition phases are lost and must be reloaded.

PRGS ERR PRGS ERR

The command PRGS has been abondoned because an error has been detected in reading or positioning the system tape.

S.P. RESET S.P. RESET

This is a reminder that the scan pattern has been reset, possibly in order to prevent the automatic execution of a pattern after an abnormal condition was detected e.g. NO S.L. or NO. S.I.

SCAN XXXXXXX FINISHED SCAN XXXXXXX FINISHED

This message occurs at scan termination time and indicates to the operator that scan number XXXXXXX has been completed.

SCAN XXXXXXX STARTED SCAN XXXXXXX STARTED

This message occurs at scan start time and indicates to the operator that scan number XXXXXXX has started.

SEQN SEQN

See SEQUENCE ERROR.

SEQUENCE ERROR SEQUENCE ERROR

This message may occur during the loading phase of system generation. It indicates that the records are out of sequence on the system library, or on paper tape. This message is usually caused by an incorrectly punched tape. Type REREAD to attempt error correction or EXIT to abort the system generation.

SIZE SIZE

The size of two equivalent common blocks is different. This message may occur during the loading phase of system generation. The cause of the error is an incorrectly coded program.

STALL ERROR STALL ERROR

An error condition has been detected in the foreground partition which caused the CPU to stall at one location.

SUBR SUBR

See TOO MANY SUBROUTINES.

TOO LATE TOO LATE

Sampling had already started when the STRT command was received.

TOO MANY SUBROUTINES TOO MANY SUBROUTINES

This message may occur during the loading phase of system generation. The external reference table has overflowed because the programs making up the user's module have used too many subroutines.

DETAILS OF SYSTEM GENERATION

When the system generator (SGEN) has been loaded from the system tape by the command NEWS its first task is to organize the creation of the sample lists. Toward this end, the operator is asked to specify the number of data streams (i.e., sample lists) that the module will contain. At least one data stream must be specified. Sample list number one is completed first, followed by numbers two and three if necessary. An example of the generation sequence for a two-stream, two-event schedule data acquisition module is illustrated in figures 6(a) and (b). Note that in these examples the statements that are in parenthesis are not listed when Operator Switch #0 is on.

After the message 'ENTER SAMPLE INDICES' has been typed the operator must specify the sampled-data entries by referring to the index of the quantity within the A directory (see Appendix F). Before each entry is made the generator types N--, where N is the number of the entry (1-8) within the sample list. It is the sequence number N which will be used as subroutine argument in order to specify the input data for each AA or QL processing subroutine. In the example shown, the first three entries in the first sample list have the indices 13, 41, and 67 which will cause the receiver output, ZA, and the operator's flag to be sampled.

When the operator has completed the sampled-data entries he may advance to the next phase by replying with a carriage return (CR) in place of a sample index. The generator will ask the operator to enter the AA subroutine specifications next, by preceding each entry with the message N␣␣AA. The operator must complete the 6-character AA name by typing the

last 4 characters followed by a delimiter (a comma will do) and the argument N which is the sequence number that defines the source of the input data for the subroutine. In figure 6(a) the fourth entry is the processing routine AAFILT which is directed to operate on the sampled receiver output by the argument value of 1. The output that each execution of AAFILT generates will be put into data stream #1 as the fourth element in each sample set. This value is itself available as an input to subsequent processing routines as illustrated in the example by the entry AAFITb,4 in element 5 of the list. In this way a complex processing program can be built up from a sequence of smaller steps where the result from each step is part of the sample set and is therefore available to further processing by AA and QL subroutines. When all the AA entries have been made, the operator can proceed to the next phase with a carriage return in place of the AA name.

Next, the quick-look subroutine requests are appended to the sample list elements that have already been created. Only one QL subroutine can be attached to each element of the sample list. Because no additional list elements are generated, the sequence number N is discontinued and the generator types QL to indicate that the name and argument should be completed as in the previous (AA) phase. In the example given, the routine QLLOOK will display the fourth element of each data set as it becomes available from the subroutine AAFILT. A carriage return after QL will step the generator to the next phase.

If another sample list remains to be generated the procedures that have been outlined are re-entered until all

the sample lists have been specified. In the example of figure 6 the operator has proceeded to generate the second sample list and has included a series of pre-planned errors which illustrate some of the mistakes that the generator will catch. For example, there must be at least one sampled-data entry in the sample list or else no list would be possible since the AA and QL subroutines would not have data to operate upon. Therefore, when the operator tried to advance to the AA subroutine entry phase, the generator repeated the request for the first element of the list. Illegal data indices (see Appendix F) produce the reply 'NO!!' and the sequence number N is re-typed to give the operator another chance to enter a legitimate value.

When the AA and QL subroutines were specified in the example their arguments were greater than the current length of the sample list and therefore could not be linked. This error also produced the message 'NO!!' and the generator gave the operator another chance to make the correct entry. Notice also that the QL subroutine name that the operator specified, and the generator accepted, contained blanks in the last 4 characters. This is a valid name for a subroutine, but if the operator had typed only 3 blanks the delimiting comma would be taken as the last character of the subroutine name. Therefore, all 4 characters must be entered when completing a name specification.

When all the sample lists have been completed the system generator will instruct the operator in the creation of the event schedules. If the operator indicates that no event schedules are to be generated at this time (by typing a carriage return) the generator will skip this phase. The

necessary event schedules can be filled-in at any time by using the command language. In fact, during this phase the generator simply lists a series of commands from the command language that guide the operator through the creation of each event schedule. If the operator follows these instructions he will use the command that is listed and follow it by a second carriage return that signals the generator to list the next instruction. In the example of figure 6, the operator generated two event schedules in this manner and the blank lines in this phase are a result of the second carriage return.

At the top of figure 6(b) the operator tried to set the sample interval at 12 samples per beamwidth with the SPB command. This specification was rejected by the command language, not the system generator, because the pilot coordinate had been set to a time function in which samples per beamwidth has no meaning.

In the next phase the operator is asked to enter one line of comments that describe the salient features or purposes of the module that he is generating. A carriage return terminates the comments and causes the 'generation complete' message after which the operator is asked if he wishes to continue to the loading stages. If a mistake had been made earlier the operator can abort the generation by typing ABRT(CR). This reply will cause the generation sequence to terminate without entering the loading stage and the operator must use NEWS if he wishes to re-enter the generator. This abort exit can also be used during stage 1 by typing ABRT(CR) when the AA and QL subroutine names are entered. Therefore the subroutine names AAABRT and QLABRT are illegal.

Any response but ABRT to the continue question at the end of stage 1 will cause the second stage to continue. At this point the operator has defined the data acquisition module and all that remains in stage 2 is the loading of the programs that make up this module. The relocatable loader SREL (or SLDR, depending upon OPSW no. 1) is loaded from the system tape and executed so that the data acquisition programs for each data stream, plus the AA and QL subroutines, are brought into the core memory from the system tape or paper-tape libraries.

Relocatable libraries can be put on the system tape (see Appendix M) and given a four-letter name beginning with LIB. These libraries are scanned automatically by the loader and those programs that have been requested are loaded when they are found. If, at the end of the system tape, the loader has not been satisfied, the message NOT FOUND is typed, and if SREL is the loader that is being used the missing programs are listed. In the example of figure 6(b) the programs AAFILT, AAFITb, QLLOOK, AA1234, and QLbbbb could not be found on the system tape. These programs can be loaded on the high-speed paper-tape reader as indicated by the message to the operator. When an object program or library has been positioned in this reader the operator will continue the loading process by typing (C/R). If the loader is still not satisfied, the missing subroutines are listed and the paper tape loading sequence can be repeated or the operator may cause the system tape to be searched again by typing SYSTEM(CR). When the last subroutine has been loaded the reply DONE is typed and the command language informs the operator that the new system is ready and the highest address

of the module is typed. In the example, the routines that were requested were not available and so the operator typed EXIT which terminated the loader and produced an inoperable module since all the subroutines had not been loaded. Therefore, do not try to execute or dump a module in which the loading phase was not completed.

In figure 6(e) the module SCAN was generated with OPSW #0 on and loaded with OPSW #1 on, so that the modified loader (SLDR) was used. Instead of listing all the missing subroutines the message LIBE was typed and the operator caused these routines to be loaded from papertape by typing (C/R).

The sample lists and the event schedules that were generated in the first example have been listed in figure 6(b) by the CPSL and CPES commands.

APPENDIX I

ANALOG FILTER CHARACTERISTICS

The pre-sampling filters that are currently in use are 5-pole Bessel filters whose amplitude and step responses are illustrated in figures I.1 and I.2 respectively.

Two independent filters are mounted on a panel below the chart recorder. Each can be switched to a bandwidth having one of the following cut-off frequencies and delay times:

Fc (Hz)	DELAY (ms)
4.5	ΔT = 86
2.5	154
1.6	241
0.8	481
0.45	855
0.25	1540
0.16	2405
0.08	4810
0.045	8550
0.025	15400
0.016	24050
0.008	48100

The delay time of the filter is given by

$$\Delta T = \frac{0.385}{Fc}$$

and the delay at each frequency in the pass band is within 1% of this nominal value.

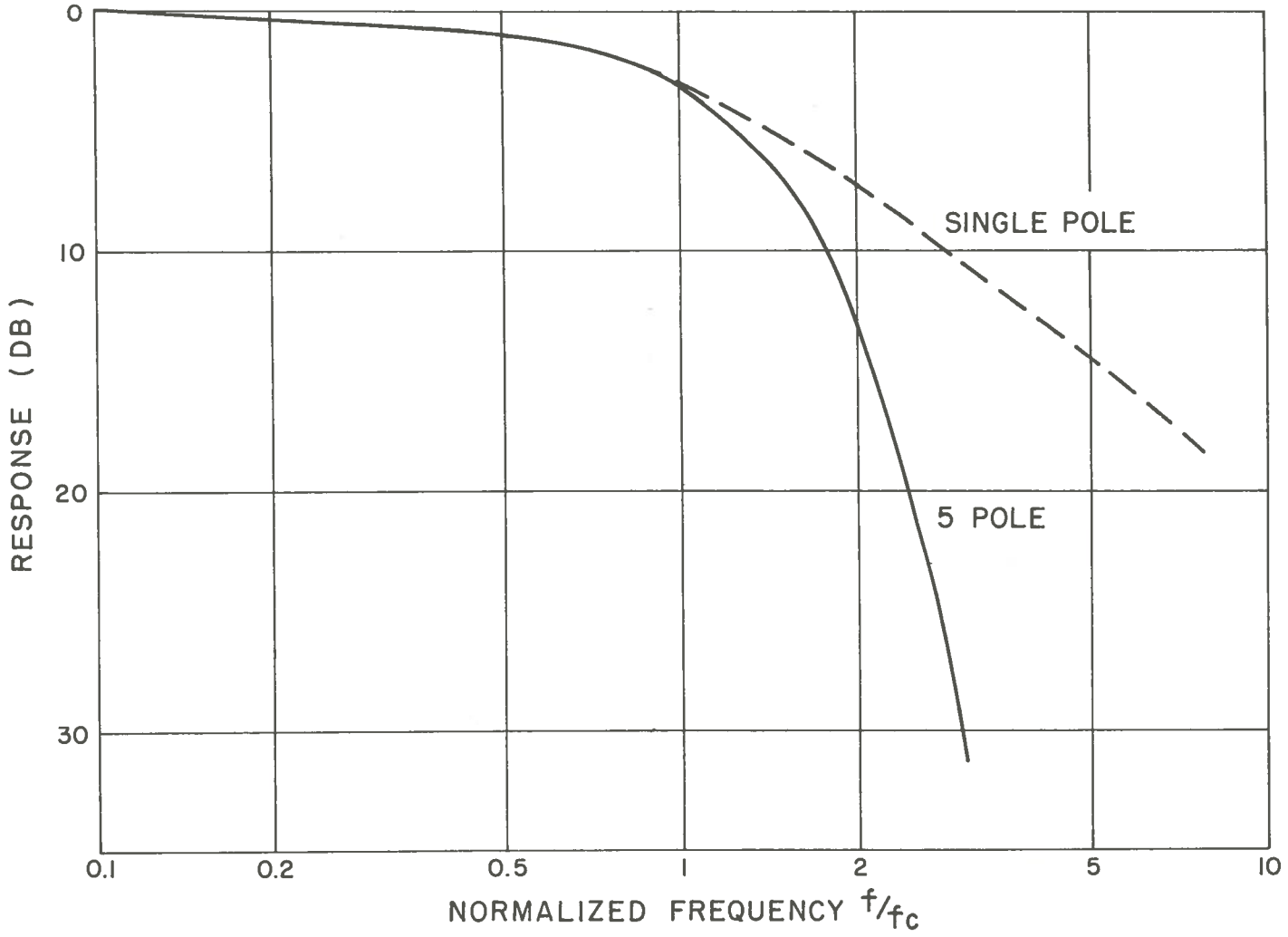


Figure I.1 Amplitude response of the pre-sampling filter

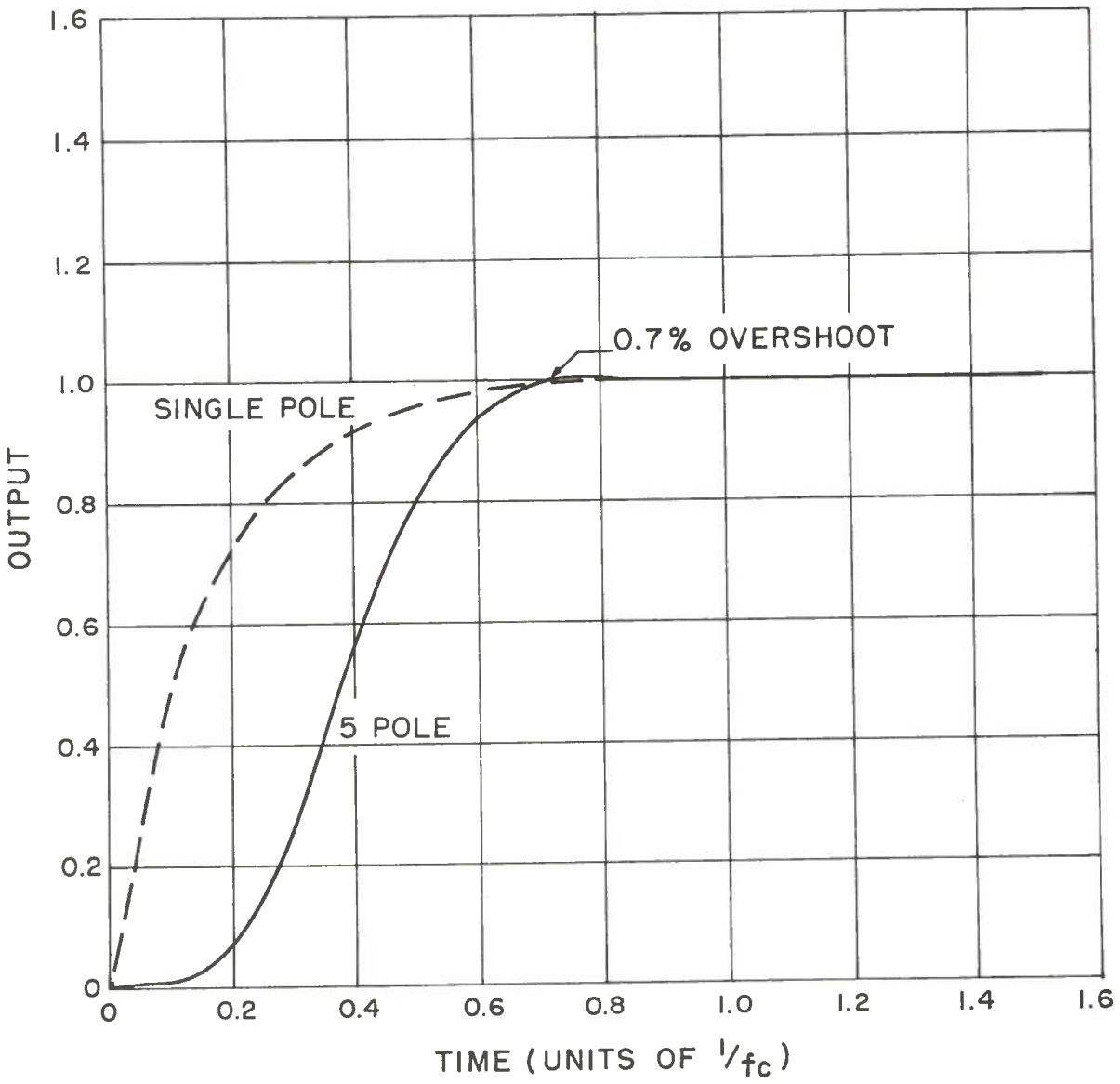


Figure I.2 Step response of the pre-sampling filter

SPECIFICATIONS FOR PROCESSING SUBROUTINES

The following specifications are guidelines to enable the Radio Astronomer to write subroutines, for use with the data acquisition system, which will be compatible with the ARO monitor. Some subroutines that have already been written are data conditioning routines (e.g., averaging or integrating), scan averaging routines, peak finding routines, etc. There are two types of subroutines: calculation subroutines and quick-look subroutines. The output data from a calculation subroutine are written on magnetic tape in the same manner as the data that are sampled directly while, in a quick-look subroutine, the output data are not written on the data tape but are output to the devices that are specified by the astronomer in the quick-look subroutine.

1. Coding Subroutines in Assembly Language

A. Calculation Subroutines

1. The subroutine name must be 6 characters in length and it must begin with AA.
2. The subroutine is entered with the input data in A Acc.
3. The subroutine is exited with output data in B Acc. and
   (i) if there is no delay between input and output values, then the A acc is zero at exit.
   (ii) if there is a delay, N, between input and output values, then the A Acc is -N at exit (e.g. in a digital filtering scheme utilizing a filter with 2N+1 weights, the delay is N

(ii) and the routine should exit with the filtered quantity in the B Acc and -N in the A Acc).

4. The subroutine should have five entry points:

(i) standard entry point

(ii) initialization entry point

(iii) termination entry point

(iv) abort entry point

(v) redo entry point

The standard entry point is the entry point for the main routine that is used when the sampled data for each sample set have been acquired. If the routine requires a special set-up procedure prior to each scan then such a routine can be entered through the initialization entry point. Similarly the termination entry point provides a means of entering a termination routine at the end of each scan. If it is necessary to "abort" a scan before completion, a different termination routine may be desired and can be entered at the abort entry point. The final entry point, which is called the "redo" entry point allows entry to a third possible termination routine when it is desired to "redo" a scan while in the midst of a series of scans. If it is not necessary to include all of the above then dummy entry points as below should be used.

```
ZZZ  **
BRU* *-1
```

5. If there is a delay between input and output samples as in 3 (ii) then the location PEAK-9 (see Figure J-1) must contain the delay N. This value is needed during initialization of the Analog Sample Processors. If there is no delay then this value should be zero.
6. It is necessary that the order of the entry points conform to that illustrated in Figure J-1 and that provision be made for all entry points plus the delay location regardless of whether or not they are used. Figure J-1 contains an example of the format of a Calculation Subroutine. It is noted that the names PEAK, HALT, STOP, REDO, and LIZE were chosen only for purposes of illustration. The astronomer is free to choose which letters and numerals he wishes with the restriction that each name does not exceed 4 characters, the first of which must be a letter.

B. Quick-Look Subroutines

1. The subroutine name must begin with QL
2. The subroutine is entered with the argument in A Acc.
3. The subroutine should have five entry points:
   (i) standard entry point
   (ii) initialization entry point
   (iii) termination entry point
   (iv) abort entry point
   (v) redo entry point

The format of the Quick-Look Subroutine is the same as the Calculation Subroutine except the name must begin with QL (e.g., QLMEAN).

C. General

1. It is important that the execution time of the astronomer's subroutine does not exceed the sampling period of the data upon which it is operating.
2. During I/O operations (e.g., D to A output for Data Display) Wait Flags should not be used with AOP or MOP instructions as they effectively lock out the interrupt system. The following Skip technique is suggested:

```
AOP  '75
BRU  *-1
```

3. The astronomer's subroutine should be continuously executable; i.e., there should be no HLT commands in the program.
4. AA and QL subroutines need not save and restore index registers at the main entry point because these functions are implemented in the monitor. Index register 1, however, is used by the SEL library programs and should be avoided if possible unless the integrity of this register is maintained within the processing subroutine.

```
      NAME AAPEAK,PEAK
      DATA 0
      ZZZ  **
      BRU  REDO
      ZZZ  **
      BRU  HALT
      ZZZ  **
      BRU  STOP
      ZZZ  **
      BRU  LIZE
PEAK  ZZZ  **


      BRU* PEAK
REDO


      BRU* PEAK-8
HALT


      BRU* PEAK-6
STOP


      BRU* PEAK-4
LIZE


      BRU* PEAK-2
      END
$
```

FIGURE J.1

FORMAT OF A CALCULATION SUBROUTINE

WRITTEN IN THE ASSEMBLER LANGUAGE

2. Coding AA and QL Subroutines in FORTRAN

The facility of coding on-line data reduction subroutines in Fortran greatly enhances the usefulness of the ARO data acquisition system. Most astronomers have at least a rudimentary knowledge of Fortran, and should be able to write and debug their routines on the IBM 360 before going to ARO. All rules applying to AA and QL subroutines mentioned previously apply to both assembly language routines, and to Fortran routines. The following rules must be followed when writing on-line routines in FORTRAN.

1) READ, WRITE, ENDFILE, REWIND, and BACKSPACE statements must not be used. The method used for Fortran input/output is incompatible with the real-time data acquisition system. READ and WRITE statements may be used during the off-line debugging stage.
2) PAUSE or STOP statements must not be used as they violate the condition that the subroutine be continuously executable.
3) All Fortran statements not mentioned previously are allowed; however, certain extensions to the Fortran language available using OS/360 are not available. In particular, mixed mode expressions are not allowed. See the SEL 840A FORTRAN IV REFERENCE MANUAL[4] for details.
4) The following instructions have been added to the Fortran language to permit the coding of the initialization, termination, abort, and redo entry points.

```
ENTRY
INITIALIZE ENTRY
TERMINATE ENTRY
ABORT ENTRY
REDO ENTRY
```

The appropriate ENTRY statement must be used for each of the four special entry points, and contains a statement number pointing to the portion of the routine (i.e., initialize, terminate, abort or redo) to be executed from this entry point.

The following coding must be used as the first executable coding in the Fortran AA or QL subroutine.

```
DATA N/0/
ENTRY S1
ENTRY S2
ENTRY S3
ENTRY S4
STA   INPUT
```

where S_1, S_2, S_3, and S_4 are the statement numbers of the REDO ENTRY, ABORT ENTRY, TERMINATE ENTRY, and INITIALIZE ENTRY statements, respectively. The integer variable INPUT is set equal to the parameter passed to this routine. For example, this parameter will be radiometer output if this routine is attached to index 13 during system generation. The return from any portion of the subroutine is accomplished by the RETURN statement.

5) An OUTPUT statement has been added to the Fortran Compiler to give output capabilities to AA and QL subroutines.

The OUTPUT statement should be coded:

$$[s_1]\ \text{OUTPUT}\ [(\text{unit no.})]\left\{\begin{array}{l}\text{variable [/[n]Iw/]}\\ \text{variable [/[n]Ow/]}\\ \text{variable [/[n]Aw/]}\\ \text{variable [/Fw.d/]}\\ \text{/n H Hollerith string/}\end{array}\right\},\left\{\begin{array}{c}\\ \\ \\ \\ \\ \end{array}\right\}\left\{\ldots\right\}$$

$\{\ \}$ indicates a choice must be made.

[ ] indicates an optional item.

In its simplest form, the OUTPUT statement reduces to:

OUTPUT variable, variable, ...

S_1: a Fortran statement number

unit number: The unit number indicates the logical unit to which the output is to be directed. It is an unsigned integer constant, or an unsigned octal constant preceded by a quote ('). If this field is omitted, the foreground logging device (logical unit '20) is used.

variable: The variable specified in an OUTPUT statement must be a non-subscripted real or integer variable that is defined within this subroutine. It must not be an array name with subscripts, or a variable passed to this subroutine as an argument in a CALL list. The first few elements of an integer array may be output by specifying the array name without subscripts, and specifying the number of elements to be output (n).

Format specification: The output format specification is enclosed by slashes and indicates how the data are to be output. If this field is missing, integer variables are output with an I8 format, and real variables are output with an F14.6 format.

n : Indicates the number of words to be output using the following output type and field width. The n numbers output are from consecutive core locations, the first of which is specified by the variable name. If n is omitted, it is set equal to one.

I,O,A,F Indicates the output type.

I will cause the data to be output in integer format.

O will cause the data to be output in octal format.

A will cause the data to be output in character format.

F will cause the data to be output in floating point format.

w : Indicates the field width of the output. An octal or decimal number begins with a blank, which is not considered to be part of the field width. The field width for octal and decimal output must be less than or equal to 8. The field width for character output (A format) may have any value between 1 and 31 inclusive. A1, A2, A3 format will output the leftmost 1, 2, or 3 characters in each word. A4 will output the entire word as four characters. A5, A6, A7...will output the entire word as four characters and fill the

remaining characters specified by the field width with blanks.
For floating point output, w indicates the entire field width.

d : Indicates the number of decimal places, and should be less than or equal to 6. w must be greater than d + 2 and less than 17 for floating point output.

Hollerith String: Literal data may be included in the OUTPUT statement by the inclusion of a Hollerith string, enclosed by slashes. In this case n indicates the number of characters in the string.

The output generated by the OUTPUT statement includes the name of the variable. By choosing meaningful variable names, the amount of Hollerith data can be kept to a minimum. Eight characters are generated for each variable specified: 1 blank, the 6-character Fortran name, and an equal sign.

EXAMPLE:

```
 I = 5
 RADX = 3.59
 RADY = - 1.005
 ISTAT = 738
 OUTPUT  I, RADX, ISTAT/I4/
OUTPUT ('20)/17 HRADIOMETERbOUTPUT/, RADY/F12.6/
```

will produce the following output:

~~b~~Ibbbbb=bb0000005bRADXbb=bb0000003.590000bISTATb=bb738
RADIOMETERbOUTPUTbbbbRADXbb=b-0001.005000

6) The in-line coding feature of the compiler has been extended to accept almost all (see ref 14) assembler instructions. Critical loops and other difficult areas may be written in a pseudo-assembly language for more efficient coding.
7) The directory is referenced through labeled common by Fortran subroutines. Note that A(1) contains the zeroth entry in the directory, part A.
8) A WAIT statement has been added to the Fortran compiler to generate an I/O wait within an AA or QL subroutine. This statement must immediately follow a CALL IOCS instruction and should be used only for INPUT. The WAIT statement causes control to be returned to the monitor with the condition that control will be returned upon the completion of the input.
9) Input of data must still be accomplished via the in-line coding feature of the Fortran compiler. See the IOCS Users Manual for details.
10) Efficiency of code produced by the Fortran compiler.

The code produced by the SEL 840A Fortran IV compiler is quite good for a one-pass, in-core compiler. The quality of the coding may be increased slightly if time or core storage is at a premium by adhering to the following rules.

```
      SUBROUTINE AAPEAK                                    1
      INTEGER A(80),B(160),C(40),RESULT                    2

      COMMON/DRTYA/A
      COMMON/DRTYB/B                                       4
      COMMON/DRTYC/C

      DATA N/0/
      ENTRY 1000
      ENTRY 2000                                           5
      ENTRY 3000
      ENTRY 4000
      STA   INPUT
        .                                                  6
        .
      LBA   RESULT
      LAA   N
      NEG                                                  7
      RETURN

1000  REDO ENTRY                                           8
        .
        .                                                  9
        .
      RETURN                                              10

2000  ABORT ENTRY                                         11
        .
        .                                                 12
        .
      RETURN                                              13

3000  TERMINATE ENTRY                                     14
        .
        .                                                 15
        .
      RETURN                                              16
4000  INITIALIZE ENTRY                                    17
        .
        .                                                 18
        .
      RETURN                                              19

      END                                                 20

$                                                         21
```

FIGURE J-2

FORMAT OF A FORTRAN-CODED CALCULATION ROUTINE

(i) The Logical If statement is much less efficient than the Arithmetic If statement. The Logical If statement could be used during the debugging stage, and then replaced by the equivalent Arithmetic If statement in order to conserve core.

(ii) Variables initialized to the same value should appear in sequential statements, for example:

```
I = 0
J = 0
KL = 0
```

(iii) Variables which do not change in value should be set by a DATA statement and not by an Arithmetic Assignment statement.

e.g., use DATA PI/3.14159/

and not PI = 3.14159

(iv) Integer arithmetic should be used wherever possible instead of the time consuming floating point arithmetic.

(v) Complex or double precision arithmetic should never be used if it can be avoided. The complex and double precision simulation package occupies a large amount of core storage.

(vi) Equivalence statements do not generate any code, but merely indicate to the compiler the order in which to store variables. This statement along with labeled common may be used to pass arguments between subroutines more efficiently than listing the arguments in a CALL statement.

J-12.0 SPECS. FOR PROCESSING SUBROUTINES

EXPLANATION (Figure J-2):

1 The NAME of the subroutine must begin with AA if it is a calculation subroutine or QL if it is a quick-look subroutine. If it is a subroutine called by an AA or QL subroutine, the name must not begin with AA or QL. AA and QL subroutines must not have any arguments specified in the SUBROUTINE statement.

2 & 4 The arrays A,B, and C specify the directory, Parts A,B, and C. These statements are included only if it is necessary to reference the directory. See Appendix F for the directory - Part A, and Appendix K for the directory - Part B. Note that the first directory index is zero, so that one must be added to the directory index to compute the proper Fortran index, i.e., A(45) represents index 44 or Right Ascension.

3 Any specification statements (Integer, Real, Double Precision, Complex, and Dimension) must appear here. Double precision and complex variables require a large number of special routines and should be used only if absolutely necessary. REAL variables require two consecutive core locations, and therefore use twice as much core as Integer variables.

5 This sequence of instructions defines the five entry points required by the data acquisition system. N is the delay in samples required by this routine; e.g., for a symmetric digital filter with 25 points, the delay would be 12 samples. For most routines, however, this value is zero. The sequence of entry statements passes control to the proper portion of coding. The

5 one parameter passed to the main-line routine is stored in the variable INPUT. The choice of the statement numbers 1000, 2000, 3000, and 4000 is arbitrary.

6 This is the main body of the subroutine. Control is given to this section of code each time a sample is taken. Analog samples passed to this section are corrected for the delay time. Note that when a scan is terminated (/STOP), delayed quantities enroute are ignored. If 61 samples are expected and the delay time is 2.2 seconds, only 58 passes will be made through this subroutine (assuming a sample interval of 1 sec).

7 This sequence of coding is the return coding for the main-line routine only. The negative value of the filter delay must be in the A register, and the calculated result must be in the B-register. The three in-line instructions may be omitted if this is a QL routine. If N is zero as in this example, the coding

```
LAA  N
NEG
```

may be replaced by

```
CLA
```

8 This statement defines the beginning of the REDO portion of code and must be present even if there is no processing required for REDO.

9 The coding that is to be executed when /REDO is typed.

10 Return from the REDO phase of the program.

11-13 The coding which will be executed when /ABRT is typed. 11 and 13 must be present, 12 is optional.

14-16 The coding which will be executed when /STOP is typed, or when a scan is terminated.

17-19 The coding which will be executed when /NABL is typed or when the next scan in a scan pattern is initialized.

20 The last statement in the program must be an END statement.

21 A $, carriage return and line feed must be the last record punched on a tape.

B DIRECTORY

The B directory is the second part of the common area described in Appendix F and is composed of 160 consecutive core memory locations. It contains the 3 event schedules, the 3 sample lists, and the scan pattern information which are necessary to carry out an observing program. The format of the B directory is illustrated in TABLE K-1.

K-2.0 ELEMENTS OF THE B DIRECTORY

MASTER EVENT SCHEDULE 1

0	P coordinate mnemonic		(Negative if temporal)
1	Sample interval	1	Positive is on
2	Sample interval	2	Zero is off
3	Sample interval	3	
4	P coordinate value		
5	Event		
6	P coordinate value		
7	Event		
8			
9			
10			
11			8 Events
12			
13			
14			
15			
16			
17			
18	P coordinate value		
19	Event		

MASTER EVENT SCHEDULE 2

20	P coordinate mnemonic		
21	Sample interval	1	
22	Sample interval	2	
23	Sample interval	3	
24	P coordinate value		
25	Event		
26			
27			
28			
29			
30			
31			8 Events
32			
33			
34			
35			
36			
37			
38			
39			

TABLE K-1

MASTER EVENT SCHEDULE 3

40	P coordinate mnemonic		
41	Sample interval	1	
42	Sample interval	2	
43	Sample interval	3	
44	P coordinate value		
45	Event		
46			
47			
48			
49			
50			
51			8 events
52			
53			
54			
55			
56			
57			
58			
59			

SAMPLE LIST 1

60	List length		
61	Time delay		
62	Block length		
63			
64		Sample 1	
65			
66			
67		Sample 2	
68			
69			
70		Sample 3	
71			
72			
73		Sample 4	
74			
75			
76		Sample 5	8 Samples

TABLE K-1 (cont'd)

SAMPLE LIST 1 (cont'd)

77
78
79 Sample 6
80
81
82 Sample 7
83
84
85 Sample 8
86

SAMPLE LIST 2

87 List length
88 Time delay
89 Block length
90
91
92
93
94
95
96
97
98
99
100 8 Samples
101
102
103
104
105
106
107
108
109
110
111
112
113

TABLE K-1 (cont'd)

SAMPLE LIST 3

114	List length	
115	Time delay	
116	Block length	
117		
118		
119		
120		
121		
122		
123		
124		8 Samples
125		
126		
127		
128		
129		
130		
131		
132		
133		
134		
135		
136		
137		
138		
139		
140		
141		
142		
143		
144		
145		
146		
147		
148		
149		

TABLE K-1 (cont'd)

SCAN PATTERN DEFINITION

150	Number of scan patterns	
151		
152		
153		
154		Scan pattern
155		Sequence number
156		
157		
158		
159	0 End flag	

TABLE K-1 (cont'd)

VARIABLES RETURNED BY GETSCN /FLAGS/

LABELED COMMON

Z	NAME	SET BY	USE
1	ERROR	Any routine	=0, no errors >0, error - see section ERROR CODES =0 initially (set by user)
2	WARN	Any routine	=0, no warning >0, warning - see section ERROR CODES =0 initially (set by user)
3	ABRTCD	Any routine	=0, no error >0, terminal error - see section ERROR CODES =0 initially (set by user)
4	STIND1	GETSCN	Index for stream 1 = number of sample sets in the scan
5	STIND2	GETSCN	Index for stream 2
6	STIND3	GETSCN	Index for stream 3
7	CLPTR1	GETSCN	Index for calibration event array (CLEVT1) = number of entries in array
8	CLPTR2	GETSCN	Index for calibration event array (CLEVT2) - stream 2
9	CLPTR3	GETSCN	Index for calibration event array (CLEVT3) stream 3
10	FLGPT1	GETSCN	Index for operator flag array (OPFLG1) = number of entries in array

L-2.0 GETSCN VARIABLES

Z	NAME	SET BY	USE
11	FLGPT2	GETSCN	Index for operator flag array (OPFLG2) - stream 2 = 0 if no stream 2
12	FLGPT3	GETSCN	Index for operator flag array (OPFLG3) - stream 3 = 0 if no stream 3
13	SCNCOD	DCDHDR	=0 normal termination =1 Redo typed =2 Scan aborted =3 End-of-tape detected
14			
15			
16	SYPTR1	GETSCN	Index for system status array (SYSST1) = number entries in array
17	SYPTR2	GETSCN	Same - stream 2 = 0 if no stream 2
18	SYPTR3	GETSCN	Same - stream 3 = 0 if no stream 3
19			
20			
21			
22	NPPDS1	GETSCN	Number of points per sample set Stream 1
23	NPPDS2	GETSCN	Same - stream 2
24	NPPDS3	GETSCN	Same - stream 3
25	MODE	GETSCN	Mode = 0 if GETSCN routine input all of scan Mode = -1 if there were too many data for the specified array. The next call to GETSCN will input the remaining data

Z	NAME	SET BY	USE
26			
27			
28			
29			
30			
31	MXDIM1	USER	The maximum dimensions for stream 1 if single dimension T(i) MXDIM1=i if > 1 dimension T(i,j) MXDIM1=i * j
32	MXDIM2	USER	The maximum dimension for stream 2
33	MXDIM3	USER	The maximum dimension for stream 3
34			
35			
36			
37			
38			
39			
40			

* Entries 1-24 are set to zero initially by GETSCN

Z	NAME	SET BY	USE
20	CLEVT1	GETSCN	A table of calibration events for scan just input (stream 1) CLEVT1 (1,i) = 1,2,3, or 4 depending upon event CLEVT1 (2,i) = sample set number at which event occurred
20	CLEVT2	GETSCN	As above - stream 2 Calibration events are 1) calibration on (initiated) 2) calibration up to temperature 3) calibration off 4) calibration down (baseline)
20	CLEVT3	GETSCN	Same - stream 3
20	OPFLG1	GETSCN	A table of operator flags set during the scan. OPFLG1(1,i) is the value of the flag OPFLG1(2,i) is the sample set number when the flag was typed
20	OPFLG2	GETSCN	*Same - stream 2
20	OPFLG3	GETSCN	*Same - stream 3
20	SYSST1	GETSCN	A table of system status SYSST1(1,i) is the value of the system status SYSST1(2,i) is the sample set during which the system status changed

* Although the value of the operator flag and system status, and the calibration events are the same for all data streams, the sample set index will probably be different.

Z	NAME	SET BY	USE
20	SYSST2	GETSCN	Same - stream 2
20	SYSST3	GETSCN	Same - stream 3
10	SLTDS1	GETSCN	A table indicating the make-up of sample set for data stream 1 The value is the index to the DIRECTORY and indicates what is being sampled (NPPDS1,2,3 give the number of entries in this array)
10	SLTDS2	GETSCN	same - stream 2
10	SLTDS3	GETSCN	same - stream 3

WARNING CODES

WARN	ROUTINE	EXPLANATION	ACTION
1	DCDHDR	Calculated length of scan header or trailer ≠ block size read	none
2	GETSCN	Length of data portion of data block is not a multiple of 4 bytes	Last partial WORD is truncated.
3	GETSCN	ID code for end-of-tape has been read	None - but any further calls to GETSCN will abort the job.
4	GETSCN	BLOCK NUMBER IN DATA HEADER ≠ calculated block no. stream 1	Calculated block no. re-adjusted.
5	GETSCN	Same - stream 2	
6	GETSCN	Same - stream 3	
7	GETSCN	No. samples/sample set > 8 (probably incorrect header or trailer) - stream 1	
8	GETSCN	Same - stream 2	
9	GETSCN	Same - stream 3	
10	GETSCN	Attempt to input a scan larger than the array reserved for it- only stream 1 checked	Z (25) (MODE) set to -1 and control returned to user. The remaining data in the scan are input when GETSCN is next called.

ERROR CODES

ERROR	ROUTINE	EXPLANATION	ACTION
1	GETSCN	More than 2 EOF's encountered reading scan header block	Return with error code, no data input.
2	GETSCN	1st BLOCK is not scan header	Return with error code, no data input.
3	GETSCN	EOF encountered reading data block	Return with error code. Data probably okay, but no trailer.
4	GETSCN	STREAM no. in data header block is not equal to 1, 2, or 3	Return with error code.
5	GETSCN	A BLOCK ID CODE that is not 0, 1, or 2 has been detected	Return with error code.
6	GETSCN	A scan header block encountered while reading data	Backspace tape 1 record, return with error code.

TERMINAL ERROR CODES

ABRTCD	ROUTINE	EXPLANATION	ACTION
1	GETSCN	Another call to GETSCN has been made after an end-of-tape code has been detected	Job aborted
2	ERROUT	Excessive number of errors (25)	Job aborted

```
C
C      USE HDR FOR REAL VARIABLES.
C      USE IDR FOR INTEGER VARIABLES.
C      USE JDR FOR HALF-WORD INTEGER VARIABLES.
C
C IDR
C HDR    JDR
C 001            SCAN HEADER FLAG  ''SHDR''
C 002            DATE                                                  INTEGER
C 003 005/006    PROJECT NUMBER              / PROGRAM NUMBER
C 004 007/008    OBSERVER                    / OPERATOR
C 005 009/010    LOG NUMBER                  / SCAN NUMBER
C 006            SPARE
C 007            SPARE
C 008            START TIME (EST  IN HOURS)                            REAL
C 009            SYSTEM STATUS                                         INTEGER
C 010            ALARM STATUS                                          INTEGER
C 011            RECEIVER STATUS AT START OF SCAN                      INTEGER
C 012            CALIBRATION SETTING                                   INTEGER
C 013            SPARE
C 014            SPARE
C 015            SPARE
C 016            RECEIVER STATUS AT END OF SCAN                        INTEGER
C 017            FILTER DELAY   (SECONDS)                              REAL
C 018            SPARE
C 019            SPARE
C 020            SPARE
C 021            POLARIZATION ANGLE AT START OF SCAN  (RADIANS)        REAL
C 022            AZIMUTH AT START OF SCAN  (RADIANS)                   REAL
C 023            ZENITH ANGLE AT START OF SCAN  (RADIANS)              REAL
C 024            DECLINATION AT START OF SCAN  (RADIANS)               REAL
C 025            HOUR ANGLE AT START OF SCAN  (RADIANS)                REAL
C 026            RIGHT ASCENSION AT START OF SCAN   (RADIANS)          REAL
C 027            SIDEREAL TIME AT START OF SCAN (A.R.O. ) (RADIANS)    REAL
C 028            SOLAR TIME (E.S.T.)     (RADIANS) START OF SCAN       REAL
C 029            COMPUTER TIME IN MIN.                                 INTEGER
```

```
C 030          COMPUTER TIME IN SECONDS                                  INTEGER
C 031          SPARE
C 032          SPARE
C 033          SPARE
C 034          SPARE
C 035          POLARIZATION ANGLE AT END OF SCAN  (RADIANS)              REAL
C 036          AZIMUTH AT END OF SCAN  (RADIANS)                         REAL
C 037          ZENITH ANGLE AT END OF SCAN  (RADIANS)                    REAL
C 038          DECLINATION AT END OF SCAN  (RADIANS)                     REAL
C 039          HOUR ANGLE AT END OF SCAN  (RADIANS)                      REAL
C 040          RIGHT ASCENSION AT END OF SCAN  (RADIANS)                 REAL
C 041          SIDERIAL TIME AT END OF SCAN AT A.R.O. (RADIANS)          REAL
C 042          SOLAR (EST) TIME AT END OF SCAN  (RADIANS)                REAL
C 043          COMPUTER TIME IN MINUTES AT END OF SCAN                   INTEGER
C 044          COMPUTER TIME IN SECONDS AT END OF SCAN                   INTEGER
C 045          SPARE
C 046          SPARE
C 047          SPARE
C 048          SPARE
C 049          SPARE
C 050 099/100  TEMPERATURE DEG. FAHR.     / PRESSURE MM. HG.
C 051 101/102  RELATIVE HUMIDITY          / WIND VELOCITY
C 052 103/104  NUMBER SAMPLE STREAMS      / P COORDINATE INDEX  (0-7)
C 053          SPARE
C 054          SPARE
C 055          RESERVED FOR SCAN RATE.
C 056          SAMPLE INTERVAL IN RADIANS                                REAL
C 057          SPARE
C 058          SOURCE NAME ( 12 CHARACTERS LONG)                         INTEGER
C 059          SOURCE NAME CONT'D
C 060          SOURCE NAME CONT'D
C 061 121/122  SAMPLE LIST START INDEX    / NUMBER OF ENTRIES IN LIST
C 062 123/124  CALIBRATION EVENTS INDEX   / NUMBER OF EVENTS
C 063 125/126  OPERATOR FLAG INIT INDX    / NUMBER OF FLAGS
C 064 127/128  SYSTEM STATUS INIT INDEX   / NUMBER  OF ENTRIES.
C 065          SPARE
```

```
C 066          SPARE
C 067 133/134  NO. SMPL SETS IN SCAN     / NO. RECORDS FOLLOWING
C 068          SPARE
C 069          SPARE
C 070          SPARE
C 071          PARALLACTIC ANGLE--START OF SCAN  (RADIANS)        REAL
C 072          PARALLACTIC ANGLE--END OF SCAN  (RADIANS)          REAL
C 073 145/146  SCAN NO. OF CALIBRATION   / SCAN TERMINATION CODE
C 074          RECEIVER WAVELENGTH IN CM.                         REAL
C
C 075-100 SAMPLE LIST, CALIBRATION EVENTS, OPERATOR FLAGS, SYSTEM STATUS.
C 075 149/150 FIRST QUANTITY SAMPLED.   /SECOND QUANTITY SAMPLED.
C 076 151/152 THIRD QUANTITY SAMPLED.   /FOURTH QUANTITY SAMPLED.
C 077 153/154 FIFTH QUANTITY SAMPLED.   /SIXTH  QUANTITY SAMPLED.
C 078 155/156 SVNTH QUANTITY SAMPLED.   /EIGTH  QUANTITY SAMPLED.
C 079 157/158 FIRST CALIBRATION EVENT   /SAMPLE SET WHERE EVNT OCCURRED.
C 080 159/160 SECOND CALIBRATION EVENT  /SAMPLE SET WHERE EVNT OCCURRED.
C              ETC. FOR ALL CALIBRATIONS IN THE SCAN  MAX NO.=12
C
C     THE INDEX VALUE FOR THE FIRST CALIBRATION EVENT IS IN JDR(123)
C     THIS INDEX IS PRESET TO  79 AT PRESENT.
C     THE NUMBER OF CALIBRATION EVENTS IS IN JDR(124).
C
C XXX IDR(XXX)=THE VALUE OF THE OPERATOR FLAG.
C     IDR(XXX+1)=THE SAMPLE SET AT WHICH THE FLAG WAS SET.
C     XXX IS IN JDR(125)
C     THE NUMBER OF OPERATOR FLAGS IS IN JDR(126)
C
C YYY IDR(YYY)=THE VALUE OF SYSTEM STATUS.
C     IDR(YYY+1)=THE SAMPLE SET AT WHICH SYSTEM STATUS CHANGED.
C     YYY IS IN JDR(127)
C     THE NUMBER OF SYSTEM STATUS CHANGES IS IN JDR(128)
C
      SUBROUTINE HEADR1(HDR, IDR, JDR,A,B)
      INTEGER A(80,2), B(160,2)
C
```

```
C
      INTEGER ERROR, WARN
C
      INTEGER                    STIND1, STIND2, STIND3, CLPTR1, CLPTR2,
     2        CLPTR3, FLGPT1, FLGPT2, FLGPT3, SYPTR1, SYPTR2, SYPTR3,
     3        SCNCOD
C
      INTEGER CLEVT1(2,10), CLEVT2(2,10), CLEVT3(2,10),
     1        OPFLG1(2,10), OPFLG2(2,10), OPFLG3(2,10),
     2        SYSST1(2,10), SYSST2(2,10), SYSST3(2,10)
C
      INTEGER SLTDS1(10), SLTDS2(10), SLTDS3(10)
      COMMON/STATUS/CLEVT1, CLEVT2, CLEVT3, OPFLG1, OPFLG2, OPFLG3,
     1              SYSST1, SYSST2, SYSST3, SLTDS1, SLTDS2, SLTDS3
C
      COMMON/FLAGS/ Z(120)
C
      EQUIVALENCE (Z(1), ERROR), (Z(2), WARN), (Z(3), ABRTCD),
     1 (Z(4), STIND1), (Z(5), STIND2), (Z(6), STIND3), (Z(7), CLPTR1),
     2 (Z(8), CLPTR2), (Z(9), CLPTR3), (Z(10), FLGPT1), (Z(11), FLGPT2),
     3 (Z(12), FLGPT3), (Z(13), SCNCOD),
     4                  (Z(16), SYPTR1), (Z(17), SYPTR2),
     5 (Z(18), SYPTR3),
     6                  (Z(22), NPPDS1), (Z(23), NPPDS2),
     7 (Z(24), NPPDS3), (Z(25), MODE)
C
      EQUIVALENCE (Z(31), MXDIM1), (Z(32), MXDIM2), (Z(33), MXDIM3)
      REAL*4 TWOPI/6.283185/, PI/3.141593/
C
      INTEGER IDR(100)
C
      INTEGER*2 JDR(200)
      REAL HDR(100)
C
C
      DATA IHDR/4HSHDR/
```

```
C
C
      DO 5010 I=1,100
 5010 IDR(I)=0
C
C--------FILL IN HDR(1-20)
C
      IDR(1)=IHDR
      IDR(2)=A(2,2)
      JDR(5)=A(1,2)
      DO 5020 I=6,9
 5020 JDR(I)=A(I-3,2)
      JDR(10)=A(7,1)
      DO 5021 I=8,12
 5021 IDR(I)=A(I,1)
      HDR(8)=BFTIME(IDR(8))
      IDR(16)=A(I,1)
      IDR(16)=A(11,2)
      HDR(17)=B(62,1)/1000.0
C
C
C--------HDR(21-44).....COORDINATES AT BEGINNING AND END OF SCAN.
C
      DO 5030 I=21,28
      HDR(I)=BFRADN(A(I+19,1))
 5030 HDR(I+14)=BFRADN(A(I+19,2))
C
C--------CHANGE RANGE OF DEC AND ZA TO -PI/2..+PI/2.
C
      IF(HDR(23) .GT. PI) HDR(23)=HDR(23)-TWOPI
      IF(HDR(24) .GT. PI) HDR(24)=HDR(24)-TWOPI
      IF(HDR(37) .GT. PI) HDR(37)=HDR(37)-TWOPI
      IF(HDR(38) .GT. PI) HDR(38)=HDR(38)-TWOPI
C
C--------FILL IN COMPUTER TIME.
C
```

```
      IDR(29)=A(48,1)
      IDR(30)=A(49,1)
      IDR(43)=A(48,2)
      IDR(44)=A(49,2)
C
C--------FILL IN MET DATA.
C
      DO 5051 I=99,102
 5051 JDR(I)=A(I-38,1)
C
C--------NUMBER OF SAMPLE STREAMS AND P.COORDINATE INDEX.
C
      JDR(103)=A(69,1)
      JDR(104)=A(74,1)
C
C--------SAMPLE INTERVAL.
C
      INDEX=(A(80,1)-1)*20+2
      HDR(56)=BFRADN(B(INDEX,2))
C
C--------NAME OF SOURCE.
C
      IDR(58)=A(77,1)
      IDR(59)=A(78,1)
      IDR(60)=A(79,1)
C
C--------SAMPLE LIST.
C
 5100 JDR(121)=75
      JDR(122)=NPPDS1
      DO 5110 I=149,156
 5110 JDR(I)=SLTDS1(I-148)
C
C--------CALIBRATION  EVENTS.
C
 5130 NAE=79
```

```
C              NAE (NEXT AVAILABLE ENTRY).
       IF(CLPTR1 .EQ. 0) GO TO 5150
       JDR(123)=NAE
       JDR(124)=CLPTR1
       DO 5135 I=1,CLPTR1
       JDR(2*NAE-1)=CLEVT1(1,I)
       JDR(2*NAE)=CLEVT1(2,I)
       NAE=NAE+1
 5135 CONTINUE
C
C--------OPERATOR FLAGS.
C
 5150 IF(FLGPT1 .EQ. 0) GO TO 5180
       JDR(125)=NAE
       JDR(126)=FLGPT1
       DO 5155 I=1,FLGPT1
       IDR(NAE)=OPFLG1(1,I)
       IDR(NAE+1)=OPFLG1(2,I)
       NAE=NAE+2
 5155 CONTINUE
C
C--------SYSTEM STATUS.
C
 5180 IF(SYPTR1 .EQ. 0) GO TO 5200
       JDR(127)=NAE
       JDR(128)=SYPTR1
       DO 5185 I=1,SYPTR1
       IDR(NAE)=SYSST1(1,I)
       IDR(NAE+1)=SYSST1(2,I)
       NAE=NAE+2
 5185 CONTINUE
C
C--------NUMBER OF SAMPLE SETS/SCAN.
C
 5200 JDR(133)=STIND1
       JDR(134)=NPPDS1*STIND1/1000+1
```

```
C
C--------PARALLACTIC ANGLE.
C
      HDR(71)=PARANG(HDR(24), HDR(25))
      HDR(72)=PARANG(HDR(38), HDR(39))
      JDR(146)=SCNCOD
C--------RECEIVER WAVELENGTH HERE.
C
      RETURN
      END
```

THE SAMPLING ALGORITHM

In order to allow for telescope control by sources outside of, and not necessarily related to, the data acquisition programs, the sampling points are derived from the raksyn coordinate data alone. The sampling algorithm must derive the times for these sampling points to an accuracy that is comparable to the finest sampling grid that can be specified.

A new value of the P coordinate is received from the raksyn encoders at intervals of about 20 ms. A reasonableness test is used to remove occasional large errors that are caused by dirty or worn encoders. The residual noise and the steps that are caused by changes in the last bit are filtered to produce a smooth track as indicated in figure M.1. When sampling is in progress the recent history of this track is used to predict the position that the telescope will be at when the next value of the P coordinate arrives. If one or more sample positions will be traversed during this 20 ms interval, the estimated time (Δt) that it will take to reach this sample position is calculated and a request is made that will cause a sample set to be taken Δt milliseconds from the current time (To). All three data streams are handled by this program but in such a way that the sampling positions (and times) for each stream are independent of those in other streams.

Within a data set the sampling of all analog values is automatically delayed by the nominal delay time of the presampling filter (see appendix I). If, in one data stream the sampling rate is such that 20 samples are taken of the highest

frequency passed by the filter (Fs/Fc = 20) the discrete samples will be (.385 x 20) = 7 sample sets ahead of the analog samples. The program that causes these analog samples to be taken retains their requests in a queue which must be large enough to handle the other data streams as well. At present this queue can hold 30 requests which should be sufficient if

(a) the operator does not oversample on all 3 data streams by using ratios of Fs/Fc > 30

(b) the raksyn encoders do not become so bad that the filtered P coordinate contains appreciable noise. When the requests exceed the queue size of 30, one or more samples are lost and the operator is warned with the alarm message 'TIMQFUL'.

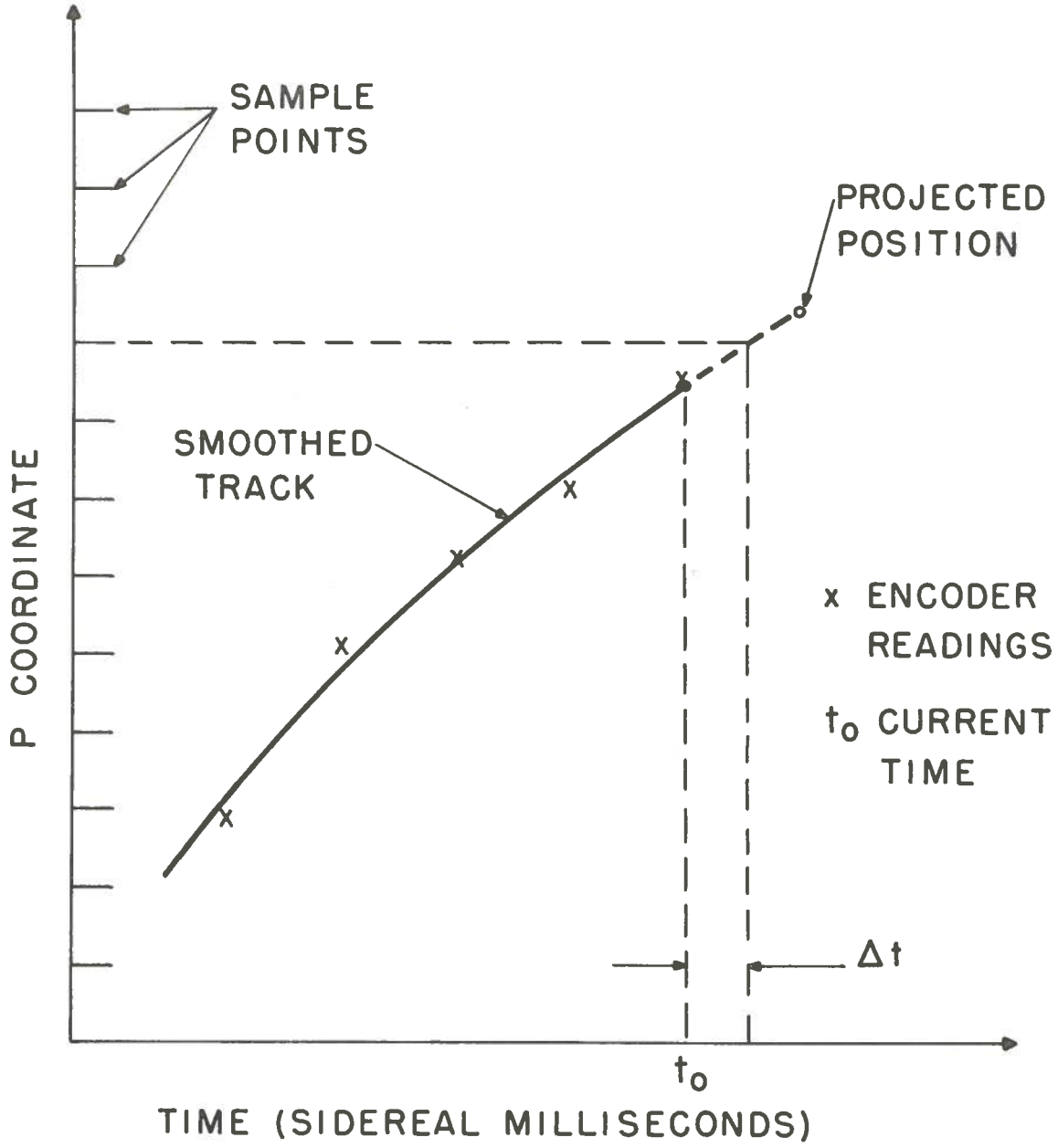


Figure M.1 Method of predicting sample times

SYSTEM TAPE MODIFICATIONS

(a) Adding Libraries to a System Tape

Relocatable libraries can be added to a system tape from object programs on paper tape by applying the following steps:

1. Mount the SEL executive tape on drive no. 0 and bootstrap it into core using the loader at 3.
2. Put the write ring in the data acquisition system tape and mount it on drive no. 1.
3. Type PLT.07..NOMO(CR) on the ASR 33.
4. Into the high-speed reader load the object tape that will be the first program in the relocatable library.
5. Type WBID07..LIBX(CR) where X is one letter greater than that used for the previous library on the system tape.
6. Set all sense switches off.
7. Type CLIB03..07(CR).
8. If this is to be the last program in the library go to step 10.
9. Load the next object program in the high-speed reader, set sense switch 0 on, press start and go to step 8 when the computer halts.
10. Turn sense switch 0 off, put sense switch 2 on and press start.
11. If more libraries are to be appended go to step 4.

12. Type WBID07..NOMO(CR)
EOF.07 (CR)
EOF.07 (CR)
REW.07 (CR)
and remove the data acquisition system tape.

(b) Removing Programs from a System Tape

The SEL executive can also remove all relocatable libraries and observer's modules past any point on a system tape. The command PRGS should be used first to get a listing of the tape programs. Start the SEL executive and load the system tape as described in steps 1 and 2 of part (a).

Pick the name of the first program that you wish to remove (say it is LAST) and type:

PLT.07..LAST

Execute step 12 in part (a).