NATIONAL RADIO ASTRONOMY OBSERVATORY
GREEN BANK, WV 24944

300-FOOT CONTROL COMPUTER MEMO NO. 6

DESIGNER'S GUIDE:
300-FOOT TELESCOPE CONTROL COMPUTER SOFTWARE

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GENERAL

This document is a summary of design goals for the 300-ft control computer software. With the exception of a few examples, the definition of specific software functions are saved for later supporting reports. The purpose here is to outline the user's requirements as well as possible without unduly restricting the software designer's imagination in how these requirements are to be met.

Although this report is associated with the 300-ft computer project, the software to be developed should be applicable to any single-dish radio telescope. The completed system will be adapted for use at the 140-ft telescope, so functions peculiar to a particular telescope should be well isolated and easily modified or substituted. The two telescope systems should look as similar as possible to the user (telescope operator, observer, electronics engineer). The design and computer code must be well documented so that maintenance and adaptation for use on other telescopes is as painless as possible. Because user requirements will change considerably during the life of this software, and because no hardware or software is forever error free, hardware and software maintenance aids must be incorporated into the design.

Scope of Task

The telescope control computer's task is to translate the user's commands into control commands to the telescope and associated receiver electronics and to monitor and display telescope status and receiver data to insure proper operation of the system. Much of the software written for this computer will be associated with the command conversion from a language familiar to the user to a form understood by the hardware. The convenience of the user is the primary requirement of the command language.

Because of the asynchronous nature of the control functions and the requirement for fast response, the control computer will not be required to perform many computationally intensive functions associated with receiver data. Data reduction not essential to monitoring data integrity will not be done in the control computer. Data routing and recording functions will also be kept to a minimum by assigning as many of these tasks as possible to peripheral processors.

Hardware configuration and data types.

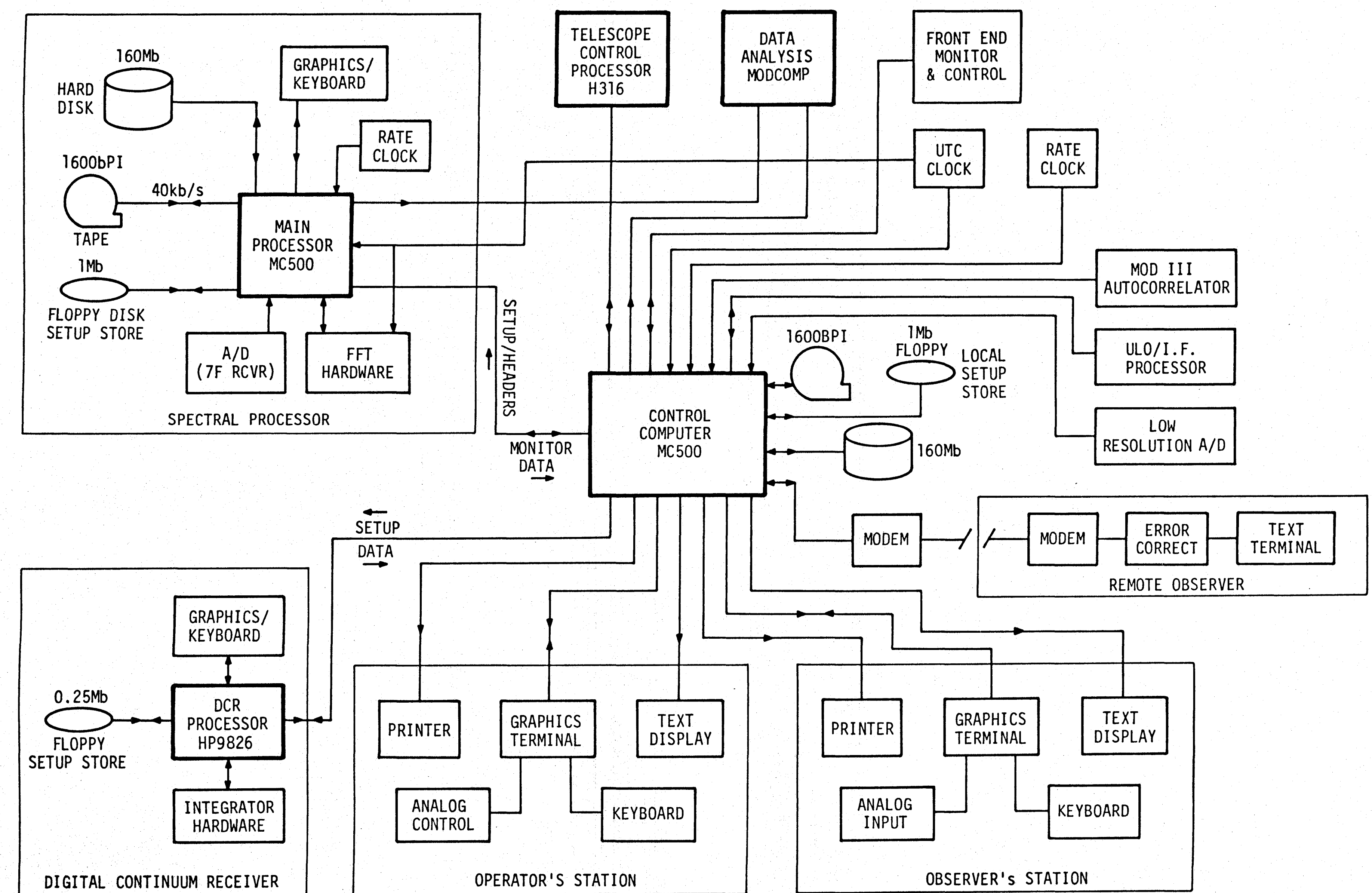
Because this computer (MASSCOMP 500) is a replacement for an existing one, many of its peripherals are already defined. Figure 1 is a rough sketch of the hardware configuration as it is defined at this time. There are four processors external to the control computer which are shown in heavy outline. (The graphics terminals might be considered to be two more peripheral processors.) Two of the external processors, the digital continuum receiver and the spectral processor, handle the moderate to high speed data manipulation. The data rate from the spectral processor can be quite high so it has a direct link to the data analysis computer and has its own data recording devices. The DCR does not have enough power to handle these functions, and its data rate is relatively slow, so output from the DCR is sent to the control computer for recording and relay to the analysis computer.

The Honeywell 316 is an intermediary between the main control computer and the telescope positioning motors and sensors. The H316 receives position commands from and sends actual position information to the control computer. The ModComp computer is strictly a data analysis computer which only receives data from the control computer or spectral processor.

The control computer has direct control of a number of peripherals which do not have their own processors. These peripherals are common to all or most of the control and data taking functions. The Model III autocorrelator will be phased out after the completion of the spectral processor. The tape, floppy disk and hard disk are part of the MASSCOMP computer package.

There are two user stations shown on the hardware diagram. One which is available full time to the telescope operator has primary control of the system. The second station is accessible to the observer for schedule changes and monitoring of telescope operation and data integrity. To prevent control conflicts and to give the operator advanced notice of upcoming control commands there will be a few real-time restrictions on the observer's station. The exact components in each station is still open to change by the design requirements. For example, two text terminals instead of one might be useful at the operator's station.

A modem connection to the control computer is shown. This could have a variety of uses such as loading of observing programs, monitoring of operation by a remote observer or use for remote diagnostics by the Observatory staff. Some data might also be made available to an observer's microcomputer through this link but this function will be of much lower priority than the control and monitor functions. Real time command of the telescope through the modem port is not intended because of the limited data feedback imposed by the slow data rate.



SPECTRAL PROCESSOR
HARD DISK
160Mb
GRAPHICS/ KEYBOARD
RATE CLOCK
1600bPI
40kb/s
TAPE
1Mb
FLOPPY DISK SETUP STORE
MAIN PROCESSOR MC500
A/D (7F RCVR)
FFT HARDWARE
SETUP/HEADERS
TELESCOPE CONTROL PROCESSOR H316
DATA ANALYSIS MODCOMP
FRONT END MONITOR & CONTROL
UTC CLOCK
RATE CLOCK
MOD III AUTOCORRELATOR
ULO/I.F. PROCESSOR
LOW RESOLUTION A/D
1600BPI
1Mb FLOPPY
LOCAL SETUP STORE
160Mb
CONTROL COMPUTER MC500
MONITOR DATA
SETUP
DATA
MODEM
MODEM
ERROR CORRECT
TEXT TERMINAL
REMOTE OBSERVER
DIGITAL CONTINUUM RECEIVER
GRAPHICS/ KEYBOARD
0.25Mb
FLOPPY SETUP STORE
DCR PROCESSOR HP9826
INTEGRATOR HARDWARE
OPERATOR'S STATION
PRINTER
GRAPHICS TERMINAL
TEXT DISPLAY
ANALOG CONTROL
KEYBOARD
OBSERVER's STATION
PRINTER
GRAPHICS TERMINAL
TEXT DISPLAY
ANALOG INPUT
KEYBOARD

FIGURE 1

One-stop telescope control.

Ideally, complete control of all telescope observing functions should be possible through the operator's station in normal operation. This requirement is intended to provide a uniform command format for all telescope functions and to make errors of omission less frequent since all functions will be included in the observing program command language. Hence, all functions can be preprogrammed. With the completion of the spectral processor and the "front end control and monitor instrument" nearly all of the telescope electronics will be under computer control.

One-stop control must not preclude stand-alone operation of major portions of the system. This stand-alone requirement is essential to hardware and software maintenance of peripheral processing equipment when they are not in use by the current observing program. Peripheral processor control from its local terminal should have the same format as that used at the operator's station terminal whenever possible.

Areas of user familarity and control expertise.

This control system must serve users with a wide range of familiarity with the system and expertise in astronomy, telescope operation and electronics. All of these users should be well served. A new user should receive quite a bit of guidance from the system, but this guidance must not get in the way of the expert.

The observer can be assumed to be expert in astronomy but may know relatively little about electronics or telescope control. Since the observer is the person whom the telescope is intended to serve, it is he or she who sets the primary standards to which the user interface, particularly the command language, is designed. Hence, the telescope and associated electronics must be controllable in an astronomical language whenever possible. Some familiarity with scientific programming languages (BASIC or FORTRAN) may also be assumed for the observer, but programming techniques should be employed only where most convenient to the observer. Some observers are very expert in electronics and may even bring their own equipment. It should be possible to bypass some of the layers of user interface without much help from the local staff so that he or she may configure the system in a way not considered in the design of the user interface.

The telescope operator is very familiar with the operation of the telescope and is conversant in electronics and some astronomy. All of the operator's working hours are spent with the telescope control system, and he or she is responsible for the proper and safe operation of the telescope. The operator can be expected to learn some control commands written in the language of the observer, but this person must not be encumbered with command verbosity. In addition to the command language, the operator should have a set of manual or semi-manual control functions, some of which may use analog devices such as a track ball, potentiometers or a joystick. The operator must have plenty of visual feedback on telescope position and status for effective use of manual control. Many of the analog control with graphics feedback features of the new control system will probably not be available when the computer is installed because these features are not well defined yet and will require considerable software effort.

The electronics engineer may know relatively little astronomy and can rely on the telescope operator for help in any telescope control requirements. Of course, the engineer has great familiarity with the system electronics and often needs control and feedback on detailed functions in the system while full computer control is active. The engineer should be able to do such things as throw individual switches, set frequencies, look at data words and configure monitor displays without having to learn many special commands. The engineer can expect some but should not require too much help from system programmers to diagnose system dependent problems in the electronics.

Qualitative design goals:

The following is a list of design goals which are not well stated elsewhere in this document but are important to the success of the project.

1. Simple requests should require only simple commands.

2. Novice aids should not get in the way of the expert.

3. There should be a smooth transition from one level of control system familiarity to another.

4. The actions necessary to cause a desired effect should be as obvious to a new user as possible. This is difficult property to achieve because the designer or frequent user of a system is not a good judge about what is not obvious to a new user.

5. The user should never be left in the dark about what to do next or whether his or her commands have been executed. The system should anticipate unusual and erroneous inputs so that it hardly ever appears to hang up inexplicably.

6. The control system must be adaptable to new user requests. All possible uses cannot be anticipated in these specifications. In other words, the control language should be functionally complete.

USER MODES OF OPERATION

This section outlines the facilities available to the user for communicating with the telescope control system and gives a rough idea about how these facilities might be used.

Telescope operator.

The telescope operator is the most frequent and most intensive user of the control system. To this person real-time feedback in very easily interpreted forms and ease of command are quite important.

The operator's station tentatively includes a graphics terminal with 400 x 600 pixel graphics and text, and a keyboard with special function keys; one or two text only displays; a small dot matrix printer; and some form of analog control.

Most of the operator's time is spent monitoring the progress of an observing program which has been provided by the observer. For this a display of the current and upcoming observing program is needed, along with displays of telescope status and position, receiver status, and receiver output data. These displays should call immediate attention to potential problems either through warning signals or obvious deviations in the displayed functions. The operator should have considerable flexibility in configuring the displays to suit the monitoring task at the moment.

The operator is called upon to make quick changes to observing programs, help new observers with setups, help diagnose receiver and control problems, make operational checks such as pointing and focus, and, in a few cases, make a limited number of observations under manual control at the request of the observer or engineer. In the past the operator has been responsible for keeping observing and maintenance logs, but most of this function should be automated in the new system with the provision to add remarks to the logs through the operator's keyboard.

Observer at the telescope.

The observer's station is intended for use during routine, preprogrammed telescope operation. At the beginning of an observing session, when conversation with the operator is important, the operator's station will be the main input and monitor location for the observer.

While at the telescope the observer needs to monitor the progress of the preprogrammed observations, check the current data for proper receiver operation, change the observing program, and, in some cases, assemble the observing program for later in the obseving session. Most of this is best done with some but not much conversation with the operator and without affecting the operator's displays. Also, the observer would like to see the program monitor and current data displays while analyzing data from the last day's observations.

The observer's station hardware is very similar to that at the operator's station, but the display functions and formats may be different at the two stations and must be under independent control. Because manual telescope control will not be possible from the observer's station, the analog control device will not be as important or may not be needed at all. The printer is intended for hard copies of observing programs and receiver setups. The feasibility of supporting the graphics terminal at the observer's station is not known at this time. Its usefulness to the observer will have to be weighed against its expense and the load it puts on the CPU.

Remote observer.

The term remote observer refers to any astronomer with time scheduled on the telescope, but who is not actually at the telescope. This includes more than just the current observer.

The only piece of hardware available to the remote observer at the control computer is a 1200 baud, dial-up modem. Hence, he or she will be limited to text communication at a modest rate. On the observer's end of the telephone line could be a simple text terminal, a terminal with page control capabilities (e.g., a VT102), or a small computer with file transfer and text editing capabilities. A terminal might be used for very limited program editing and program monitoring. A small computer could edit more extensive observing programs locally and transfer these files to the control computer with an error checking data transfer protocol. Old or partial observing programs, limited source lists, and some other program editing aids may be transfered from the control computer to the remote computer for use by the remote observer. Receiver data transfer via the telephone line from the control computer will necessarily be limited by the transmission rate and the relatively low priority assigned to the task by the control computer, but this capability should not be ignored.

Actually, most of the editing and storage of future observing programs at Green Bank will be performed on an off-line computer to prevent interference to current observing, but this should make little difference to the remote user.

The remote observer will be asked to supply hardware and software which conforms to a few necessary communications standards, but most observers will already have access to the necessary hardware, and the software must be easily obtained and implemented.

Observer in Green Bank with small computer.

The proliferation of relatively inexpensive but powerful microcomputers has led to requests for the transfer of telescope receiver data to these computers. These requests will grow in frequency and in the amount of data to be transferred, and some convenient method for satisfying these requests must be provided. The main problem to be solved then is one of finding a common transfer medium.

For small amounts of data the interface which is the most widely available is the 1200 baud modem, and this interface will be supported. Direct connection without a modem between Green Bank computers and the observer's computer will generally be discouraged because an adequate interface standard is not widely supported, and the Observatory cannot affort the effort necessary to learn and adapt to the multitude of hardware and software configurations possible in other computers. (Specifically, RS-232C is not a sufficient standard.) For transfer of large amounts of data the Observatory will support 9-track magnetic tape and one or at most a few small disk formats which can be read by the most popular microcomputers. Magnetic media will be discussed in a later section.

THE COMMAND LANGUAGE

The necessity of preprogramming an extensive observing sequence requires a telescope control command language. In the past this has taken the form of setup and source cards and predefined procedures. Recent thought along these lines is leading more and more to the use of command languages that look like high level computer programming code partly because of its widespread familiarity and partly because it allows more flexibility than does the predefined procedure approach. For these reasons a command language shall be rigorously defined for the 300-foot control system.

The command language should satisfy the following requirements:

1. It must contain all of the components with which an observing program can be assembled.

2. The language "constructs" must not be specific to any one telescope. Telescope peculiarities must be well isolated at the function level.

3. The constructs must be familiar (e.g., look a lot like those in a popular computer language) and be reasonably simple.

4. It must be very readable and self-documenting to the observer and telescope operator.

5. It must be modifiable while executing.

6. Its source code must be capable of being written with common text editors.

7. It must support a hierarchy of function and subroutine references.

8. It must allow for the examination of user-chosen parameters while executing.

9. It should not rely on learning a large new vocabulary of function names.

10. It must be associated with an extensive and particularly helpful set of error diagnostics.

MANUAL CONTROL

Manual telescope control is directly available only to the operator, but it is sometimes important to the observer when experimenting with observing techniques or running pointing, gain, and focus checks before starting a session. Manual control efficiency is often important to the best use of telescope time. In this document we shall broadly define manual control as any control action that requires telescope operator intervention for purposes other than modification of an upcoming program sequence.

Manual control can be arbitrarily divided into two categories: one-at-a-time entry and execution of command language steps and direct control of a function's direction and rate of change. The latter requires very good visual feedback.

As far as possible, manual use of the command language should be exactly like its use in a programmed sequence with the result of each command immediately apparent to the operator. Functions and subroutines should be usable in the manual mode if it makes sense to do so. Some of the common functions should be available through special function keys. Command error messages must be explanatory and suggest remedies or request more information when appropriate, and retyping of a whole command to correct a spelling error must not be required. Reminder aids such as parameter tables and function lists should be easily accessible. It should be possible to override warnings if damage does not result.

Manual rate and direction control has not traditionally been thought of as a computer function, but with the advent of good computer graphics this should no longer be the case. Some abstract operations such as positioning an antenna beam on a sky map can now be displayed, and this may be very useful for some observing requirements. Since little experience exists in this area, there is a need for quite a bit of experimentation. The following list offers some guidelines.

1. Feedback to the operator is crucial. It is this area that requires the greatest amount of thought.

2. The physical control action should be natural to the desired operation and precision.

3. This type of control should be smoothly integrated into the command language mode of operation.

4. Not all operations are amenable to this type of control.

5. Error messages are still needed, but good graphic feedback should greatly reduce the need for them.

PROGRAM PREPARATION FACILITIES

At the expense of repeating some requirements that have been stated elsewhere, this section outlines the methods of assembling an observing program that should be available to the observer. Three computers will be available for this purpose: the observer's home computer be it a micro, mini, or mainframe; the MASSCOMP in the Green Bank lab; and the MASSCOMP telescope control computer. Not all will be appropriate in all situations.

All telescope commands will be stated in common printable characters, so that nearly any text editor can be used. This has the advantage of being able to use a familiar editor on a familiar computer. Some programming aids such as source lists, predefined tables and setups, and some help files can be down loaded to the home computer from Green Bank, but a small printed command language manual will still be required. Some facilities such as a program verifier and an automatic scheduler will generally not be available at the observer's home institution.

The Green Bank lab MASSCOMP computer will have the most powerful control programming facilities, but it will be less familiar to many observers and will require a rudimentary knowledge of UNIX. Access will be possible through a dial-up modem, but this will limit the text display speed, and the full screen editor will require a compatible terminal. All of the programming aids and utilities described in a later section will be available on this computer. The use of graphic aids to the assembly of an observing program shall be given serious consideration but implementation of these aids may have to wait until the control system is installed.

The telescope control MASSCOMP will have most if not all of the lab computer editing capabilities, but these will be available only to the current observer and even then only as the control workload permits. Without a good estimate of the amount of computer capacity that will be necessary for telescope control it is impossible to say how useful the telescope computer will be for program editing. In any case, the observer should plan to arrive at the telescope with as complete a program as possible. In addition to the normal editors associated with the computer's operating system(UNIX), the control system will need to include some editing capabilities to permit quick changes to the current program.

DATA STORAGE AND TRANSFER

There are at least three requirements for direct transfer of data files to and from the control computer: loading of observing programs which have been prepared in another computer, transmission of a limited amount of receiver data to an observer's microcomputer, and, when this system is installed at the 140-foot telescope, transfer of MKIII VLBI observing programs from the MKIII system. The last requirement shall not be included in the 300-foot design except to make its addition as easy as possible. None of the specifications below necessarily apply to MKIII data.

Also, data must be read from and written to transportable magnetic storage media for the above purposes as well as for program archival and the transferal of large amounts of astronomical data to other computers.

Information format.

All of the data transfered into and out of the control system must be available in 128-character ASCII format. Of course, this does not apply to communications with the system peripherals in Figure 1. Text files such as observing programs shall contain only printable, English characters (carriage return included). Format control characters shall not be allowed in text. The ASCII format is inefficient for numerical data transfer, but its universality and the dominance of textual information in most of the data transfer makes its use very attractive. Other formats may be supported, but the guarantee of ASCII support is required.

Storage media.

Two magnetic storage media will be supported for external data transfer: 9-track, 1600 bpi magnetic and small flexible disk. At least one of, if not the only, external tape format shall conform to the FITS standard. The wide range of flexible disk formats makes support of all of even the most popular ones impractical. After further study, one, or at most a few, of the most widely available formats will be selected. Format in this context includes microcomputer operating system dependent features such as disk directories and sector skew factors, so the format(s) to be supported shall be defined in terms of specific microcomputer configurations.

All tape and disk formats need not necessarily be written by the telescope control computer. The primary requirement is that the import and export of data be convenient to be observer without a lot of help from the Green Bank staff.

None of the above format restrictions apply to internal Green Bank data transfer.

Direct file transfer.

Two computer-to-computer file transfer protocols will be supported by the control computer and the Green Bank lab computer: Kermit and Xmodem. Kermit is a 7-bit, half duplex system with CCITT, CRC error checking and variable packet lengths up to 96 bytes. This protocol has been defined at Columbia University (cf. June 1984, Byte magazine), and much support software is in the public domain. Control characters and 8-bit data require two transmitted bytes as defined in the protocol. All protocol features shall be supported by the control computer.

Xmodem is commonly used in the microcomputer world for bulletin board services. It is an 8-bit, half duplex system with 128-byte, fixed length packets. The originally defined protocol, sometimes called "Christensen protocol" (cf., ASCII Express "The Pro" docmentation), uses checksum error checking while newer versions use the CCITT, CRC method. Both will be supported by the control computer. Two common software packages using this protocol are PC Talk for the IBM PC and ASCII Express "The Pro" for the Apple II.

UTILITIES FOR PROGRAM PREPARATION

Of necessity the command language is an imperfect compromise between simplicity and flexibility. The benefit of doubt must be given to flexibility which leads to the need for programming aids. Many of these aids can only be made available on the Green Bank computers, but this should satisfy most of the user's needs.

All users need a program verifier whose function is to scan a program for syntactical errors, schedule conflicts, and missing information before the program is run. It must include instructive error messages with suggested solutions and prompts for more information. A very useful extension to the verifier is a telescope simulator with good use of graphics which would allow a faster-than-real-time preview of the telescope response to a program sequence. If this were built as a receiver for the actual control software it could also be used as a software test device and operator training aid.

The novice user needs a heavily instructed method for setting up relatively simple observing programs. This could use techniques such as question and answer, table fill-ins with defaults, menus, and example schedules to make sure that nothing is left out and to provide some translation to the control language. None of these techniques should be relied on exclusively since each had disadvantages in some situations. For example, question and answer might make a good start-up but is cumbersome for a large number of decisions. Menus and tables present a fair bit of related information together, but switching menus and searching for other information can be frustrating. Any prompting technique should use descriptive labels and have easily accessed brief descriptions of each item.

The more experienced user will find many novice aids a hindrance. This person wants the following aids:

1. Extensive radio source lists from published catalogs and as supplied by the user. These should contain names, positions, velocities, flux densities, etc. A cross reference list of alternate names would also be useful.

2. Sorters and editors for the source lists.

3. Positions of the sun, moon, planets, satellites, comets, etc., at specified times.

4. A spectral line frequency list.

5. A position precessor and doppler calculator.

6. Command language function and subroutine lists with explanations grouped in a logical fashion.

7. An automatic scheduler to create an observing program from one or more source lists optimized for a limited number of criteria and priorities.

<u>ON-LINE CONTROL MONITORING</u>

All telescope control and receiver electronics status information is to be displayable at the operator's station. A limited number of important items will be on display at all times, and the rest may be called as needed. The operator will be the primary user of this information, but most, if not all of it, should be available at the observer's station. Specific lists of parameters and display designs will be given in another report, but the categories and some examples are listed below. The displays should not be so tightly designed that new parameters cannot be comfortably added or that the design has to be completely redone for a different telescope. Displays will not necessarily be grouped in the same manner as presented below.

Telescope status might include critical component temperatures, power voltage and frequency, control switch states and limit and position check switch states.

Environmental parameters include wind speed and direction and outside temperature.

Telescope position may require both gross and fine scale displays of different forms. In this category are main beam position in several coordinate systems, focus and feed offset position, and feed rotation.

Corrections in use include pointing corrections, position dependent focus and subreflector deformation parameters, and tower level readings.

Electronics configuration and parameters include switch positions, peripherals active, frequencies, integration times, bandwidths, etc.

Warnings of out-of-limit conditions should appear when detected by the computer along with the value of the parameter in question. Some assessment of the severity of the problem should be made by the computer so that the display is appropriate to the response required.

RECEIVER DATA MONITORING

The concern of the control system with receiver data is almost exclusively one of assuring data integrity. Relatively few operations are performed on the data by this computer, and in some cases it will not be in the primary data stream to the analysis computer. Receiver data monitoring depends heavily on visual inspection by the operator and observer.

Some receiver output such as total power and synchronous detector output have traditionally been displayed on chart recorders. Since multichannel chart recorders are now more expensive and require more frequent maintenance than a good graphics terminal, the chart recorder function will be replaced by CRT displays and 24 to 72 hours worth of hard disk storage. The CRT display should provide up to four display channels, simulate the chart display rather closely, and allow easy scroll-back through the data on disk. Any of the functions which might naturally be displayed on a chart recorder should be assignable to the CRT channels. It should also be possible to dump selected portions of the receiver monitor data on hard disk to the MASSCOMP 5 1/4" floppy disk or to the printer for the use of the receiver engineer.

The control computer shall have the ability to continuously check the receiver data for deviations outside of selected limits, mainly for the benefit of the receiver engineer. This will be an aid to detection of receiver irregularities for a wider range of functions than can be displayed on the CRT. Setting of limits and review of out-of-limit conditions should be easy and straightforward.

Some data types, particularly those of more interest to the observer than to the engineer, are not amenable to chart recorder display. These take special display formats and sometimes tax the CRT capabilities. A limited number of display formats for these functions will be defined with some flexibility of scale selection and data averaging. Three reasonably well defined data types are as follows:

1. Spectral line data will have as many as 2048 channels of intensity vs. frequency information divided into as many as four groups. The display should accommodate a wide range of numbers of channels up to 2048. In some cases there are two sets of spectra taken simultaneously (signal and reference), and the display options should include one or the other alone, the difference of the two, and the difference of the current observation and a previously designated one.

2. Continuum data is normally a slow stream from a limited number of receiver channels (up to 14 on the 300-foot). Observing techniques can include simple on-source/off-source measurements, one and two dimensional scanning of the beam through the sky, and point by point mapping. Sometimes a simple chart recorder type of display is sufficient, but for mapping or multibeam observations a more nearly two-dimensional display in sky coordinates would be very useful.

3. Pulsar data can come in an array of forms including fast sampled data streams, synchronously averaged intensity vs. time data groups, and moderately frequent spectra. This type of data is more taxing on the display than either of the other two, and some cleverness will be needed to display enough of the data to monitor it to sufficient sensitivity level to detect subtle receiver malfunctions.

CONTROL SYSTEM CHECK LIST

After the control computer and peripherals have been down for maintenance day or because of a power failure there are a lot of observing parameters that must be reestablished and peripheral equipment that must be checked for proper operation. This restarting operation is very error prone, and any assistance that the control software can give the operator would help minimize the start-up time.

Some checks the computer can perform on its own such as comparison of UT and LST clocks, polling of peripherals for proper response, and oscillator frequency checks. At start-up of the control software or on operator demand the control computer should provide a list of possible problems that require action or acknowledgement by the operator. Warnings about peripherals not needed by the current type of observing should be avoided as much as possible, and, with a few exceptions, the existence of warnings should not prevent further observing in case the problem can be circumvented without the comptuer's knowledge. Warning messages must be informative to the operator.

Some checks cannot be performed completely by the computer. These must be done by the operator with the aid of computer generated prompts, check lists, or status displays. Somehow the control system must avoid portraying a false sense of security to the operator by leading him or her to believe that all is o.k. if the computer is happy. The operator should participate in system verification and be encouraged by the computer prompts to look beyond the preconceived list of check areas.

Where feasible a few overall system tests should be performed at start-up. These might include injection of a known frequency signal into the spectral line signal path or a pointing check on the nearest continuum radio source at the suggestion of the computer. Of course, if the observing program itself provides adequate proof of proper operation, some of these checks would be unnecessary.

HARDWARE DIAGNOSTICS

With a system as complex as the one in Figure 1 some hardware faults are evident only in operation of the entire system and can be very difficult to reproduce and isolate. The control computer software should provide some routine hardware checks at start-up and on demand, but more importantly it should incorporate diagnostic aids for the digital engineer. These might include bit by bit displays of some key control and data words, error trapping under specified conditions with dumps of certain words, program counter look-back capability, or peripheral exercise programs to look for intermittent faults. The exact requirements are best specified by the engineer, and sometimes software routines must be invented for special situations. Routine and common diagnostics should not require much help from the system programmer.

RECORD KEEPING (LOGS)

Two types of logs have traditionally been kept by the Green Bank telescope operators: one records the observations on a scan by scan basis, and the other is a maintenance log filled out once every eight hours which records telescope usage, weather, problems encountered, and other remarks. The first is primarily for the benefit of the observer and the second is for internal NRAO use. Most of the logging functions can now be automated in the control computer with the provision for easy entry of remarks by the operator or observer. Hard copy logs are still required in a format not unlike the ones in use now, although the amount of paper necessary might be reduced. The observer's log should record what actually happened, not just what was programmed to happen. In addition to the routine logs, the observer should have the facility to get a printout of all setup parameters on request.

DATA RECOVERY

Power and hardware failures must not result in excessive loss of data, and the recovery of the current observing setup and program must be nearly automatic when the control computer is restarted. This implies moderately frequent transfer of data to a magnetic medium and some redundancy in data recording. Data storage redundancy may include any of the control computer disks or tape and any of the peripheral processor recording equipment which would normally be in operation. Some balance will need to be struck between recording frequency, control computer CPU load, and wear and tear on the recording equipment.

The following data loss limits are suggested: Power or computer failure should result in the loss of no more than 5 minutes of receiver data, and the observing setup within 15 minutes of power failure must be recoverable. Destruction of a recording medium must not result in the loss of more than 8 hours of receiver data, and this must not happen more frequently than once in 3 years. Observing programs pepared more than 8 hours before a magnetic recorder crash must always be recoverable.