CPG MEMO NO. 12

Revised 3/18/83

# GREEN BANK COMPUTER PLAN 1983-87

## I. Introduction

Computing in Green Bank encompasses a wide variety of users and requirements. It is both telescope-oriented and lab-oriented. In addressing our needs, we must consider not only our function as a telescope site where on-going observations dictate certain imperative computing capabilities, but also our role as the home site of numerous astronomers and engineers whose computing goals are quite separate from purely observational ones. The scientific staff obviously needs computing power not only for data reduction but also for astrophysical analysis; moreover, the Green Bank staff needs access to data reduction facilities for all of NRAO's instruments, not just those located in Green Bank. The vitality of a scientifically productive staff in Green Bank will have significant impact on the continued excellence of the instruments here. Similarly, technical computing by the Green Bank electronics staff will ultimately result in improvements in radio astronomy. Better designs, documentation and testing will result in better equipment, fewer failures and decreased down-for-repair time.

As the underlying tenet of the Green Bank site plan, we emphasize that our computing needs are not satisfied by our current facilities.

## II. Summary of Computing Requirements

The general categories which may be used to separate the many purposes of computing capability are:

a). Telescope control and data recording;

b). Telescope data reduction;

c). Remote observing;

d). General purpose scientific and engineering computing;

e). Data acquisition and control system (DACS);

f). Word processing;

g). Fiscal computing;

h). Record keeping;

i). Electronic mail to other sites.

While we are currently in good order with regard to several of these categories, our capabilities in others are woefully inadequate. Therefore, the Green Bank site plan has two aims: first, to bring us up to an acceptable level of computing power so that our current requirements are met, and second, to accomodate updates and permit incorporation of advances in other areas of our technology. In the immediate future, we should achieve the first goal while at the same time laying the foundations for the second.

Our major computing requirements are discussed according to each separate category.

a). Telescope control and data recording

The major modifications to the on-line telescope control systems over the next five years will be the proposed replacement of the DDP116 at the 300-foot. A by-product of changes at the 300-foot will be an upgrading of the system at the 140-foot which is already underway. We are currently studying alternatives to the proposed replacement of the 116 with a MODCOMP II, identical to the analysis MODCOMPS and the 140-foot control computer. The arguments in favor of a MODCOMP are its versatility as a real-time control computer, our familiarity in terms of software and maintenance, and the possibility that parts may be available from the VLA and CV. Under more favorable economic conditions, several arguments against the MODCOMP, namely its lack of universality and the fact that the current 140-foot operating system already fills the MODCOMP there deter us from investing in a computer which is in the process of being discontinued. Furthermore, a MODCOMP II could not handle 2048-point spectra from the 300-foot signal processor under construction and we should not restrict the potential of that device by attaching it to an inadequate control computer. Substantial software changes will result from additional data taking capablities added by the signal processor and multi-feed front ends. In addition to the added attractions of some of the new devices, upgrades of existing systems will warrant increased monitoring and control of receiver setups at the telescopes. A software approach to interference excision should also be developed.

We conclude that a Modcomp II would not meet the future requirements of a 300-foot control computer.

We are currently involved in observatory-wide discussions on the relative merits of various control systems. It seems advisable to follow one of three routes for the 300-foot control computer: a MODCOMP Classic, a small VAX or a 68000-based machine. Our basic requirements are modest real-time speed, sufficient capacity to handle advances in data taking and analysis, software friendliness and reliability. Since our manpower both in software development and in hardware interfacing and maintenance is limited, the choice of a control computer for the 300-foot must be considered as part of the computer upgrade throughout Green Bank. For us, software and hardware duplication within the site is a great advantage. Proposed solutions will be discussed in Section IV.

The main thrust of the software changes at both telescopes will be an effort to make the control systems more interactive and user friendly. At the 300-foot, we will develop a menu-driven terminal system, rather than the existing push-button control panel. The control panel will serve only as a back up when the computer is down. Punch card input will still be allowed as a possible input medium at least for a transition period, but tape and/or data link input of telescope parameters will become the norm. Additional terminals will certainly be necessary at both telescopes. It will be imperative that a medium be available on site for transferral of telescope control input from the all-purpose computer to the on-line control computer (such as we now do via the RJE card punch).

Software changes for the control systems can be achieved with the current personnel.

b) Telescope data reduction

We can assume fairly securely that as long as we maintain our tradition of excellence in support and development, the proposal pressure for the 140-foot and 300-foot telescopes will not decrease. The backlog is still 9-10 months despite the fact that the schedulers in the last two years (JRF and MPH) have been increasingly stingy in granting time in order to keep those backlogs down to an acceptable level. The development of the low noise 1-2 and 2-5 GHz receivers, the second channel of the upconverter/maser, a 6-cm multifeed system and the 300-foot signal processor all are going to play important roles in astronomical research in the next five years. The only major change that might affect telescope usage is the advent of the VLBA; VLBI now accounts for 25% of observing time at the 140-foot. Assuming that there will be no VLBA antenna in Green Bank, the 140-foot may be even more in demand as a VLBI instrument. At the same time, as we make the 140-foot increasingly competitive at the higher frequencies, it is clear that even more time could be devoted to high quality single antenna investigations (e.g. mapping programs) that are not undertaken now just because the telescope time is unavailable. In any event, for the period covered by this plan, we assume that VLBI studies will continue to incorporate the 140-foot.

In terms of reduction of data taken with the Green Bank telescopes, our current capabilities are only marginally adequate. The programs and procedures for data reduction, while getting the rudimentary job done, have not been addressed on a major scale for a decade or more. A circumstance that affects our approach must first be reassessed. Unlike the past, it is now unusual for visiting observers to undertake data reduction in Charlottesville; such was the case before concurrent data analysis was available at both telescopes. At the same time, the percentage of users of the Green Bank telescopes who are NRAO staff resident in CV has decreased. The necessity of sending tapes to Charlottesville for processing on the IBM, or its equivalent, is no longer strong, except in the cases where large amounts of data require handling in a batch mode. Today, the major reason why telescope tapes are sent to Charlottesville is the convenience of bookkeeping and tape storage. Most often, the observer never looks at the data on a CV computer. On the other hand, at present Green Bank does not have the facilities to handle and store telescope tapes. Furthermore, several deficiencies in the Green Bank MODCOMP system make it difficult, if not impossible, to undertake some of the tape copying/sorting tasks which are necessary. To this end, the lab MODCOMP analysis computer should have a second tape drive and software should be written to accomodate the needs of tape copying, sorting and editting. Additionally, it is a major drawback to Green Bank data reduction that we have no on-site high resolution, high quality (comparable to a CALCOMP) plotting device. This issue will be discussed further under d).

Increased usage of the Jansky Lab Modcomp for all facets of data reduction will induce further demand on that machine. It is limited by its single user status. The work load should be shared, as now, among the telescope analysis computers, the lab MODCOMP, and some multi-user machine (IBM, VAX or whatever serves us in Green Bank). Despite whatever potential complications, we should upgrade as necessary so that Green Bank data can be fully reduced in Green Bank.

The development of new receivers and backends as mentioned in a) will of course also impact software development within the analysis package. Major rewrites will be required to handle data taken with the new spectrometer. Furthermore, since the single dish data reduction packages are ten years old, it is time to rethink their effectiveness. NRAO is, after all, the preeminent single dish observatory in the world, with Green Bank its major single dish site. While the spectral line package is adequate, it is nonetheless limited. As observers try to do all their reduction in Green Bank, these limitations are becoming more apparent. The state of continuum data reduction software is notorious and needs to be remedied even before we add multibeam maps of the sky. It is also hoped that we will have time within the next year to determine how single dish data might be incorporated into the AIPS system since such a large amount of display software is available and it would be desirable to have a unified approach to all such astronomical tasks. Continuum mapping and two- and three-dimensional spectral mapping are obvious cases where AIPS should be applied. For this development, input from members of the AIPS group as well as from Tucson would be more than welcome, since this should be an observatory effort rather than just a Green Bank one. We certainly do not have enough manpower in Green Bank to undertake the job alone.

It is, of course, highly desirable to maintain a single dish analysis system in CV so that the research staff there may have the convenience of data reduction there.

c). Remote observing

With the exclusion of VLBI, remote observing in Green Bank has not actually been undertaken; remote data analysis has, in two cases, made use of a dial-up modem to attach to the CONDAR program on the 300-foot analysis computer. We can probably work on two assumptions: the demand for remote observing, not just remote analysis, will increase, and, this demand will be stronger at the 300-foot than at the 140-foot. Until the new telescope control system is installed at the 300-foot, remote observing will be impossible there; however, with increased file manipulation capability, there is great potential for a demand for remote observing in the future of the 300-foot where the average proposal requests two weeks of time.

High sensitivity spectral line experiments at the 140-foot will still demand that the astronomer be present. However, we must design our new systems to allow the possibility of remote observing. In addition to the obvious dial-up hardware, this will also exert pressure for increased monitoring and control capabilities. For the next couple of years, only additional modems and phone costs are foreseen. Substantial usage of remote observing practices in the future will require additional support personnel.

The current demand for VLBI absentee and remote observing stretches our resources; what we can offer in the future will continue to be restricted by our limited manpower. Upgraded control of the 140-foot system will allow further access for absentee and remote VLBI observers with little additional burden on the support staff, once the changes are made. On the other hand, we now find ourselves hiring an outide software specialist (Vandenberg) at premium price because there is no one in house who is familiar with the Mark III-HP computing system. It seems to be more reliable (and cheaper!) to maintain NRAO control, but the expertise and time are not currently within the bounds of our resources.

d). General purpose scientific and engineering computing.

The major point to be made in this category is that our current capabilities range from inferior to nonexistent and that substantial improvements must be made if we are to achieve a satisfactory level in support of both our scientific and engineering efforts. It is fair to say that the current usage of the larger computers in Green Bank is more reflective of their cumbersome and frustrating operation than of the interest of users. There are a variety of computing tasks which fall into this category including: computer-aided design for electrical and mechanical engineering, calculation of radio wave propagation as part of the Quiet Zone administration, numerical and statistical analysis for a variety of scientific and technical problems, estimation of instrumental effects, and the myriad of problems which one can lump under theoretical astrophysics (now that we've got all that data, what does it all mean???). What must be recognized is that data reduction is only one aspect of the tasks undertaken by computer users in Green Bank. We do not recognize among the Green Bank staff a continuous need for a large machine, but rather one which is versatile, interactive, and accessible. Our present link to the IBM4341 in CV is unsatisfactory for a variety of reasons. Use of the lab MODCOMP for general purpose computing is ruled out because of the high demand placed on that machine for telescope data reduction and system development and because of its limitations in terms of computer power, operating system and single user orientation. Our highest priority requirements are an interactive user-friendly operating system, interactive graphics, on-site high resolution plotting and hard copy, on-site tape drives, and multi-user accessibility.

Four terminals will not be enough if we can actually get something accomplished!

Both for analysis of single dish, VLA, and VLBI data, it is desirable to develop our own AIPS capability to a comparable level to any other location. Again the need for graphics, plotter and tape drive arise. The ideal system would include a VAX-class machine $I^2S$ and ultimately an AP and two or three disk drives.

Significant software packages (e.g. general purpose plotting) are desperately needed. Furthermore, the electronics group has specified a number of desirable existing packages such as SUPERCOMPACT which would be useful to staff at all sites; hence we should not restrict access to such packages to one site versus another. Some of these are detailed in Brundage's memo of 3 Feb. 1983.

We will not be able to develop much general purpose software with our current manpower and the demands upon it to accomplish more telescope-oriented projects. However, investment in our computing capability will certainly reap results in both our scientific productivity and technical development.

e). Data acquisition and control system (DACS).

Increased usage of computer control in the laboratory is to be expected. Just recently, the Telescope Operations APPLE computer was used by the central shops in the machining of an orthomode transition for the L-band receiver; as a result, the APPLE was unavailable to Telescope Operations. We should expect to make a small but increasing investment in small computers for such purposes. This will include minor improvements to some of the existing systems, as well as the addition of new ones.

Following these lines, electronics will need to develop one or more complete stand-alone data acquisition and control systems (DACS) which will contribute greatly to our technical development projects. Details are included in Brundage's memo. It is also desirous to have a link between this data acquisition lab computer and the computer aided design machine. Compatibility with other NRAO machines at other sites will also be a goal. Most modern microwave test equipment uses the IEEE-488 (=HP-IB) bus system. Again, the need for an interactive user-friendly system with modern graphics is affirmed.

Rich Lacasse's memo summarizes the requirements of the Green Bank electronics groups specifically.

f). Word processing

We are just beginning to gain insight into the potential uses of word processing in Green Bank. We desire accessibility, user friendliness, reliability and high quality output. The IBM DISPLAYWRITER meets almost all of our present requirements; it is still somewhat limited as a technical typing machine. Our two-month experience has been favorable, however, and supports our suspicion that one printer can easily support two work stations (and probably three). The next step would be to add another printer and multiple work stations to the electronics/administrative services area on the ground floor. As discussed in i), it is desirable to have compatible word processing equipment at all sites so that intersite communication can be facilitated.

g). Fiscal computing.

The needs of the fiscal division must fit in with our overall needs, for it services the entire observatory. It is mandatory that a dedicated line to the other sites be maintained. Fiscal will desire to upgrade its word processing capability.

h). Record keeping.

It is as yet unclear how useful the DISPLAYWRITER will be in record keeping. Such tasks are diverse and could include telescope scheduling, statistics on telescope usage, and job priority setting. Much of this is now done on the IBM, on an APPLE, or on a pad of paper. If the DISPLAYWRITER is inadequate, record keeping tasks must be maintained on some other machine.

i). Electronic mail.

It will certainly be desirable to extend our communications in the direction of all other NRAO sites. The explosive field of telecommunications will certainly offer us numerous advances in the next few years.

## III. Independence versus the Link to CV

The precise manner in which to satisfy our requirements is as yet unclear. However, improvements must be made in order to achieve a viable computing capability in Green Bank which frankly we do not have today. Furthermore, we must also insure that our operation is not hampered during any transition period, since our primary responsibility must be to the on-going success of observing in Green Bank.

The question of whether we should maintain the current link to a main computing center in CV or develop our own independent system must be incorporated into the general observatory plan. However, the current arrangement does not meet our needs. A substantial upgrade of the link to CV would be necessary; it is unclear that it could ever be possible to give us adequate flexibility. For example, can a high enough data rate be achieved to allow us to transmit tape data to CV? On the other hand, we would probably not be able to justify the expense of such software packages as SUPERCOMPACT for each site, or for Green Bank only, whereas, if one copy were accessible to electronics users at all four sites, its purchase might be warranted.

The link to the IBM as it currently serves us is inadequate, and its deficiencies place severe limitations on our scientific and technical staff as well as on visiting observers. On the other hand, total independence from CV is not an obvious solution to all our requirements. Just because the link to the IBM is there does not mean that it provides all the capabilities we require; at the same time, were we to acquire our own smaller machine, we would still desire to communicate with machines at other sites, particularly CV.

The installation of a VAX in Green Bank would solve several existing problems and create new opportunities for the future. First, our general purpose computing capability would become viable (it isn't now) and easily accessible. Requirements include the ability to mount tapes, run interactive graphics with hard-copy output, produce publishable quality plots, and other I/O oriented tasks which are currently difficult or impossible to do with the present Green Bank setup. Second, the inevitable adaptation of single dish observational data into an AIPS environment could begin. Since Green Bank is the major single dish facility, this effort should properly be concentrated in Green Bank although personnel from all sites should be involved. The idea of setting up a "single dish" group similar to the AIPS group is a step in the right direction; it is time that NRAO recognizes that it has three different, popular and unique single dish instruments which deserve the full support of NRAO resources. Third, radio astronomy data processing must now be considered "standard" in a VAX-AIPS environment. This is evident by the proliferation of these systems in a wide range of universities and other institutions. For Green Bank, the major US single dish observatory, <u>not</u> to have this standard computational facility is inconsistent with the NRAO tradition of excellence. It may mean not only a declining ability to attract talented staff to Green Bank, but also may be a discouragement to otherwise prospective visitors. With its relatively inexpensive accomodations, Green

Bank could potentially be an attractive location for visiting astronomers to undertake VLA or VLBI data reduction. Moreover, visitors may wish to combine observing trips to Green Bank with data reduction trips, possibly resulting in decreased travel reimbursement costs for NRAO.

The argument has been advanced that it might not be prudent to continue with the VAX while other cheaper and more powerful computers are on the horizon (e.g. VAX on a chip, 68000-based machines, etc.). There are several reasons why this argument may not apply. First, the VAX system with complete, working AIPS software is available now. To wait two years (or more) for a new super-machine and perhaps several more years for delivery, installation and development of software is an intolerable delay for a NRAO site with no computer now. Second, if the VAX can handle the tasks required of it in Green Bank for the next several years, and we believe it can, it makes no difference if newer, more powerful, and cheaper computers are available in five years. Third, the VAX is now the standard radio astronomy processing machine. With a large number of recently-installed VAXs now doing physics in general, and radio astronomy in particular, one can reasonably assume that there will be no sudden abandonment of the VAX in the next few years. These considerations must be weighed in any decision to gamble our computer needs on a 68000-based machine.

We reemphasize the desirability of maintaining some link to other main NRAO computers so that programs may be exchanged and/or shared. However, it does not seem likely that all of our requirements can be met by the existing link to the IBM without major hardware additions in Green Bank. Furthermore, we could not be expected to maintain our own VAX-class machine without additional personnel to handle the additional headaches.

There will be maintenance problems on both the hardware and software sides. This question of semi-independence is fundamental to much of our plan, and again, should not be decided without the best interests of the entire observatory in mind.

IV. Which computer?

In deciding which major computer investments to make, we must realize that, in fact, we are talking about at least four cpu's:

1) 300-foot control computer;

2) 300-foot signal processor computer;

3) Lab all-purpose computer;

4) Duplicate of 1) to allow system development and to serve as backup in the event of a hardware failure in the telescope control system.

All of the considerations discussed previously concerning future requirements must be met. The lab all-purpose computer should be capable of handling one AIPS user plus multiple other users simultaneously. The 300-foot control computer must be capable of handling the signal processor. These investments will have a major impact on the future of Green Bank. It should be noted that the cpu here is only a portion of the total systems required. Tape drives, disks, etc. will add substantially to the cost of all systems.

Reliability is a major requirement for all of these machines. Moreover, the same personnel will be involved in the development of the 300-foot control system and signal processor, and all systems will be maintained on-site. Our manpower limitations dictate that duplication of hardware and software be considered wherever possible.

Three possible routes to follow are:

| | A | B | C |
|---|---|---|---|
| 1) 300-foot control | MODCOMP Classic | VAX730 | 68000 |
| 2) signal processor | 68000 | 68000 | 68000 |
| 3) Lab | VAX730/750 | VAX730/750 | VAX/68000 |
| 4) Backup | MODCOMP Classic | VAX730 | 68000 |

A and B are conservative routes, with C perhaps offering the greatest potential for flexibility and expansion. It is clear that new systems will be installed in Green Bank and thus our computer personnel will have to familiarize themselves with new machines. One point to make is that the cost of any of these plans is large since the price differential among the different cpu's is only a small fraction of the total system cost. Major questions involve the reliability and the availability of adequate software for the 68000-based machines. Right now, we have no experience with these, but certainly they have great potential. Since Marc Damashek and Ron Weimer will be involved in both the 300-foot control and signal processor projects and cannot work simultaneously on both, a possible approach is to invest in one 68000-series machine immediately, ostensibly for the signal processor. After working with the device for six months or so, Marc and Ron would probably be better able to evaluate the potential of such a machine than we are now. The signal processor computer is scheduled to be purchased in June and hence by the end of 1983, we could have a good idea of what route to follow at the 300-foot. Marc and Ron will be visiting Charles River Systems to see their machine on March 22.

The lab computer depends a good deal on what happens within the rest of the observatory. Here we hope to rely on the observatory's experience with multi-user systems, since we have none on-site at present.

## V. Summary of new items

We believe that the total independence of Green Bank computing from the rest of the observatory is not in anybody's best interests, and therefore, we support the continued development of the observatory's digital communication link. However, we again emphasize that our research and development productivity is currently hampered to no small extent by our inadequate computing capability.

In terms of new hardware, we cannot yet make a shopping list of the specific items needed, but we can identify the following general acquisitions in order to satisfy our mimimum requirements:

1) New control computer at 300-foot telescope;

2) Additional tape drive on lab Modcomp;

3) Additional terminals at telescopes;

4) Additional modems for remote observing;

5) High resolution-high quality plotting device accessible to both lab Modcomp and general purpose computer.

6) Additional multi-user access to general purpose computer.

7) Interactive operating system on general purpose computer.

8) High resolution interactive graphics (software, terminals and hard-copy unit) for general purpose computer. The recently arrived HP graphics terminal is a great improvement but can only be considered as a temporary band-aid solution.

9) Two tape drives for general purpose computer.

10) Full AIPS capability with $I^2S$. AP and two disk drives desirable.

11) Data acquisition and control system (DACS) probably incorporated into a network with other sites.

12) Additional small computers to fulfill specific tasks (e.g. in shops).

13) Additional word processing and record keeping capability in all areas. Devices could be shared.

On the software side, mimimum modifications include the following:

1) Update to control system at 140-foot telescope;

2) New control system at 300-foot telescope;

3) Modifications to existing data taking programs to incorporate new front- and back-ends, most notably the multifeed continuum receivers and the pulsar processor/spectrometer.

4) Modifications to the spectral line data reduction package to accomodate the pulsar processor/spectrometer.

5) Modifications (rewrite?) of the continuum data reduction package.

6) Development of AIPS capability for single dish data reduction.

7) Interactive graphics/plotting package for general purpose computer.

8) Special purpose software for electronics including schematics, block diagrams, circuitry, etc. The purchase of a package such as SUPERCOMPACT for observatory wide use is desirable.

Many of our needs are shared by other sectors within the observatory; moreover, much expertise which we do not possess is available. With our current personnel levels, we will not be able to fulfill our goals in either maintenance or development of new hardware and software.

Because of our current crisis-state, our plan has two phases, one that brings us to an acceptable level with our most pressing needs on a short time scale (one year), and a second that takes us into the future.

Hopefully, decisions on the second will be made soon enough that choices for the first can be made intelligently. We must not be tempted by short term fixes that may shut us out of future expansion for years. Furthermore, it is important to users who are not computer experts that the computing environment be stable. We urge development of systems which, in terms of operating systems, editors, graphics packages, etc., promise stability as well as the quality of software that long-term commitments dictate.