# VERY LARGE ARRAY PROGRAM

NATIONAL RADIO ASTRONOMY OBSERVATORY
ASSOCIATED UNIVERSITIES, INC.
VLA PROGRAM
PROGRAM PLAN FOR CY 1979
December 1, 1978

**NATIONAL RADIO ASTRONOMY OBSERVATORY**
**P.O. Box 0, Socorro, New Mexico 87801**



**OPERATED BY ASSOCIATED UNIVERSITIES, INC.**
**UNDER CONTRACT WITH THE NATIONAL SCIENCE FOUNDATION**

NATIONAL RADIO ASTRONOMY OBSERVATORY

ASSOCIATED UNIVERSITIES, INC.

VLA PROGRAM

# PROGRAM PLAN FOR CY 1979

December 1, 1978

NATIONAL RADIO ASTRONOMY OBSERVATORY
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Mr Lancaster

RECEIVED

MAR 19 1979

VLA PROJECT

1 - ~~Skinner~~

2 - R. Dow

3 - J Lancaster

Take copies if you wis

March 15, 1979

D.L.

Send cc to all VLA people who have Plan

Thank/ow

Dr. William E. Howard, Director
Division of Astronomical Sciences
National Science Foundation
1800 G Street, NW
Washington, D. C. 20550

Dear Bill:

I am enclosing revisions for the VLA Financial Plan for CY 1979. This material updates a Preliminary Plan dated December 1, 1978 sent you earlier.

The principal changes reflect the impact of reduced 1980 monies for construction and installation of the VLA as per your letter of February 7, 1979. We had planned on $5.16M for 1980 to allow completion of the VLA (see Fig. 11, page 54 of the December 1 Plan). Your target figure of $4.7M forces a reduction of $460k in these plans. This reduction is reflected in the modified page 54 enclosed with this letter and is described in the accompanying text.

You will note that in both the original and revised Budget Analysis, we have allocated $1.0M of the remaining (1979 and 1980) funds for contingency. We feel it only prudent that such a contingency fund be carried. However, in your letter of February 7, 1979 you ask that "for the present [we] reserve $400k as a contingency from the FY 1980 $4.7M for potential tax liabilities". We, of course, share your concern for such unexpected costs and hope that no contingency monies are needed for any of the items needed for completion of the VLA. We are therefore reluctant to identify any single item as a potential source of additional costs and especially one that has yet to be adjudicated--for the assignment of such monies could be interpreted as our own recognition of default. If some construction item, for whatever reason, needs additional monies, i.e., contingency monies, we feel that, within our charge to construct the VLA, we must be able to call upon such a contingency fund.

If contingency monies remain as the project draws to a close, we expect to be able to use such funds for those items which have been eliminated

or postponed because of your $4.7M 1980 ceiling. We have also listed other "Alternate Items" in our Program Plan (see page 79) that are necessary for the future operation and safety of the Very Large Array.

Sincerely,

Morton S. Roberts
Director

MSR/pj

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

REVISION OF PROGRAM PLAN FOR CY-1979
6 March 1979

## GENERAL

By letter dated February 7, 1979, the National Science Foundation instructed the National Radio Astronomy Observatory to revise the proposed funding level for CY 1980 from $5,160,000 to $4,700,000, thus reducing the total estimated cost of the VLA Program from $79,030,000 to $78,570,000. This document will set forth the various revisions to be made in the Program Plan dated December 1, 1978.

## REDUCTIONS IN ESTIMATED COST

The reduction, which amounts to $460,000, will change the following items:

| | |
|---|---|
| Wye Construction - Reduction due to low bid price for stone ballast | $ 35,000 |
| Building Complex - Elimination of Visiting Scientists' Quarters No. 3 ($90k) and furnishings ($15k) | 105,000 |
| Computer Systems - Postponement in the acquisition of part of the Mass Storage System. Reduction in estimated costs from $600,000 to $280,000 | 320,000 |
| Total | $460,000 |

## EFFECT ON THE VLA PROGRAM

The items selected for reduction will have the least permanent harmful effect on the construction and operating efficiency of the VLA.

The first item is a cost savings which would normally be returned to contingency and held against possible future overruns.

The elimination of the third Visiting Scientists Quarters will reduce available beds for visitors from 20 to 14 and the number of rooms from 16 to 10. This will limit the size of visiting research teams and their length of stay. It is a second order restraint and does not directly impair the scientific output of the instrument.

The reduction of the mass data storage capability will have long term harmful effects on the instrument, particularly when the VLA begins to handle the very massive amounts of spectral line data. The $280,000 remaining will permit the procurement of a number of tape drives and the start of the overall system.

The remainder of the mass storage equipment will have to be purchased from CY-1981 operating funds in order that the operation of the VLA not be impaired.

We have revised all of the other activities and have concluded that they have higher priority than the areas selected for reduction.

DETAILED REVISIONS IN THE PROGRAM PLAN

Computer Systems

Insert new Computer-Block Diagram dated January 1, 1979 in lieu of Page 29.

Computer Systems - Page 36 - Replace second paragraph with following two paragraphs:

"Work will continue in 1979 to determine the direction to be taken for long- and intermediate-term data storage. $280,000 has been budgeted for the mass storage system, split between the years 1979 and 1980. With the very rapid advances being made in this field, it is desirable to hold off procurement until a more compact media is available. It is expected that a number of tape drives and some other equipment will be purchased in 1979."

"Work will also begin on hardware procurement and programming for the Observer Image Processor for post-processing of VLA data mentioned on pages 28 and 41 of this program. $290,000 of the necessary equipment funds will be made available in 1979."

We have also taken this opportunity to revise the cost estimates in all of the categories. The revised sheets included:

VLA Financial Report - Page 44 (Fig. 8)

Insert attached new page.

Estimated Cost - Design and Construction on 12/01/78 - Page 46 (Fig. 9)

Insert attached new page.

Cost Estimate 12/01/78 - Pages 50-53 (Fig. 10)

Insert attached new pages.

Budget Analysis by Program Year - Page 54 (Fig. 11)

Insert attached new page.

Financial Plan - CY-1979 - Pages 50-60 (Fig. 13).

Insert attached new pages.

NATIONAL RADIO ASTRONOMY OBSERVATORY
ASSOCIATED UNIVERSITIES, INC.
VLA PROGRAM
PROGRAM PLAN FOR CY 1979

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# INTRODUCTION

This update of the Program Plan for the design and construction of the Very Large Array Program reports the progress which has been made during the last year, discusses changes which have been made in the previous plan, and forecasts activities to be undertaken in future years. In addition, revised cost estimates and commitment and expenditure schedules are included and discussed. Some sections, such as a description of the instrument and organizational details, are included to make the Program Plan understandable to one who is not intimately acquainted with the previous Plan.

The CY 1978 Program Plan was based on a funding level of $12,500,000 in CY 1978, a $13,000,000 per year level in CY 1979, and the balance necessary in 1980. The total estimated cost for the VLA with this funding level was projected to be $78,043,000.

On July 7, 1977, the Foundation formally requested NRAO to complete a Zero Base Budgeting study of the VLA for 1979 funding. This study showed that, should the proposed $13,000,000 CY 1979 funding level be cut to $11,500,000, the VLA Program would suffer a $223,000 cost increase. The cut of $1,500,000 would require two Site and Wye construction contracts, one in 1979 and one in 1980. In addition to escalation running at 8-10% per year, there are large inefficiencies, mobilization and demobilization expenses, associated with the placement of two small construction contracts rather than one large one.

At the December 22, 1977, NSF Semiannual Review Meeting, a vugraph was shown indicating an increase in cost of over $300,000 would occur if the 1979 funding was reduced by $1,500,000. This later estimate included funds for necessary construction personnel in 1981. This vugraph was shown again and discussed at the July 18, 1978, Semiannual Review Meeting at the VLA site.

On September 12, 1978, the Foundation formally advised the

National Radio Astronomy Observatory to plan on a $11,500,000 level in CY 1979 instead of $13,000,000. This Plan is based on the $11,500,000 level, which postpones $1,500,000 of planned work into 1980. At an 8% rate of escalation, this amounts to a direct cost increase of $120,000, plus the inefficiencies mentioned in the previous paragraphs.

Based on the CY 1979 funding level $11,500,000, the August 1977 cost estimate is $79,030,000. Included within this figure is the transporter No. 2 at $800,000, a Stand-alone Observer Image Processing System at $425,000, the third Visiting Scientist Quarters at $90,000, and additional costs for a first set spare parts inventory of $510,000. The contingency sum included is $1,000,000, which represents 6.3% of the uncommitted 1979 and 1980 funds. This is a modest contingency for a state-of-the-art instrument such as the Very Large Array.

The estimate does not include two items which we believe are necessary for the future operation and safety of the site facilities. These are a Visitors Center at $150,000 and the fire protection water sprinkling of the smaller site buildings at $120,000.

The estimate also does not include transporter No. 3, which a study shows is not vital to the efficient operation of the VLA; the airstrip; and the completion of the Dichroic Reflector System, estimated to cost $101,000. It is believed that the need for the airstrip must develop during the early years of operation and prove that it is an economic necessity before it is constructed. The dichroic system will be completed in 1980, using contingency funds, or in 1981, using OOE funding.

It is the intention of the National Radio Astronomy Observatory that activities during CY 1979 will follow the detailed Program Plan set forth. Should unforeseen conditions arise which require a major shift of emphasis or change the material or data presented in any substantial manner, the 1979 Plan will be revised.

## SUMMARY

CY 1978 saw the continuation of scientific operations although construction and test operations maintained their priority. By October sixth, sixteen antennas had obtained fringes, with the seventeenth scheduled for early December. Thirteen antennas have been declared operational, with the balance undergoing final test and tune-up. The maximum baseline was increased to 15.6 km in October and is scheduled to go to 19.1 km during December. Scheduled scientific and test observations increased from 38% during the last quarter of 1977 to 64% during the third quarter of 1978. Downtime for 1977 was 21% of the scheduled time, which dropped to 8% for the third quarter of 1978.

Fabrication of the antennas and electronics continued as scheduled. The retrofit of certain modules in the local oscillator system for the first ten antennas was completed May twenty-second and resulted in an improvement of phase stability and more reliable operation. On November second, the first half of the final spectral processor was put on line. Development of software for the computer systems kept pace with the expanding use of the instrument, and the final configuration of the "pipeline" spectral line and map making system was determined and procurements begun.

The Davis-Bacon wage determination matter was settled by the Department of Labor's Wage Appeal Board completely in NRAO's favor; bids were taken, and the Phase IV construction contract placed June twentieth. This work consists of 21.9 km of wye trackage and all twenty-one remaining antenna stations. Visiting Scientist Quarters No. 2 and a small office-library building were constructed and occupied. Waveguide installation continued and it is expected that 16,500 meters will be installed this year. Tested in place, attenuation is usually in the 1.01 to 1.10 dB/km range, compared to a manufacturer's acceptance specification of 1.40 dB/km.

CY 1979 will see the continued activation of fully equipped antennas so that, at the end of 1979, the VLA should consist of at least twenty operational antennas working on a baseline of approximately 40 kilometers. Operating time for the antennas is expected to increase slowly and a major effort will be made to decrease the downtime percentage. The twenty-eighth antenna is due for acceptance in late November. Production of electronics, the mechanical and electronic outfitting of the antennas, their final testing, adjustment, and placing into service will continue during the year as scheduled. Construction of the second unit of the spectral processor will begin early in the year, after thorough operational testing of the first unit. The major programming effort will be in the spectral line area. A major effort will be expended in 1979 to procure all the rail, accessories, and ties required for the balance of the wye construction. After these materials are in hand, remaining funds will be utilized to construct additional wye trackage and utilities. During the year it is planned to construct the third Visiting Scientist Quarters building and to install approximately 18,000 meters of waveguide.

## DESCRIPTION OF THE INSTRUMENT

Higher resolution and sensitivity have always been major goals of radio astronomy instrumental development. The general concept of a very large antenna system that could obtain radio pictures with very high resolution, sensitivity, and speed was developed in the early sixties. The initial studies at the NRAO in 1961 and 1962 led to the detailed design beginning in 1964. The design study was carried out by the NRAO staff, with the assistance of a number of radio astronomers from other institutions, and it resulted in the Proposal for the Very Large Array (VLA), published in 1967 (Vols. I and II), 1969 (Vol. III), and 1971 (Vol. IV).

In order to achieve the desired angular resolutions, a radio telescope with dimensions of 35 km (23 miles) is needed. Since a conventional radio telescope having these dimensions is impossible to construct, other techniques which will simulate such a telescope must be used. By interconnecting several separated, smaller diameter antennas, the information leading to the desired resolution can be obtained. Many configurations of the antenna elements are possible, and careful studies of this problem, with the purpose of optimizing the use of a relatively small number of antennas, have resulted in the VLA system, consisting of 27 antennas, each 25 meters (82 feet) in diameter, distributed along three 21 km (13 mile) arms of an equi-angular wye. All the antennas will be movable over railroad tracks so that the picture area (field of view) and the resolution may be varied within wide limits. In this respect, the VLA is similar to a zoom lens.

Each antenna element consists of a steel structure carrying a shaped reflector which is movable in azimuth and elevation in order to be able to point to any part of the sky. The reflector structure supports an aluminum reflector surface consisting of 172 aluminum panels. The surface accuracy and the precision of the drive system

permit operation at wavelengths as short as 1.2 cm. During operation, the antennas are placed on observing stations. Seventy-two such stations will permit the four different configurations planned for the array. The antennas will be moved between observing stations by a transport vehicle; one such transporter is now available, running on a double, standard gauge railroad track system. In 1979 an additional transporter will be procured. A reconfiguration of the antenna system, using two transporters, is estimated to take a maximum of about thirty-six hours. When the railroad tracks are not used for moving antennas, they will be used for transportation of maintenance personnel and equipment.

The initial operating wavelengths for the system will be 21 cm, 6 cm, 2 cm, and 1.2 cm, with full polarization measurement capabilities. Spectral line capabilities for the array are also being developed.

The central computer system will control the telescopes, monitor the system performance, and collect and analyze the data. The system output will consist of high resolution maps of the observed objects.

Power and telephone communications between the central site complex and the observing stations will be distributed through buried cables. Signal and local oscillator distribution, as well as control and monitor signals of all antenna functions, will be accomplished by a buried circular waveguide system.

The central building complex consists of several buildings. A 22,060 square foot Control Building houses the control room, central electronic equipment, digital delay equipment, large central computers, specialized shops, laboratories, and office space. Three small, prefabricated metal buildings, which total 20,000 square feet, house maintenance shops, the electronic and cryogenic shops, storage facilities, and office space. The subcontractor, who is fabricating and assembling the antennas, has constructed a 14,600 square foot Assembly Building, which he will use during his contract and which

will be available for later use for antenna maintenance. In addition, a 5,320 square foot Cafeteria Building and a 2,400 square foot Office-Library Building have been constructed, and a grouping of Visiting Scientist Quarters will be constructed, as well as necessary site work, water supply, sewage, electric utility, and similar facilities.

## ORGANIZATION

### Program Organization

The NRAO organization is shown on the accompanying Organization Chart (Figure 2). The VLA has been designed and is being procured as a program of the NRAO, with the Observatory being its own "prime contractor" for the job. Overall responsibility for the design and procurement of the VLA rests with the Director of the NRAO, who, in turn, is responsible to the President of the Board of Trustees of AUI. AUI, in addition to its internal trustee committees, has the NRAO Visiting Committee to assist it in reviewing and evaluating the performance of the NRAO. The Director has the NRAO Users Committee, the VLA Advisory Committee, and the VLA Steering Committee to assist and advise him on VLA matters. A description and the membership of each of these committees is given in Appendix A.

Within the NRAO, primary responsibility for the VLA design has been assigned to H. Hvatum, Associate Director. Responsibility for the construction implementation has been assigned to J. H. Lancaster, Assistant Director and VLA Program Manager. On June 7, 1978, C. M. Wade was appointed Acting Assistant Director for VLA Operations.

### Program Implementation and Staffing

Implementation of the VLA, including the contracting and managing of all fabrication and construction, is the responsibility of the Program Manager. This work is being carried out according to previously agreed upon drawings, specifications, budgets, and time schedules.

On January 1, 1973 the Program was officially begun with the transfer of 15 existing NRAO staff members to the VLA. This staff has gradually increased since then to the present level of 129 full-time members. Beginning in January 1977, at the start-up of scientific operations, the staff was divided for cost-keeping reasons into Construction, Operations, and Common Cost centers. This breakdown is shown on Page 9.

| | 1977 Program Plan Forecast 12/31/78 | Present Level 10/31/78 | Present Forecast 12/31/78 | Planned Level 12/31/79 |
|---|---|---|---|---|
| CONSTRUCTION GROUP | | | | |
| Antennas | 9 | 9 | 9 | 5 |
| Electronics | 38 | 41 | 43 | 29 |
| Computer | 5 | 4 | 4 | 5 |
| Systems Integration | 1 | 2 | 2 | 0 |
| Site and Wye | 2 | 2 | 2 | 2 |
| Program Management | 3 | 3 | 3 | 3 |
| Totals | 58 | 61 | 63 | 44 |
| OPERATING GROUP | | | | |
| Antenna Maintenance | 6 | 6 | 6 | 12 |
| Electronics Maintenance | 11 | 10 | 10 | 24 |
| Scientific Services | 10 | 12 | 12 | 13 |
| Telescope Operations | 7 | 7 | 7 | 11 |
| Totals | 34 | 35 | 35 | 66 |
| COMMON COST GROUP | | | | |
| Business | 19 | 19 | 19 | 20 |
| Fiscal | 4 | 5 | 5 | 5 |
| Plant Maintenance | 7 | 7 | 7 | 7 |
| Totals | 30 | 31 | 31 | 32 |
| TOTAL FULL-TIME PERSONNAL | 122 | 127* | 129 | 136 |

*Includes four positions where replacements are now being hired.

Although for costing purposes the staff is split into Construction, Operation, and Common Cost centers, it cannot be split so in actual practice except at the penalty of very inefficient operations. Each of the groups responsible for a specific technical portion of the construction and operation of the Array works together and reports to a single Group Leader. In this manner the maximum manpower may be utilized where priorities indicate. On June 7, 1978, a Telescope Operations Division was formed, reporting directly to Dr. Wade. The distribution of the staff by groups is shown in Figure 3.

# National Radio Astronomy Observatory
## Organization Chart
November 1, 1978

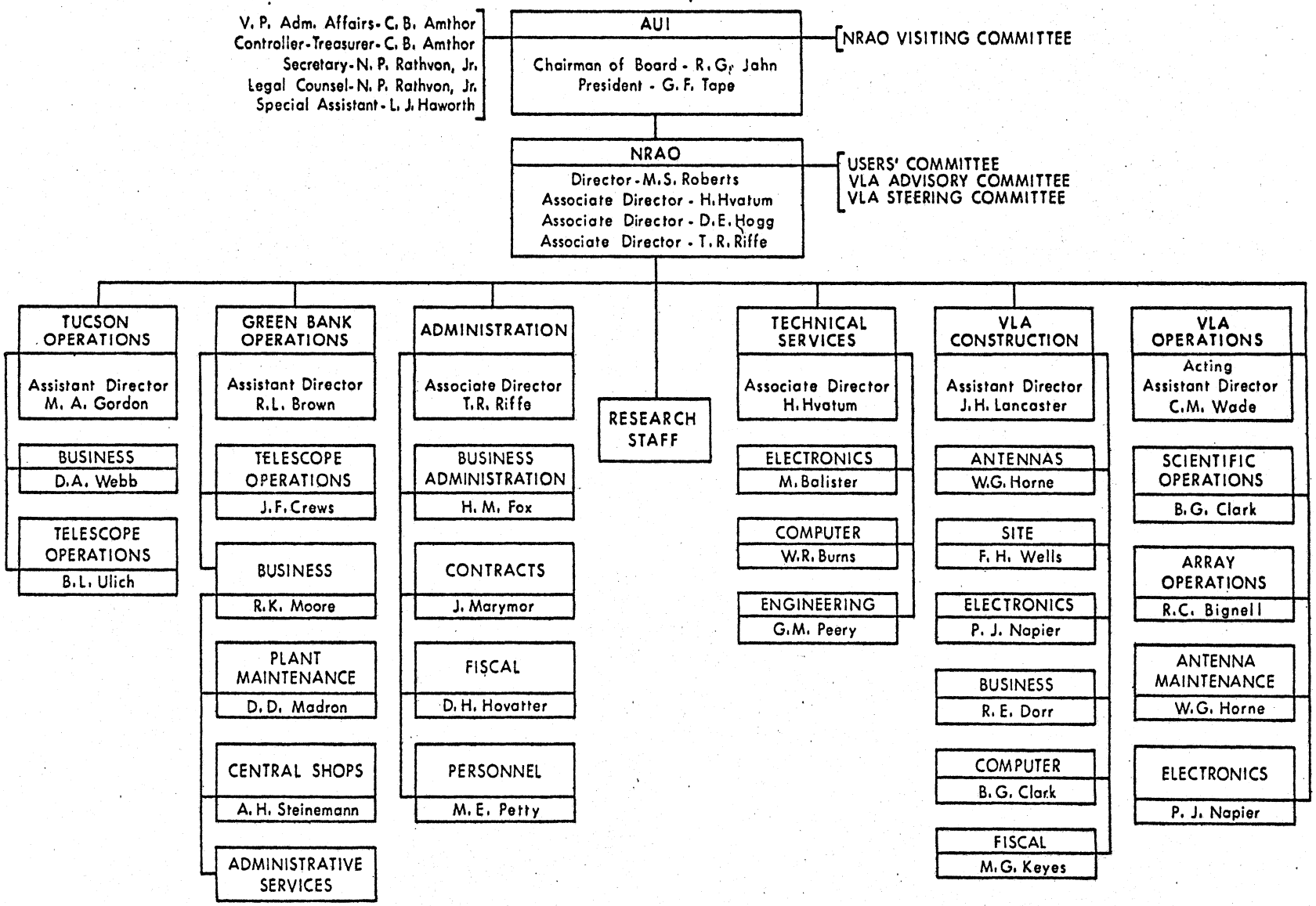
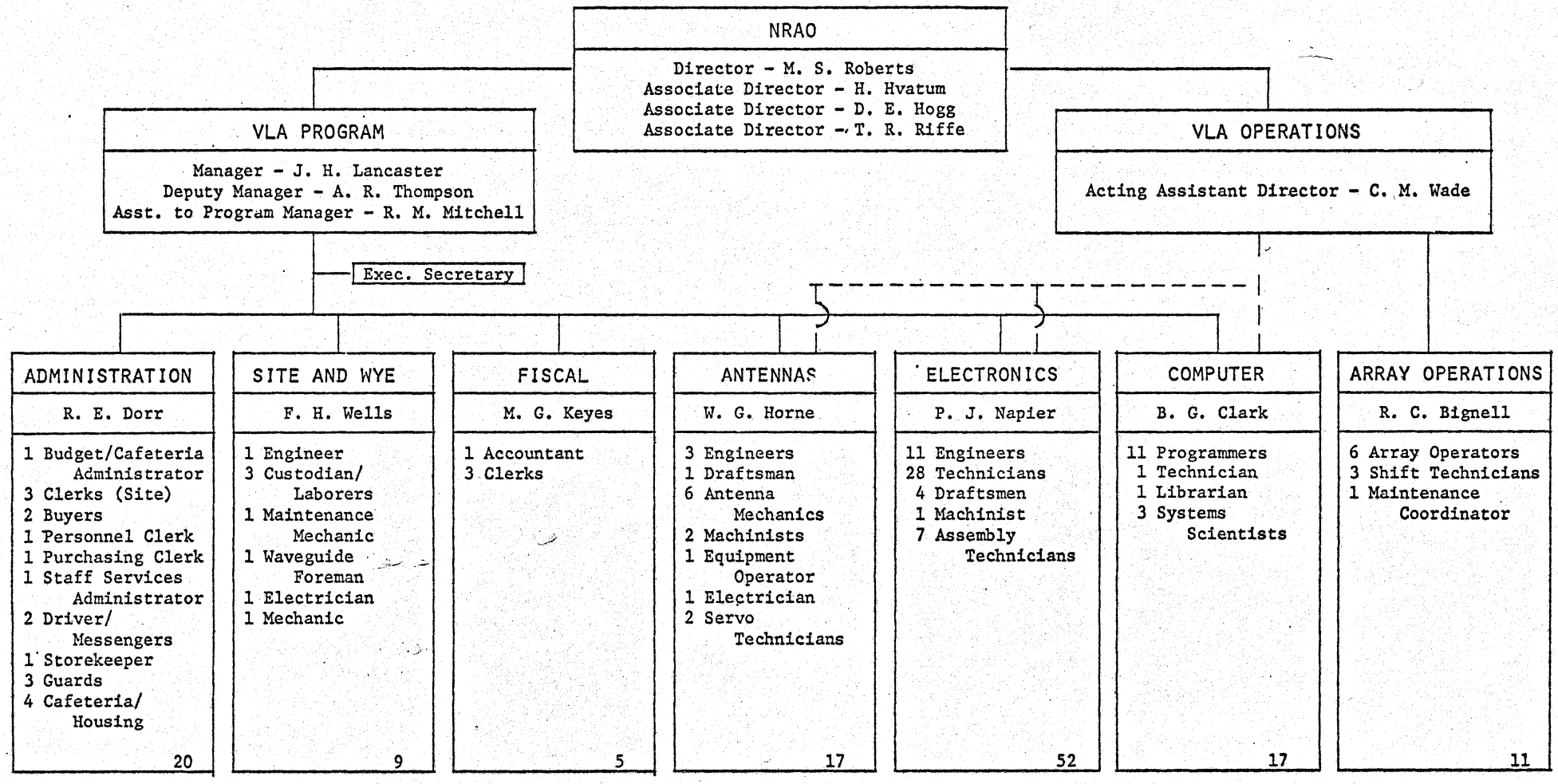



Figure 2

Figure 3

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM ORGANIZATION
PEAK STAFFING - 1979




TOTAL SHOWN 136

12/01/78

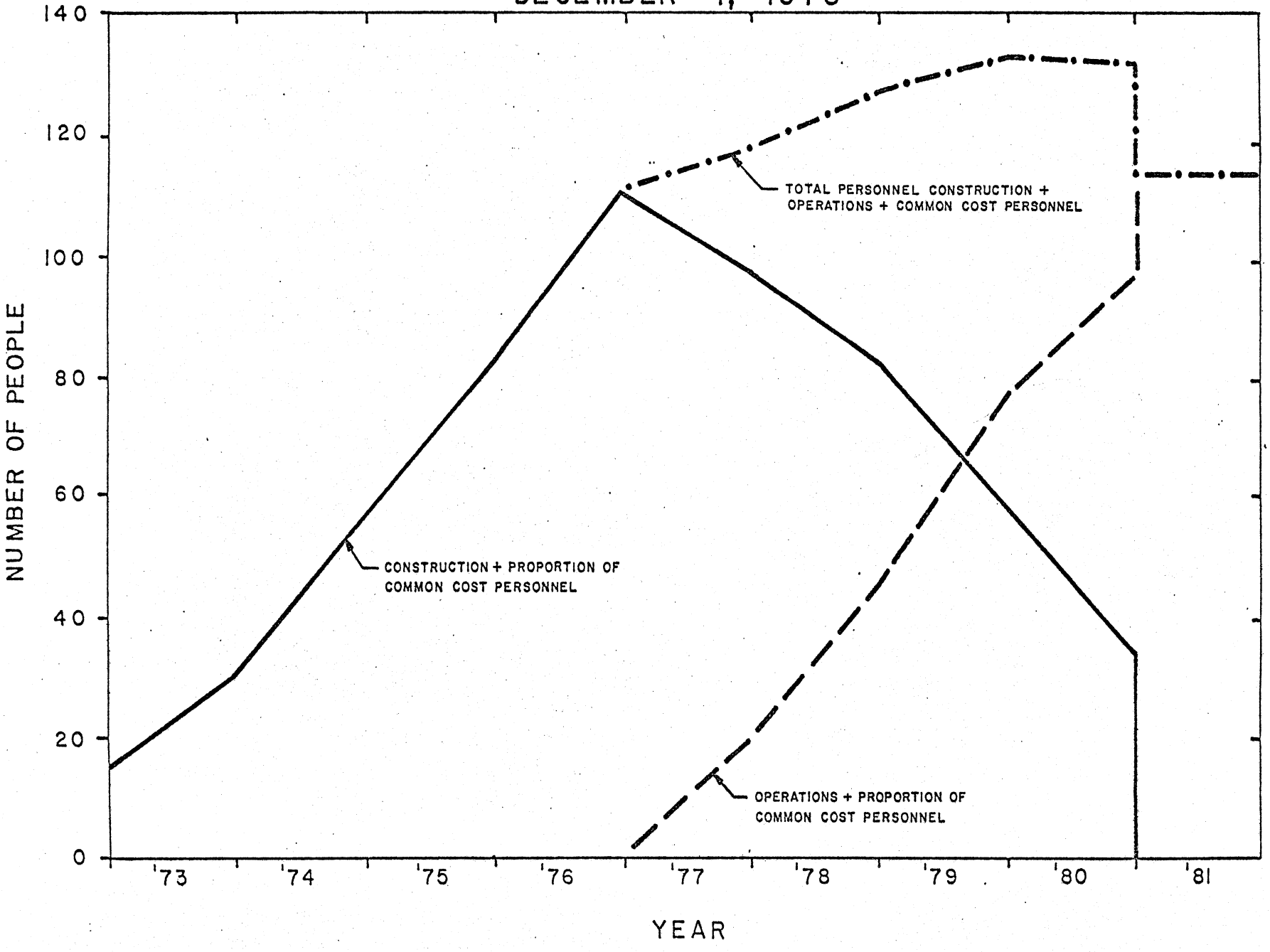

VLA — NRAO
MANPOWER SUMMARY
CONSTRUCTION/OPERATIONS
DECEMBER 1, 1978
NUMBER OF PEOPLE
140
120
100
80
60
40
20
0
'73
'74
'75
'76
'77
'78
'79
'80
'81
YEAR
TOTAL PERSONNEL CONSTRUCTION + OPERATIONS + COMMON COST PERSONNEL
CONSTRUCTION + PROPORTION OF COMMON COST PERSONNEL
OPERATIONS + PROPORTION OF COMMON COST PERSONNEL

Figure 4

## PROGRAM ACCOMPLISHMENTS - 1978

### General

The sixth year of the Program has been highlighted by the placing of fifteen operational antennas on line using a baseline of 17.16 km on the southwest arm and 1.95 km on the southeast arm of the wye. In addition to the fifteen operational antennas, two other antennas have been outfitted with electronics and have achieved "first fringes". Receipt of antenna structures was about on schedule and the design, fabrication, and prototype testing of the electronics was on schedule. During the year the final configuration of the "pipeline" asynchronous computer was determined and procurement actions begun to obtain the necessary hardware for spectral line work. Software programming kept ahead of scientific and test operational requirements. The Davis-Bacon wage determination was resolved in NRAO's favor, the Phase IV construction was successfully bid and at year's end will be approaching 50% completion. A second six-unit Visiting Scientist Quarters and a 2,400 square foot Library-Office building were constructed and occupied. All waveguide requirements for the instrument were placed under firm price contract and about 16,500 meters were installed.

### Contractual

Work continues under Prime Contract NSF AST 74-13427 with the National Science Foundation. The record of funds received to date is as follows:

| | | | |
|---|---|---|---|
| Available | 11/01/77 | | $49,176,189 |
| Amendment No. 29 (CY78) | 11/03/77 | $7,200,000 | $56,376,189 |
| Amendment No. 30 (CY78) | 01/26/78 | $5,280,000 | $61,656,189 |
| Amendment No. 32 (CY78) | 06/05/78 | $ 218,000 | $61,874,189 |
| Amendment No. 33 (CY78) | 09/26/78 | $ 175,000 | $62,049,189 |
| Amendment No. 34 (CY79) | 10/31/78 | $3,700,000 | $65,749,189 |

The total appropriated to date is $66,075,000 and the difference, $325,811, between this amount and $65,749,189 received represents $15,700 withheld by the Foundation for the ECAC study of radio interference, $293,000 withheld for land acquisition, and $17,111 withheld for the Ad Hoc Advisory Committee expenses.

New Mexico Gross Receipts and Compensating Tax

On September 30, 1977, the United States Department of Justice assumed responsibility and filed suit against the State of New Mexico to recover the $127,122.59 paid to the state in 1977. E-Systems, Inc. was instructed to file periodic reports, stating that no tax was due. No further action occurred until August 4, 1978, when the VLA received a copy of an Interrogatory document. Answers were prepared and forwarded to the Department of Justice through the Foundation. On October 27, 1978, two attorneys from the State Department of Finance and Taxation and two attorneys from the United States Department of Justice, Washington, DC, toured the site and observed the movement of an antenna.

Land Acquisition

No further action has been taken by Messrs. Ake, Taylor, or Dunlap to protest the amount of compensation offered by the U. S. Corps of Engineers for their land interest. At least three hearings before a panel established by the U. S. District Court in Albuquerque were scheduled during the year but all of them were cancelled.

Archaeological Study

On November 1, 1977, the U. S. Department of Justice in Washington was considering how best to obtain rights of entry onto the Ake property so that the study contract to New Mexico State University could proceed. The Department filed a motion to enforce possession on November 21st with the U. S. District Court.

On December 6th the court issued a "Writ of Assistance" and an "Order for Writ of Assistance", which was served on Mr. Ake. On December 8th, Mr. Ake filed an objection; a judicial hearing was held December 9th, at which time the objection was denied. On December 13th the Corps of Engineers notified NRAO that the archaeological work could proceed. Mr. Ake was then contacted and gave permission to use all his ranch roads to obtain easy access to the archaeological site.

Due to vacation and winter conditions the actual excavation did not begin until February 20, 1978. Field work was completed May 11, 1978. Lab work and consultant studies will require the balance of 1978, with the report to be issued early in 1979. The land is not required for wye construction until 1980.

During excavation the archaeologists found three specific areas of interest. One of these is believed to be of Folsom culture, which might date back ten thousand years and would be the first time that Folsom man has been found that far west of the Rio Grande river. The other two areas are of the later Cochise culture, which dates back four to six thousand years.

Appeal of the Davis-Bacon Decision

A formal hearing before the Department of Labor Wage Appeal Board was held December 8, 1977. On January 9, 1978, the Board rendered its decision, which stated the following:

1. The Building and Heavy Construction wage rate schedule could not be used.
2. The Department was instructed to make a wage survey for the VLA and issue a project determination.
3. The validity of the Phase III wages was affirmed and the Department instructed to utilize them in their survey.
4. The survey was limited to Socorro and Catron counties.
5. The Department was instructed to issue its new VLA determination as soon as possible.

On March 10, 1978, the Department issued a special wage determination for the VLA Phase IV construction which followed very closely the Phase III wage rates.

Ad Hoc Advisory Committee

The Ad Hoc Advisory Panel for the Very Large Array (VLA) issued its final report on the VLA on December 31, 1977. This panel was appointed by the Foundation at the suggestion of the Committee of Science and Technology of the United States House of Representatives.

In general the report was complimentary, although the Committee expressed some concern on: the adequacy of the remaining cost estimate, contingency, and escalation allowances; operational reliability; signal/data processing; long-range planning; and the adequacy of the VLA operating budgets.

Scientific and Test Operations

A summary sheet showing operating data is attached as Figure 5.

Figure 5

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

## OPERATING EXPERIENCE OF THE VLA

| PERIOD | UPTIME SCHEDULED | ANTENNAS NO. OPER. | ANTENNAS MAX. NO. | MAX. NO. BASELINES | LONGEST "ON-WYE" BASELINE | DOWNTIME OPER. ANT. |
|---|---|---|---|---|---|---|
| YEAR ENDING: | | | | | | |
| DECEMBER 1977 | 39% | 7* | 10 | 45 | 10.5 KM | 21% |
| QUARTER ENDING: | | | | | | |
| MARCH 1978 | 42% | 9* | 11 | 55 | 11.0 KM | 19% |
| JUNE 1978 | 55% | 10* | 12 | 66 | 12.1 KM | 10% |
| SEPTEMBER 1978 | 64% | 11* | 12 | 66 | 12.1 KM | 8% |
| MONTH ENDING: | | | | | | |
| OCTOBER 1978 | 58% | 11* | 12 | 66 | 15.2 KM | 10% |
| DECEMBER 1978 (ESTIMATED) | 54% | 13* | 15 | 105 | 19.1 KM | - |

*DOES NOT INCLUDE TWO ANTENNAS USED AS AN ENGINEERING ARRAY.

11/01/78

Dated Highlights for the 1978 Period

| | | |
|---|---|---|
| November | 1977 | Ten antennas operating on a maximum baseline of 10.5 km. |
| November | 7, 1977 | Antenna station DE4 occupied. Maximum baseline increased to 10.6 km. First research operations using the east arm. |
| December | 6, 1977 | U. S. District Court in Albuquerque issued "Writ of Assistance" to permit VLA to have access on the Ake property for the Archaeological Survey. |
| December | 8, 1977 | Hearing on the Davis-Bacon wage matter was heard by the Wage Appeal Board of the Department of Labor. |
| January | 16, 1978 | Contract placed for Office-Library building and second Visiting Scientist Quarters. |
| January | 17, 1978 | The New Mexico State Highway Commission accepted the last 0.4 mile of the VLA access road and agreed to pave it at their expense. |
| January | 19, 1978 | The Wage Appeal Board of the Department of Labor issued their Davis-Bacon Wage Decision, which was completely favorable to the VLA. |
| January | 20, 1978 | Antenna #10 declared operational. |
| February | 1, 1978 | Antenna #11 achieved first fringes. |
| February | 20, 1978 | Archaeological work on west arm started by NMSU. |
| March | 4, 1978 | Antenna station DE8 occupied. Maximum baseline increased to 11.0 km. |
| March | 10, 1978 | Department of Labor Determination fully supporting NRAO request. |
| March | 27, 1978 | Antenna #12 achieved first fringes. |
| March | 27, 1978 | Antenna #11 declared operational. |
| April | 3, 1978 | Phase IV construction IFQ issued for bid. |
| April | 28, 1978 | Antenna #13 achieved first fringes. |
| April | 30, 1978 | Antenna station CE8 occupied. Maximum baseline increased to 12.1 km. |

| | | |
|---|---|---|
| May | 11, 1978 | Bids received for Phase IV construction. |
| May | 11, 1978 | All excavation for archaeological work on west arm completed. |
| June | 19, 1978 | Visiting Scientist Quarters #2 occupied. |
| June | 19, 1978 | Burn Construction Company protested to the GAO the award of the Phase IV construction contract to Pacific Railroad Constructors. |
| June | 20, 1978 | Phase IV construction contract awarded; $2,916,080. |
| June | 22, 1978 | Antenna #14 achieved first fringes. |
| July | 17, 1978 | Antenna #12 declared operational. |
| August | 8, 1978 | Antenna #15 achieved first fringes. |
| August | 9, 1978 | RFP for transporter No. 2 issued. |
| August | 21, 1978 | The General Accounting Office denied the Burn protest covering the award of the Phase IV construction contract. |
| September | 27, 1978 | Antenna #13 declared operational. |
| October | 6, 1978 | Antenna #16 achieved first fringes. |
| October | 13, 1978 | Antenna station AW7 occupied. Maximum baseline increased to 15.2 km. |
| October | 31, 1978 | Proposals on transporter No. 2 received. Negotiations started. |
| November | 1, 1978 | Antenna station CE9 occupied. Maximum baseline increased to 15.6 km. |
| November | 2, 1978 | New Spectral Processor placed in operation. |
| November | 2, 1978 | New cryogenics facility completed. |
| December | 1978 | Antenna #17 scheduled to achieve first fringes. Antenna station AW8 scheduled to be occupied. Maximum baseline will be increased to 19.1 km. Antennas #14 and #15 expected to be declared operational. |

Antenna Systems

During the period of November 1977 to November 1978 the antenna subcontractor, E-Systems, Inc., completed the delivery of six additional antennas, numbers 15 through 20. Material for fabrication of the remaining antenna structures is on hand at the fabricator's plant; all equipment or components to be assembled on the antennas by the antenna subcontractor are on hand with the exception of surface panels, which are on hand through antenna 27, and the azimuth bearing for antenna 28, which is scheduled for delivery in early 1979.

Mechanical and electrical outfitting, including installation of cable trays and cabling, addition of cryogenic compressor platform, installation of subreflector and subreflector supports, installation of modified access stairways, installation of waveguide, installation of telephone-activated fault resets, and installation of antenna feeds, were performed by NRAO on antennas 12 through 18 during this period.

A design change to the air conditioning system for the vertex room has been accomplished for eleven of the operating antennas and will be installed in the remainder of antennas on hand and those yet to be delivered. This change provides modulation of refrigerant flow to provide more stable temperatures in the vertex room and has proven quite satisfactory.

Figure 6 displays the status of the antenna schedule for antennas 3 through 28. It will be noted that the antenna subcontractor at the end of the period has lost approximately five weeks from the schedule which was established in July of 1976. The antenna subcontractor has informed AUI that the schedule slippage is due to fabrication delays at the structural fabricator's plant and that necessary corrections have been made to correct the slippage and regain the schedule.

As the number of operating antennas had, by the beginning of the period, reached an appreciable number and the first two antennas had been in AUI possession for two years, a scheduled preventive

maintenance program was instituted, which provides routine inspections, cleaning, lubrication, adjustment, and servicing of the mechanical, structural, and electrical components of the antenna system. A partial supply of spare components, parts, and equipment to support the continuing operating of the present number of antennas has been obtained. A study of predicted failure rates for the antenna components has been prepared and is the basis for manpower and spare parts planning.

Transport Vehicle

The transport vehicle was used extensively during the period for movement of the antennas at the Assembly Building during assembly, movement of antennas to outfitting and test stations, and movement of antennas to regular observing stations. As of the present date, the transporter has made ninety-six antenna moves without difficulty. The transporter, because of its unique capabilities, serves as the main service vehicle for lubrication, repair, and maintenance of the antennas and has been used to perform this function.

NRAO has made a number of modifications to the existing transport vehicle, as suggested by operating experience with the vehicle, in order to improve its performance. Included in these modifications are the additions of truck centering devices to improve turning at spur intersections, the modification of hydraulic routing to minimize wear on flexible hoses, and the modification of the truck suspension collar to ease the turning torque.

A design review of the transport vehicle was completed, drawings revised, and a request for proposal for an additional transport vehicle was issued August 9, 1978.

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

## STATUS - PROCUREMENT OF ANTENNAS 3 THROUGH 28

### E-SYSTEMS DELIVERY DATES

| ANTENNA NUMBER | SCHEDULED | ACCEPTANCE | ANTENNA NUMBER | SCHEDULED | ACCEPTANCE |
|---|---|---|---|---|---|
| 3 | 04/15/76 | 04/20/76 | 16 | 02/15/78 | 02/14/78 |
| 4 | 05/24/76 | 06/07/76 | 17 | 04/07/78 | 04/04/78 |
| 5 | 07/15/76 | 07/16/76 | 18 | 05/31/78 | 06/19/78 |
| 6 | 08/30/76 | 09/03/76 | 19 | 07/21/78 | 08/25/78 |
| 7 | 10/15/76 | 10/29/76 | 20 | 09/13/78 | 10/20/78 |
| 8 | 11/30/76 | 12/17/76 | 21 | 11/03/78 | |
| 9 | 01/17/77 | 02/25/77 | 22 | 01/12/79 | |
| 10 | 03/01/77 | 04/26/77 | 23 | 03/09/79 | |
| 11 | 04/29/77 | 06/09/77 | 24 | 05/03/79 | |
| 12 | 06/22/77 | 07/15/77 | 25 | 06/22/79 | |
| 13 | 08/12/77 | 09/02/77 | 26 | 08/15/79 | |
| 14 | 10/12/77 | 10/21/77 | 27 | 10/05/79 | |
| 15 | 12/09/77 | 12/07/77 | 28 | 11/30/79 | |



Figure 6

Electronics Systems

During the period November 1977 to November 1978 electronics outfitting and first operation has been completed as planned on antennas 11 through 16. Antenna 17 should be in operation in early December, 1978. In most areas, the electronics construction covered seven systems, providing for antennas through 24. In the feed and front end area six systems were procured and construction commenced, providing for antennas through 21. Testing of the electronics, and modifications where necessary, has continued.

The most extensive modification made to the electronics during the year was the retrofit program carried out to improve the phase stability of the local oscillator system in antennas 1 through 10. This retrofit program was completed in June and resulted in significantly improved phase stability. The problem of phase jumps received considerable attention during the year and improvements were made by providing control on the pressure inside the 60mm waveguide and by improving the computer software used to apply the round-trip phase correction. As the year ends, isolated cases of antennas with poor phase stability or phase jumps still remain, but it is thought that these result from individual malfunctions rather than system-wide problems.

Two programs of electronics upgrading, the front end filter system and spectral line IF system, which were planned to start in 1978, have been delayed by problems encountered during the design or prototype testing phases. The front end filter system will allow the installation of bandwidth selection filters at the antennas to improve the selectivity of the instrument against interference and eliminate some known spurious responses. Interference by other spectrum users is experienced occasionally in the 18-21 cm band but is not a serious problem. As the year ends, prototype testing is being completed on the front end filter system. The spectral line IF system (now called the baseband system) will provide the wide range of narrow band filtering needed for spectral line observations. As the year ends,

the design of this system is being completed and prototype assembly and testing is beginning.

Work on the antenna feed system during the year has been directed mainly to improving our understanding of the polarization behavior of the antennas. Prototype circular polarizers for the 18-21 cm band were successfully designed and tested.

In the cryogenics area an important decision was made to replace all Air Products and Cryomech cryogenics systems with more reliable CTI systems. Experience at the VLA and other NRAO observatory sites shows that the CTI systems are much more reliable than the other available systems. Antennas 13 through 17 have CTI cryogenics systems and retrofitting of the older antennas has commenced, with antennas 5 and 10 completed. The new cryogenic laboratory facilities, with special clean rooms and systems testing area, should also improve cryogenics reliability.

The AIL 6 cm parametric amplifiers used in the front ends since antenna 7 have proven to be very reliable and the decision has been made to substitute them for the less reliable Comtech amplifiers used in antennas 1 through 6. This substitution has already been made in antenna 5.

Progress has been made in several areas of the 60mm $TE_{01}$ mode waveguide system during the year. The attenuation of the waveguide continues to remain constant with time. As the waveguide run has increased in length, the average loss has decreased because improved burial techniques have reduced the loss of the more recently installed waveguide. The design of the waveguide sector coupler was finalized during the year and a production run of sixty-four couplers was fabricated. These are enough couplers for the complete array except for the special beam splitter couplers which are needed for the A8 station. One of the beam splitter couplers was constructed and tested for AW8. The waveguide was pressurized with nitrogen for the first time in February. Initially large leak rates were reduced to acceptable levels in September when the final design couplers were

installed in place of the prototype couplers.

Considerable effort was expended during the year to understand and improve the problem of spurious signals in the 18-21 cm band. Unwanted signals from the local oscillator system are picked up at several frequencies throughout the 18-21 cm band. The most significant development in this area was determining that the phase detectors in the F2 (upconverter pump) and F3 (17-20 GHz LO) modules radiated harmonics of 200 MHz in the 18-21 cm band. These detectors were redesigned and successfully tested.

The new digital spectral processor was brought into permanent operation in November. The problems of spurious correlation which delayed the commissioning of the processor for several months were traced to problems of crosstalk between the long wire-wrap runs involved in the integrator. The crosstalk was reduced to an acceptable level for astronomical purposes by shielding the wire-wrap runs and by changing some of the logic types. As the year ends the remaining low level crosstalk is being investigated to eliminate it completely.

Computer Systems

The effort expended on the on-line computers in 1978 has been primarily in support of the new correlator system and other modifications necessary to accommodate spectral line observing. This has included the hardware and software support of a common memory area between two of our Modcomp computers. Without this, the exchange of information was consuming too much I/O bandwidth for the final system.

Modest investments have been made in altering the correlator data handling, and substantial amounts of support software for the new correlator have been written. No great effort directly leading to spectral line observations has yet been made; this will be mounted in the early part of 1979.

DEC-10 programming has been primarily in a phase of small improvements in 1978. The basic system was organized by the beginning of the year and has been polished throughout the year, adding functions and making things more convenient. The standard command interpreter, which is incorporated to a greater or lesser extent in all the programs in the reduction package, is now a polished command language which compares well with any other developed for similar purposes. The addition this year of a long-term memory to the programs, for automatic saving of input parameters, has made them extremely convenient to use.

The PDP 11/70-FPS AP120B map making system is now supported with software which makes it easily usable with the DEC-10 computer; files can be flexibly transferred throughout the system. There is a program, as yet quite primitive, which makes maps from standard DEC-10 data bases and makes them accessible to the standard map display routines. By the end of 1978 it is hoped that this program will be sufficiently developed that it can start taking some of the load from the DEC-10.

Design studies have progressed far enough that many components of a spectral line data sorting system have been ordered. This consists

of ten disk drives storing 250 MBytes each attached to a PDP 11/70 computer.

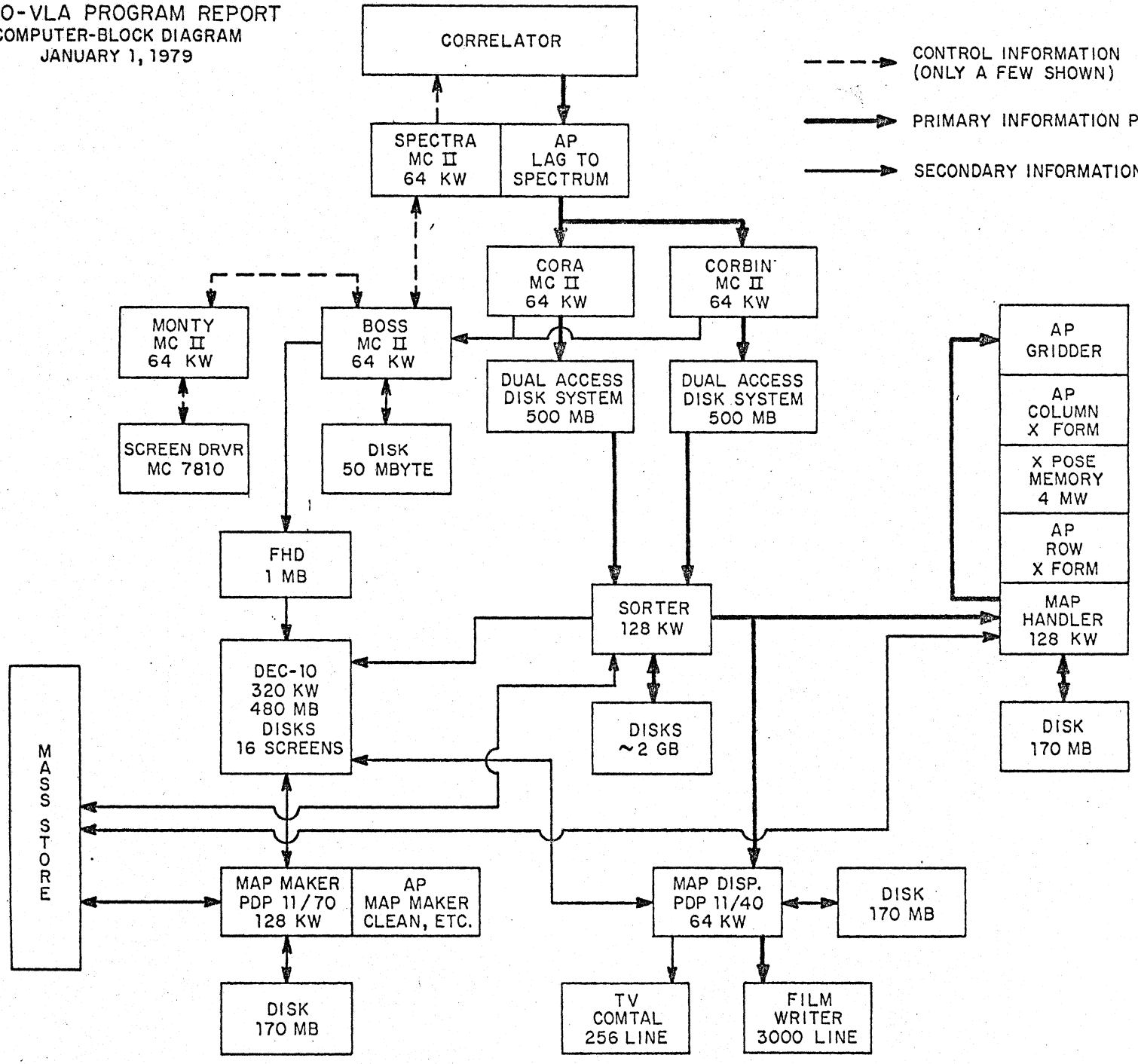
A map manipulation program, the Interactive Map Processing System (IMPS), has been written for the PDP 11/40-Comtal Image Display System. The system is usable but has only a few application programs and is still very clumsy to get data into and out of. A Dicomed film writer has been installed and work is proceeding on the software interface to make map images; a primitive version should be available by the end of 1978.

The Group is currently investigating the possibilities of making this set of programs a bit more general, to be the basis of a transportable image display system (i.e., one which can be installed in a different computer with an effort much smaller than a complete rewrite).

During 1978 a considerable amount of effort was expended to determine the final configuration of the "through-put" or "pipeline" system to carry raw data through the system to the initial radio map. A schematic or block diagram of the proposed system is included as Figure 7.

During October 1978 it was decided to activate a small group in Charlottesville under the direction of Dr. W. R. Burns to study the requirements of the post-processing of VLA data and to select hardware and develop software programs to accomplish the necessary tasks. The intent is to produce a software system which is as machine-independent as is practical using FORTRAN language.

NRAO-VLA PROGRAM REPORT
COMPUTER-BLOCK DIAGRAM
JANUARY 1, 1979



# PROGRAM REPORT
## COMPUTER – BLOCK DIAGRAM
## NOVEMBER 1, 1978

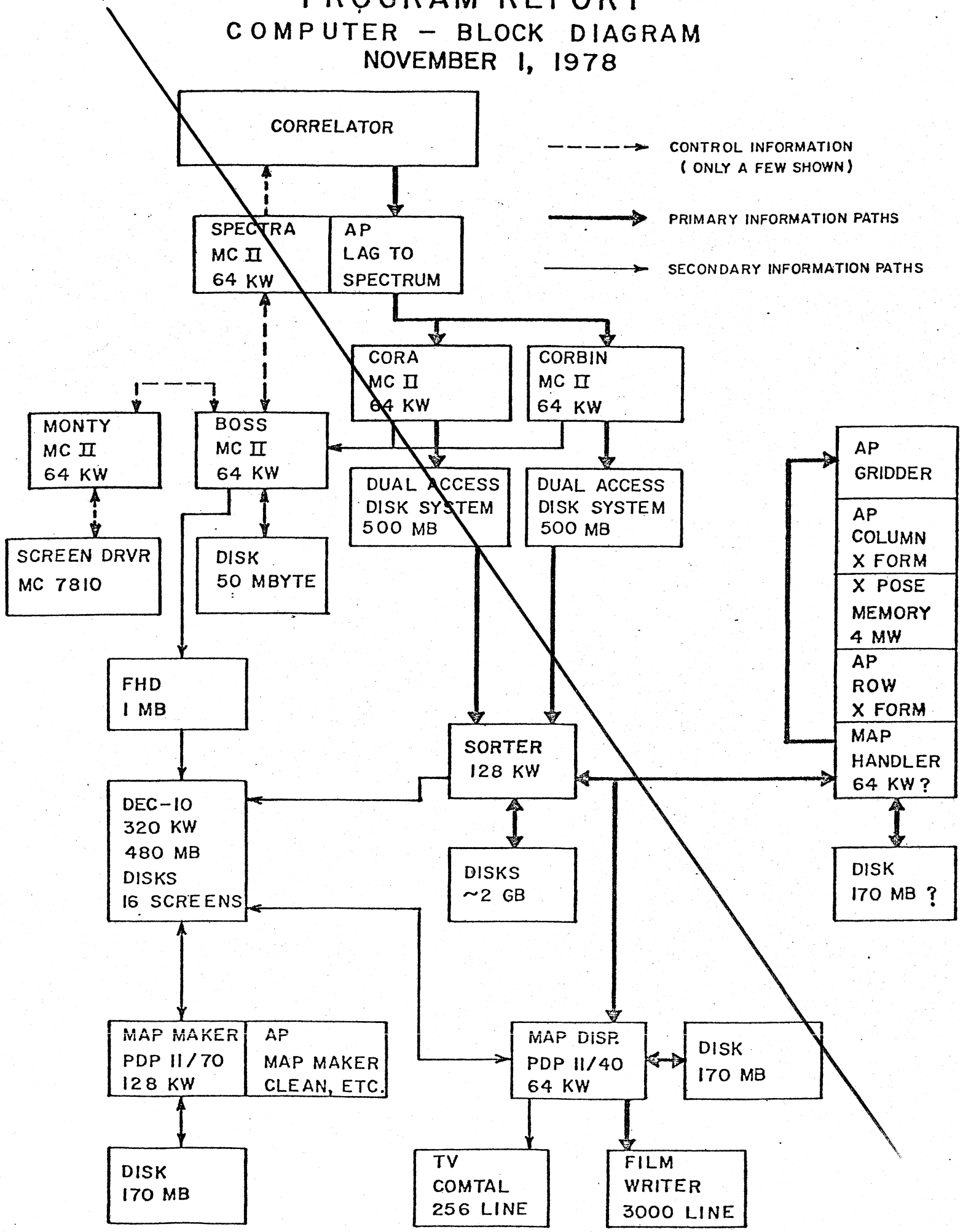





Figure 7

Site and Wye

After the favorable resolution of the Department of Labor construction wage classification problem, Phase IV construction went out for bid in April and a contract for $2,916,080 was executed with Pacific Railroad Constructors, Inc. on June 23, 1978. Construction will consist of 21.9 kilometers (13.6 miles) of wye trackage, with eleven interchange and antenna spurs along with twenty-one antenna foundations. Electrical work included consists of 15.2 kilometers (9.5 miles) of 15 KV primary feeder circuits and antenna station power for nine antenna stations. The Site and Wye group supervise the construction with assistance of monthly inspections by the Engineer/Architect. The contract is scheduled for completion in September 1979.

A second six-unit motel type prefabricated Visiting Scientist Quarters building was received in May 1978. The slump block veneer was installed, patio and access walks were poured, and the building was furnished and ready for occupancy in June.

A 2,400 square foot prefabricated library-office building with a library and eleven single offices was also received in May. Slump block veneer and access walks were installed in May. The building was furnished and ready for occupancy in June.

Landscaping adjacent to the new buildings was complete in October.

A 24 foot by 40 foot garage building was erected to house the ambulance and electric vehicles. It was completed in October.

A 40 foot by 50 foot addition to the Technical Services Building for the Cryogenics Shop and Front End Lab was built. The addition was furnished and ready for occupancy in October.

Waveguide installation is complete to station AW8 on the west arm of the wye and essentially complete beyond station AE7 on the east arm of the wye. A total of 16,500 meters of waveguide will be installed during the year.

Program Management

During the past year, ending November 15, 1978, the Program Management Group has issued over 2,300 subcontracts and purchase orders, having a total value in excess of $9.1 million. In many instances it has been feasible to place orders for sufficient quantities to complete the requirements of the Program. This has allowed advantage to be taken of larger quantity orders and the elimination of potential escalation. The advanced 1979 funding was used in this manner for a number of procurements, the most noteworthy of which were:

| | | |
|---|---|---|
| 60mm Waveguide | Sumitomo Corporation | $1,178,190 |
| Focusing Feed Mounts | Sterling-Detroit, Inc. | $ 267,620 |
| Cryogenic Systems | CTI Corporation | $ 99,900 |
| Parametric Amplifiers | AIL Corporation | $ 159,600 |

In addition to these, a number of other similar procurements are in progress.

Twenty-nine new employees have been hired to fill vacancies that have occurred and to meet the planned additional requirements of Program staffing. There has been a continuing effort to help these new employees, as well as transferring NRAO employees, to find housing in the local area.

This past year there have been an estimated 2,500 casual visitors to the site and the number is growing steadily as the VLA becomes better known. There has been a marked increase in the usage of the Visiting Scientist Quarters. Room day occupancy totaled 1,038 in 1978.

Efforts continue to obtain the remaining required rail material from government excess channels. The rail at Aberdeen Proving Ground, which would have completed the Program needs, proved to be too costly because of site restoration requirements and was released. There have been several small quantities of rail obtained in the last year but there remains some five miles of track needed.

Fiscal Operations

During 1978 considerable growth was experienced in the volume of work. This involved the separate accounting for Operations, Common Costs, and Construction, using a new chart of accounts which became effective January 1, 1978. The volume of checks being processed has approached five hundred per month. Due to these factors a new accounting clerk was hired in May 1978.

A number of items completed during the year were transferred from construction to the completed asset accounts. Among these were the antennas 3 through 14, several antenna foundations, portions of the rail bed, rail trackage, the Visiting Scientist Quarters, the fuel facility, the generators, and many smaller items.

## PLANNED ACTIVITIES - 1979

### General

Although the main emphasis during 1979 will remain on construction, outfitting of antennas and electronics, and working toward completion of the computer hardware and software programs, an increasing emphasis will be placed on scientific and test operations. The year's goal remains the same as the original schedule, that is, to increase the operational antennas to twenty-one by the end of the year.

During CY 1979 sixty-six people at the VLA site will be charged to support of research and test operations. Summary details of personnel, including operating personnel, are included within this Program Plan for completeness, but details of scientific programs, objectives, personnel, and costs for this and future years of operation are included within the regular NRAO Program Plan.

### Systems Operation

At the end of 1978 the construction Systems Operation Group will be totally absorbed into the Array Operations Division under the direction of the Acting Assistant Director for VLA Operations. During 1979 this division will complete the testing of completed antennas and their integration into the operating array. Percent on-line operation is expected to increase from 64% during the third quarter of 1977 to approximately 85% in late 1979. The balance of time will be required for testing and run-in of new computer hardware items, development and proving of computer software programs, and routine maintenance of items such as the waveguide or correlator system, which require the entire array to be down.

Antenna Systems

E-Systems, Inc. subcontract provides that they will deliver antenna 28 to NRAO for acceptance on November 30, 1979. While there has been a slippage in delivery date of approximately five weeks through antenna 20 from the schedule established in July 1976, the cause of the slippage is easily identified as the fault of the antenna structural fabricator and steps have been taken by E-Systems to insure that the fabrication regains its position. E-Systems has assured AUI that the field assembly effort can reduce the slippage and regain the schedule if fabricated structure is received as needed. Delivery of the fabricated structure has accelerated and it is anticipated that the schedule will be regained by March of 1979. The Antenna Group will continue to supervise the fabrication and assembly of the antennas.

All materials and equipment required for the fabrication and assembly of the antennas are on hand or scheduled for delivery early in 1979. There should be no slippage of delivery dates due to material shortages.

Procurement of NRAO supplied equipment, such as focusing feed mounts, subreflectors, vertex feed ring and towers, and antenna platforms, is in progress, using contingency funds and advance 1979 funds. These items must be placed on order in November of 1978 for use on antennas 23 through 28 because of long lead time for procurement or because they must be furnished to E-Systems for installation during the antenna assembly. This material supply work is proceeding to meet all required schedules.

During the period of November 1978 to November 1979, NRAO will outfit antennas 19 through 25. By November 1979 the warranty period on all antennas through antenna 20 will have expired and NRAO will have the responsibility of repair of any breakdowns on those antennas. The present spare parts inventory, which has remained essentially static since late 1977, will be expanded during 1979 to provide sufficient inventory to support the operation of the full array. A test and alignment fixture will be set up to permit repair

and adjustment on site of the position transducers to reduce AUI dependence on factory repair.

NRAO has modified the air conditioning system on eleven of the antennas presently in service and during 1979 will modify the remainder of the antennas to this gas modulating system. This modified air conditioning system permits control of the temperature in the vertex room to within $1.0^{o}$ C variation.

Transporter No. 2

A contract will be awarded for the fabrication, assembly, test, and delivery of transporter No. 2 during January 1979. During the early part of the year the Antenna Group will follow the material and equipment actions of the subcontractor and later supervise the actual fabrication. They will perform similar functions at the site during the assembly of the transporter late in the year and will supervise the acceptance tests.

Electronic Systems

During 1979 the installation of electronics for antennas 18 through 24 will be completed and these antennas brought into operation. The electronics used will be mainly from the 1978 procurement. In 1979 procurement now under way will cover all remaining electronics needed to outfit through to antenna 28 and to provide the spare parts and modules needed for full operation. The electronics for the second two RF channels will also be purchased to take advantage of cost savings, but will not be assembled until 1980.

The two main electronics upgrading programs, the front end filter system and spectral line IF system, are planned to begin in April and July 1979, respectively. Several smaller retrofit programs begun in 1978 will be completed in 1979. These will include replacing all Comtech parametric amplifiers with AIL amplifiers, and modifying local oscillator modules to improve the 18-21 cm spurious signal problem.

A major part of the Electronic Division activities during

1979 will be concerned with using the VLA as a spectral line instrument for the first time. Early in the year the spectral processor will be ready for full spectral line as well as continuum work and the new spectral line IF modules will be tested on two antennas operating in a spectral line mode. Then, starting in July, progressively more antennas will be available for spectral line operation. It is expected that at this time, because of the greater sensitivity of spectral line observations to undesired system characteristics such as spurious signals and passband ripple, instrumental characteristics not previously detected will become noticeable and require investigation.

Construction of the second half of the spectral processor, which will allow four instead of two IFs to be processed, will begin during 1979.

Finally, an ongoing task throughout the year as the array expands outward will be the learning process of how best to maintain the sophisticated electronics at the antennas located far from the laboratory. Problems of transportation and spare parts availability will need solution as will maintenance manpower allocation. By the end of 1979 almost all antennas will be in operation and will require maintenance whilst construction will have to continue at previous levels.

Computer Systems

This year the main effort of the Computer Group will center about the spectral line data map making system. During 1978 the block diagram for the "pipeline system" was completed, which is shown in Figure 7. Procurement specifications will be prepared in late 1978 or 1979 for a large external memory, two array processors, and an array processor host computer to provide control and line data sorting. A major software effort will be required to integrate this new hardware.

Work will continue in 1979 to determine the direction to be taken for long- and intermediate-term data storage. $600,000 has been budgeted for the mass storage system. With the very rapid advances

being made in this field, it is desirable to hold off procurement. It is hoped that a much more compact media will be available at an affordable cost rather than to depend on conventional computer tape.

In 1979 the capabilities of the map display and manipulation system will be expanded. The exact form of the expansion is not yet determined, but the goal is to provide two gray scale display screens and sufficient computing power to make both work stations responsive to the observer using them.

The Modcomp synchronous system will be upgraded through the addition of a graphics terminal, a plotter, a text terminal, and an external I/O processor.

Site and Wye

The Site and Wye Group will continue to oversee the construction of the Phase IV construction contract with Pacific Railroad Constructors, Inc.. It is expected that this work will be completed during the fall. When completed, baselines of 17.2 kilometers will be available on both the southeast and southwest arms of the wye. In addition, all antenna foundations will be completed.

In December 1978, or early in 1979, a contract of approximately $700,000 will be placed for the balance of the stone ballast required for the remaining wye trackage. The production and delivery of this material will be supervised.

The decision as to how to proceed with the balance of the wye construction is not clear. One year ago it was intended to award a Phase V construction contract for about $2,701,000, with about $617,000 in options, acceptable on November 15, 1979, when 1980 funding would become available. With the reduction of $1,500,000 in overall 1979 funds, it leaves only $1,201,000 for the 1979 contract work and $2,237,000 for the 1980 options. This amounts to an estimated cost of $3,438,000 for the contracts. It is not believed that a base contract can properly be bid or awarded where the base portion is only

35% of the expected final cost. It is also believed that, for construction work at the remote VLA site, $1,201,000 is too low a contract amount to attract good contractors and to obtain a good competitive price. The Phase I construction proved this to be the case.

With the advent of the Solar Year in October 1979, it is important to the solar astronomers to have at least 6.0 kilometers of the north arm of the wye constructed and occupied by September 1979 to prepare for "snapshot" solar pictures in October 1979.

The only practical method of meeting this scientific requirement, provided additional funds cannot be found to augment the $1,201,000 presumably available, is to negotiate a change order to Pacific Railroad Constructors to push the north arm out to at least antenna station BN9 (5.76 km) at an estimated cost of about $550,000. This should achieve the efficiencies of a large contract. The balance of the construction would then be bid in September 1979 for award on November 15, 1979, when 1980 funding is available.

A final decision on this matter must await the year-end closing and a thorough canvassing of the program for 1979 funds.

The installation of the buried $TE_{01}$ mode 60mm waveguide will proceed with a goal of placing 18,000 meters during the year.

Program Management

The efforts of the Program Management Group in 1979 will be similar to activities during 1978. Efforts will continue to obtain the balance of the needed rail material from government excess. Much of the procurement effort will be directed toward completing Program requirements.

Fiscal

With increased emphasis on operations in 1979 and future years, the Fiscal Group will be focusing more attention on the accounting for those funds. The common costs, that is, costs related

to both operations and construction, will be accumulated and prorated to operations and construction on the same basis as they were in 1977 and 1978.

Increasing effort will be expended in transferring completed assets from construction into the various fixed asset accounts.

Other areas of concentration during 1979 will include review of the existing procedures and internal controls and making improvements or changes where necessary. Other areas would include inventories, property, and any special requests or projects requested by management.

## PLANNED ACTIVITIES - 1980

### General

Construction activities will be drawing to a close, with the scientific work and general maintenance activities dominating the activities of the VLA staff. The year will start with at least twenty-one antennas operational, gradually building up to the full complement of twenty-eight by year's end.

With the drastic cut of $1,500,000 from the 1979 funding, a considerable amount of site and wye construction cannot be started until 1980 and this may not be completed until after January 1981. Every effort will be expended to complete the trackage and waveguide work prior to this date but much depends on the weather at the VLA site.

### Antenna Systems

During the early part of 1980, NRAO will complete the mechanical and electrical outfitting of antennas 26 through 28. It is anticipated that outfitting of antenna 28 will be completed in April of 1980. Scheduled maintenance of antennas 1 through 25 will be performed during this period and will require an increased amount of manpower as will unscheduled repair of malfunctioning components. In 1980 NRAO will occupy the Antenna Assembly Building and will initiate a program of removing one antenna at a time from service for repainting and refurbishing. It is anticipated that this refurbishing will take approximately five to six weeks.

The operational testing of transporter No. 2 will be completed early in 1980 and the vehicle will be placed in full service.

### Electronic Systems

During 1980 electronics will be outfitted to antennas 25 through 28. The major construction task will be the modules to

increase the number of IF channels from two to four. Slots to receive these modules, with all connectors in place, will be ready on existing racks and bins. Thus, bringing the additional channels into operation should not be a difficult procedure. The spectral processor will also be completed and brought into operation at its full capacity. Testing of the array with its full IF bandwidths and spectral line capability will begin. Early in 1980 work will begin on the design of the control room console, followed by its construction and installation.

Computer Systems

During the early months of 1980, the major hardware items for the spectral line system, display system, and mass storage system will be installed and integrated into the asynchronous system.

The display system will be augmented through the addition of a video readout device, either a video disk or video tape recorder, to save video images for later use. Also in 1980 will come the addition of another array processor and the upgrading of the computer host so that it will have a larger memory.

One major new initiative will be begun and completed in 1980: the design and procurement of a Stand-alone Observer Image Processor. The need for post-processing equipment at the site entirely separate from the main on-line "pipeline" data system has been developing through the years. Many observers are returning to the VLA site to analyze their data. To date a good part of this work could be accommodated during downtime periods or when the asynchronous computer was not fully occupied. With the advent of near continuous operations and the processing of voluminous spectral line data, this will not be possible under full operating conditions.

This equipment will be entirely independent of the main asynchronous computer, possibly installed in the Library-Office Building or in Socorro. Software will be compatible with similar systems to be developed in Charlottesville or at other institutions using VLA data.

Tentative thinking is that the Observer Image Processor would consist of a CPU with 512K Bytes memory, a 350 MBytes disk unit, two tape drives, Interactive Image Display System, film writer, terminals, graphic printer, et cetera. Estimated cost is $425,000.

Site and Wye

Early in the year a contract or contract supplement will be awarded for the balance of the wye trackage and electrical utilities. Rail, rail accessories, ties, and stone ballast will have been procured and stockpiled, using 1979 funds. It is probable that the 1980 work will consist of the completion of the A8 to A9 sectors on all three wye arms. This would total some 11.2 kilometers. The Site and Wye Group will supervise and manage this construction contract.

Waveguide installation work will continue, with the goal of completion of the remaining 12,500 meters and the hook-up of the last three or four antenna stations.

During 1980 the third Visiting Scientist Quarters will be constructed, roads along the wye in the central area will be improved, and the telephone system completed.

Program Management

Work will continue along the lines of the previous years. Near the end of the year and early in 1981 the personnel people will see to the termination of approximately twenty employees. Records and completion statements will be prepared for the closeout of the construction program.

Fiscal

Fiscal work will continue as in previous years. Final completion statements for the construction program must be prepared and the completed construction transferred to NRAO fixed assets.

## FINANCIAL PLANNING

This section of the CY 1979 Program Plan will present the various budget estimates and other schedules necessary for the proper financial planning of the program. Presented are the following:

VLA FINANCIAL STATUS REPORT - Program summary report which details the financial condition of the program from the standpoint of the authorized program ceiling compared to total program outlook.

VLA COST ESTIMATE - 12/01/78 - Shows in summary and in detail the current cost estimate for the program and compares the present estimate with that presented in the CY 1978 Program Plan. To show the magnitude of the sums assigned to escalation and contingency, these items have been set forth separately.

BUDGET ANALYSIS BY PROGRAM YEAR - CY 1973 THROUGH CY 1980 - Shows the cost estimate by Program year.

SUMMARY OF COMMON COST BUDGET - CY 1977 THROUGH CY 1980 - Shows Common Cost Estimate by Program year.

FINANCIAL PLAN - CY 1979 - The financial plan for CY 1979 and CY 1980 broken down into various categories. For comparison, the actual allocation of CY 1973 through CY 1977 funds has also been included.

CY 1978 REVIEW OF FINANCIAL PLAN - A detailed analysis of the revisions that have been made to the CY 1978 Financial Plan, giving the reasons for the changes.

EXPENDITURES AND COMMITMENTS - CY 1978 CUMULATIVE ACTIVITY - A report in graph form, showing scheduled and actual expenditures and commitments by months.

EXPENDITURES AND COMMITMENTS - CY 1979 CUMULATIVE ACTIVITY - A graphic presentation, showing planned CY 1979 expenditures and commitments by months. This graph will be the basis of monthly reports.

Figure 8

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL STATUS REPORT
(thousands)
AS OF: NOVEMBER 1, 1978

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|
| | | ALLOCATION TO DATE | | | | OUTLOOK | | |
| ITEM | ORIGINAL PROGRAM CEILING | ALLOCATED | EXPENDED AND COMMITTED | ALLOCATED BALANCE | UN-ALLOCATED BALANCE | ESTIMATE TO COMPLETE | ESTIMATE TOTAL | (OVER) UNDER CEILING |
| Site and Wye | 27,860 | 19,291 | 19,100 | 191 | 8,569 | 7,967 | 27,067 | 793 |
| Antennas | 20,400 | 21,081 | 21,089 | (8) | (681) | 1,635 | 22,724 | (2,324) |
| Electronics | 17,000 | 14,076 | 13,549 | 527 | 2,924 | 4,091 | 17,640 | (640) |
| Computer | 4,850 | 4,140 | 3,395 | 745 | 710 | 2,787 | 6,182 | (1,332) |
| Systems Integration | 400 | 201 | 198 | 3 | 199 | 3 | 201 | 199 |
| Program Management | 2,650 | 1,799 | 1,768 | 31 | 851 | 334 | 2,102 | 548 |
| Common Cost | - | 1,249 | 1,120 | 129 | (1,249) | 994 | 2,114 | (2,114) |
| Subtotal | 73,160 | 61,837 | 60,219 | 1,618 | 11,323 | 17,811 | 78,030 | (4,870) |
| Contingency | 2,840 | 212 | - | 212 | 2,628 | 1,000 | 1,000 | 1,840 |
| TOTAL | 76,000 | 62,049 | 60,219 | 1,830 | 13,951 | 18,811 | 79,030 | (3,030) |

NOTES: (A) Includes $293K for site acquisition, $15.7K for ECAC Study, and $17.1K for NSF Ad Hoc Advisory Panel.

(B) Estimate to complete is as of November 1978 and it excludes $172K for airstrip.

(C) Escalation included for future years for site/wye work (8%); NRAO labor (6%); and certain electronic elements (8%). Antenna estimate is based upon the existing contract costs for fabrication of the antennas.

(D) The antenna estimate includes $800K for transporter No. 2.

(E) Allocated includes new funds received from the NSF in the amounts of $200K on Amendment No. 32 and $175K on Amendment No. 33.

(F) The above statement does not reflect the $3,700K advanced by the NSF for CY 1979 commitments and expenditures on Amendment No. 34 dated October 31, 1978.

Figure 8

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL STATUS REPORT
(in thousands)

11/01/78
Rev 3/01/79

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|
| | | Allocation to Date (D) | | | | (B) Outlook | | (C) | |
| Item | Program Ceiling | Allocated | Expended and Committed | Allocated Balance | Un-allocated Balance | Estimate to Complete | Estimate Total | (Over) Under Ceiling | Notes |
| Site and Wye | 27,860 | 24,541 | 21,405 | 3,136 | 3.319 | 5,562 | 26,967 | 893 | |
| Antennas | 20,400 | 22,600 | 22,271 | 329 | (2,200) | 428 | 22,699 | (2,299) | |
| Electronics | 17,000 | 16,948 | 15,236 | 1,712 | 52 | 2,436 | 17,672 | (672) | |
| Computer | 4,850 | 5,127 | 3,778 | 1,349 | (277) | 1,941 | 5,719 | (869) | |
| Systems Integration | 400 | 201 | 201 | - | 199 | - | 201 | 199 | |
| Program Management | 2,650 | 1,905 | 1,805 | 100 | 745 | 400 | 2,205 | 445 | |
| Common Cost | - | 1,723 | 1,312 | 411 | (1,723) | 795 | 2,107 | (2,107) | |
| Subtotal | 73,160 | 73,045 | 66,008 | 7,037 | 115 | 11,562 | 77,570 | 4,410 | |
| Contingency | 2,840 | 504 | - - | 504 | 2,336 | 1,000 | 1,000 | 1,840 | |
| TOTAL | 76,000 | 73,549 | 66,008 | 7,541 | 2,451 | 12,562 | 78,570 | (2,570) | |

NOTES: (A) Includes $293K for site acquisition, $15.7K for ECAC Study, and $17.1K for NSF Ad Hoc Advisory Panel. Allocated and Expended includes $11K in assets which were retired in prior tears.

(B) Estimate to complete is as of November 1-78 and it excludes $172K for airstrip. Escalation included for future years for Site/Wye work (8%); NRAO labor (6%); and certain electronic elements (8%). Antenna estimate is based upon the existing contract costs for fabrication of the antennas.

(C) The antenna estimate includes $800K for transporter No. 2.

(D) Includes $11,500,000 of CY 1979 Funding

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL STATUS REPORT
(thousands)
AS OF: NOVEMBER 1, 1978

EXPLANATION TO ACCOMPANYING STATEMENT

COLUMN (2) - ORIGINAL PROGRAM CEILING: Original Estimates.

COLUMN (3) - ALLOCATED: Funded by NSF and included in total funds provided in Contract C-780 and AST 74-13427.

COLUMN (4) - EXPENDED AND COMMITTED: Actual cash paid out and orders written and accepted by vendors.

COLUMN (5) - ALLOCATED BALANCE: Column (3) less Column (4). Current funds available for expenditure and commitment.

COLUMN (6) - UNALLOCATED BALANCE: Column (2) less Column (3). Funds due from NSF to fund the total Program as originally estimated.

COLUMN (7) - ESTIMATE TO COMPLETE: Original estimate updated to take into account current or known costs.

COLUMN (8) - ESTIMATE TOTAL: Column (4) plus Column (7).

COLUMN (9) - (OVER) UNDER CEILING: Column (2) less Column (8).

Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA PROGRAM

## ESTIMATED COST - DESIGN AND CONSTRUCTION ON 12/01/78

(THOUSANDS)

| ITEM | ORIGINAL CEILING | ESTIMATE 8/1977 | ESTIMATE 8/1978 | CHANGE 1977 vs. 1978 |
|---|---|---|---|---|
| SITE AND WYE | 27,860 | 27,103 | 27,067 | - 36 |
| ANTENNA SYSTEMS | 20,400 | 22,115 | 22,724 | + 609 |
| ELECTRONIC SYSTEMS | 17,000 | 17,225 | 17,640 | + 415 |
| COMPUTER SYSTEMS | 4,850 | 5,598 | 6,182 | + 584 |
| SYSTEMS INTEGRATION | 400 | 205 | 201 | - 4 |
| PROGRAM MANAGEMENT | 2,650 | 2,103 | 2,102 | - 1 |
| COMMON COST | - | 1,961 | 2,114 | + 153 |
| SUBTOTAL | 73,160 | 76,310 | 78,030 | + 1720 |
| CONTINGENCY/RESERVE | 2,840 | 1,733 | 1,000 | - 733 |
| TOTAL PROGRAM | 76,000 | 78,043 | 79,030 | + 987 |
| EXCLUDES DEFERRED ITEMS - AIRSTRIP | | 268 | 172 | |
| TRANSPORTER #3 | | - | - | |

12/01/78

Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

ESTIMATED COST - DESIGN AND CONSTRUCTION ON 12/01/78
(THOUSANDS)

| ITEM | ORIGINAL CEILING | ESTIMATE 8/1977 | ESTIMATE 8/1978 | REVISION 3/1/79 | CHANGE 8/77 - 3/79 |
|---|---|---|---|---|---|
| SITE AND WYE | 27,860 | 27,103 | 27,067 | 26,967 | - 136 |
| ANTENNA SYSTEMS | 20,400 | 22,115 | 22,724 | 22,699 | + 584 |
| ELECTRONIC SYSTEMS | 17,000 | 17,225 | 17,640 | 17,672 | + 447 |
| COMPUTER SYSTEMS | 4,850 | 5,598 | 6,182 | 5,719 | + 121 |
| SYSTEMS INTEGRATION | 400 | 205 | 201 | 201 | - 4 |
| PROGRAM MANAGEMENT | 2,650 | 2,103 | 2,102 | 2,205 | + 102 |
| COMMON COST | - | 1,961 | 2,114 | 2,107 | + 146 |
| SUBTOTAL | 73,160 | 76,310 | 78,030 | 77,570 | + 1260 |
| CONTINGENCY/RESERVE | 2,840 | 1,733 | 1,000 | 1,000 | - 733 |
| TOTAL PROGRAM | 76,000 | 78,043 | 79,030 | 78,570 | + 527 |
| Excludes Deferred Items - AIRSTRIP | 268 | 172 | 172 | | |
| TRANSPORTER #3 | | | | | |

12/01/78
Rev. 3/01/79

ESTIMATED COST - DESIGN AND CONSTRUCTION ON 12/01/78

NOTES CONCERNING THE 1978 ESTIMATE:

SITE AND WYE — Reduction of $36,000

1. The major portion of this reduction is in the forecast of escalation included last year. Phase IV was successfully bid. The new cost estimate is based on unit prices which have been increased 8% from those received for Phase IV.

2. The estimate includes $90,000 for the third Visiting Scientist Quarters to be constructed in 1980. This is considered a high priority item.

3. Includes $52,000 for spare parts considered necessary to the continuous operation of building equipment at the remote VLA site.

ANTENNA SYSTEMS — Increase of $609,000

1. The estimate includes $211,000 to purchase antenna spare parts.

2. Includes $240,000 increase for transporter No. 2 to a total of $800,000. Priced proposals have been received and negotiations with proposers are under way.

3. Includes $47,000 extra for rhe focusing feed mounts where inflation has been extremely severe over the last few years.

ELECTRONIC SYSTEMS — Increase of $415,000

1. The estimate includes $298,000 for spare parts for the electronic systems.

2. Includes an extra $100,000 for metal parts for modules, bins, cabinets, and racks where escalation has been very high over the last few years.

3. Includes $205,000 for the retrofits of cryogenic systems, parametric amplifiers, upconverters, and F2 modules.

4. Includes a reduction of $101,000 for the dichroic reflectors and mounts which will be financed from contingency in 1980 or accomplished using OOE funds after 1981.



Figure 9

COMPUTER SYSTEMS — Increase of $584,000

1. The estimate includes an additional $112,000 for hardware for the Spectral Line Sorting/Mapping System.

2. Includes $167,000 additional for Computer Display equipment.

3. Includes $425,000 for a Stand-alone Observer Image Processor. This unit will be used for post-processing observers' data. Details are contained in the Computer section of the 1980 program presentation.

COMMON COST — Increase of $153,000

1. The estimate includes an added $68,000 for electric power and $42,000 for communications.

2. Includes $48,000 for two additional people required to operate the cafeteria and visiting scientist quarters.

SPARE PARTS

A thorough analysis of the spare parts requirements for the VLA indicates that a total spare parts inventory of $1,191,000 should be maintained to ensure the most efficient operations. It was realized that in the early years of construction, before operating funds became available, the spare parts inventory cost would have to be financed from construction funds. The 1978 Program Plan (page 51) estimated that $735,000 of this sum would be financed from Operating funds principally in 1979 and 1980. As requested, VLA operating funds have been reduced and it has become necessary to finance the balance of the spare parts required, some $510,000 in 1979, from construction funds.

A summary of the financing of the spare parts inventory is as follows:

| | | Operating | Construction |
|---|---|---|---|
| Construction Funds through 1977 | | - | $421,000 |
| Operating Funds | 1976 | $ 45,000 | - |
| | 1977 | 117,000 | - |
| | 1978 | 47,000 | |
| Construction Funds | 1978 | - | 51,000 |
| | 1979 | - | 510,000 |
| Subtotals | | $209,000 | $982,000 |
| TOTAL | | $1,191,000 | |

Figure 9

## ESCALATION

The cost estimate includes within the detailed unit prices the best possible estimates of what items will cost when purchased in late 1978 or early 1979 when every effort will be made to purchase all items required until the completion of the project. Unfortunately, this cannot include site and wye construction.

For work which must be accomplished in 1980, an escalation allowance of $412,000 has been included, which amounts to an increase on estimated 1980 costs of 9.0%. In accord with the Ad Hoc Committee's recommendation, a separate section of this Plan concerns escalation.

## CONTINGENCY

The cost estimate includes a contingency allowance of $1,000,000, which represents 6.3% of estimated 1979 and 1980 costs. As a considerable portion of 1979 costs are now known, such as the final waveguide purchase, $1,178,190; the parametric amplifiers, $159,600; the refrigeration systems, $99,900; the focusing feed mounts, $267,620; and the transporter, $760,000, this contingency actually amounts to over 7.5% of the remaining costs.



Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM



COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ESTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| ANTENNA SYSTEMS | | | | |
| Antenna Element Design | 230 | 230 | | 230 |
| Prototype Antennas | 1,624 | 623 | | 1,623 |
| Production Antennas | 17,363 | 17,550 | | 17,550 |
| Transporter Design | 121 | 120 | | 120 |
| Transporter Prototype | 364 | 372 | | 372 |
| Transporter Production Model | 594 | 800 | | 800 |
| Assembly Structure | 403 | 413 | | 413 |
| E.D.I.A. | 1,416 | 1,599 | 17 | 1,616 |
| TOTAL | 22,115 | 22,707 | 17 | 22,724 |

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM



COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ESTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| ANTENNA SYSTEMS | | | | |
| Antenna Element Design | 230 | 230 | | 230 |
| Prototype Antennas | 1,624 | 1,623 | | 1,623 |
| Production Antennas | 17,363 | 17,539 | | 17,539 |
| Transporter Design | 121 | 120 | | 120 |
| Transporter Prototype | 364 | 372 | | 372 |
| Transporter Production Model | 594 | 800 | | 800 |
| Assembly Structure | 403 | 413 | | 413 |
| E.D.I.A. | 1,416 | 1,585 | 17 | 1,602 |
| TOTAL | 22,115 | 22,682 | 17 | 22,699 |

COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ISTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| ELECTRONIC SYSTEMS DEVELOPMENT | | | | |
| Feed System | 142 | 141 | | 141 |
| Front End System | 324 | 322 | | 322 |
| Local Oscillator System | 111 | 133 | | 133 |
| Monitor/Control System | 85 | 85 | | 85 |
| Waveguide System | 256 | 263 | | 263 |
| IF Transmission | 216 | 202 | | 202 |
| Delay/Multiplier System | 21 | 21 | | 21 |
| Spectral Processor | 173 | 151 | | 151 |
| General Electronics | 13 | 13 | | 13 |
| E.D.I.A. | 553 | 695 | 6 | 701 |
| Subtotal Development | 1,894 | 2,026 | 6 | 2,032 |
| ELECTRONIC SYSTEMS PRODUCTION | | | | |
| Feed System | 1,582 | 1,304 | | 1,304 |
| Front End System | 3,170 | 3,333 | 3 | 3,336 |
| Local Oscillator System | 1,008 | 1,012 | | 1,012 |
| Monitor/Control System | 668 | 590 | 2 | 592 |
| Waveguide System | 388 | 433 | | 433 |
| IF Transmission System | 1,368 | 1,163 | | 1,163 |
| Delay/Multiplier System | 300 | 302 | | 302 |
| Spectral Processor | 1,062 | 1,089 | | 1,089 |
| General Electronics | 1,408 | 1,415 | 3 | 1,418 |
| E.D.I.A | 4,361 | 4,931 | 44 | 4,975 |
| Subtotal Production | 15,315 | 15,572 | 52 | 15,624 |
| TOTAL ELECTRONIC SYSTEMS | 17,209 | 17,598 | 58 | 17,656 |



Figure 10

COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ESTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| ELECTRONIC SYSTEMS DEVELOPMENT | | | | |
| Feed System | 142 | 146 | | 146 |
| Front End System | 324 | 321 | | 321 |
| Local Oscillator System | 111 | 134 | | 134 |
| Monitor/Control System | 85 | 85 | | 85 |
| Waveguide System | 256 | 251 | | 251 |
| IF Transmission | 216 | 202 | | 202 |
| Delay/Multiplier System | 21 | 21 | | 21 |
| Spectral Processor | 173 | 142 | | 142 |
| General Electronics | 13 | 13 | | 13 |
| E.D.I.A. | 553 | 693 | 6 | 699 |
| Subtotal Development | 1,894 | 2,008 | 6 | 2,014 |
| ELECTRONIC SYSTEMS PRODUCTION | | | | |
| Feed System | 1,582 | 1,302 | | 1,302 |
| Front End System | 3,170 | 3,345 | 3 | 3,348 |
| Local Oscillator System | 1,008 | 985 | | 985 |
| Monitor/Control System | 668 | 587 | 2 | 589 |
| Waveguide System | 388 | 440 | | 440 |
| IF Transmission System | 1,368 | 1,162 | | 1,162 |
| Delay/Multiplier System | 300 | 304 | | 304 |
| Spectral Processor | 1,062 | 1,085 | | 1,085 |
| General Electronics | 1,408 | 1,429 | 3 | 1,432 |
| E.D.I.A. | 4,361 | 4,919 | 44 | 4,963 |
| Subtotal Production | 15,315 | 15,558 | 52 | 15,610 |
| TOTAL ELECTRONIC SYSTEMS | 17,209 | 17,566 | 58 | 17,624 |



Figure 10

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ESTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| SITE FACILITIES AND WYE | | | | |
| Site Acquisition | | | | |
| Preliminary Design | 225 | 225 | | 225 |
| Detailed Design | 513 | 506 | | 506 |
| Construction Supervision | 155 | 139 | | 139 |
| Survey/Soils | 347 | 322 | | 322 |
| Construction Site Preparation | 86 | 77 | | 77 |
| Computer Site Trailers | 42 | 42 | | 42 |
| Archaeological Preservation | 107 | 107 | | 107 |
| Construction Facilities | 146 | 145 | | 145 |
| Equipment/Maintenance Vehicles | 155 | 161 | | 161 |
| Building Complex | 2,479 | 2,653 | 7 | 2,660 |
| Site Work/Utilities | 810 | 855 | 1 | 856 |
| Wye Construction | 13,966 | 13,852 | 187 | 14,039 |
| Waveguide Procurement | 5,130 | 4,859 | | 4,859 |
| Waveguide Installation | 1,427 | 1,386 | 18 | 1,404 |
| Waveguide Antenna Stations | 501 | 419 | 3 | 422 |
| E.D.I.A. | 711 | 797 | 13 | 810 |
| TOTAL | 26,800 | 26,545 | 229 | 26,774 |
| COMPUTER SYSTEMS | | | | |
| Synchronous Subsystem | 485 | 470 | | 470 |
| Asynchronous Subsystem | 3,367 | 4,027 | | 4,027 |
| Computer Maintenance | 189 | 166 | | 166 |
| E.D.I.A. | 1,557 | 1,505 | 14 | 1,519 |
| TOTAL | 5,598 | 6,168 | 14 | 6,182 |

Figure 10

Figure 10

COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ESTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| SITE FACILITIES AND WYE | | | | |
| Site Acquisition | | | | |
| Preliminary Design | 225 | 225 | | 225 |
| Detailed Design | 513 | 504 | | 504 |
| Construction Supervision | 155 | 138 | | 138 |
| Survey/Soils | 347 | 328 | | 328 |
| Construction Site Preparation | 86 | 75 | | 75 |
| Computer Site Trailers | 42 | 42 | | 42 |
| Archaeological Preservation | 107 | 107 | | 107 |
| Construction Facilities | 146 | 145 | | 145 |
| Equipment/Maintenance Vehicles | 155 | 160 | | 160 |
| Building Complex | 2,479 | 2,574 | 7 | 2,581 |
| Site Work/Utilities | 810 | 844 | 1 | 845 |
| Wye Construction | 13,966 | 13,859 | 187 | 14,046 |
| Waveguide Procurement | 5,130 | 4,862 | | 4,862 |
| Waveguide Installation | 1,427 | 1,375 | 18 | 1,393 |
| Waveguide Antenna Stations | 501 | 412 | 3 | 415 |
| R.D.I.A. | 711 | 795 | 13 | 808 |
| TOTAL | 26,800 | 26,445 | 229 | 26,674 |
| COMPUTER SYSTEMS | | | | |
| Synchronous Subsystem | 485 | 456 | | 456 |
| Asynchronous Subsystem | 3,367 | 3,601 | | 3,601 |
| Computer Maintenance | 189 | 152 | | 152 |
| E.D.I.A. | 1,557 | 1,496 | 14 | 1,510 |
| TOTAL | 5,598 | 5,705 | 14 | 5,719 |

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ESTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| SYSTEMS INTEGRATION | | | | |
| Personnel Costs | 152 | 152 | | 152 |
| Material, Services, Supplies | 31 | 30 | | 30 |
| Travel | 22 | 19 | | 19 |
| TOTAL | 205 | 201 | | 201 |
| PROGRAM MANAGEMENT | | | | |
| Personnel Costs | 1,238 | 1,230 | 15 | 1,245 |
| Material, Services, Supplies | 724 | 825 | | 825 |
| Travel | 126 | 118 | | 118 |
| TOTAL | 2,088 | 2,173 | 15 | 2,188 |
| CONTINGENCY/RESERVE | 1,733 | 1,000 | | 1,000 |
| COMMON COST | 1,961 | 2,028 | 79 | 2,107 |
| Subtotal Program | 77,709 | 77,832 | 412 | 78,244 |
| Funded Directly by NSF | 334 | 326 | | 326 |
| TOTAL PROGRAM | 78,043 | 78,158 | 412 | 78,570 |



Figure 10

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COST ESTIMATE 12/01/78
(thousands)

| | 1978 PROGRAM PLAN 12/01/77 | PROGRAM COST ESTIMATE 1978 BASE | ESCALATION | TOTAL |
|---|---|---|---|---|
| SYSTEMS INTEGRATION | | | | |
| Personnel Costs | 152 | 152 | | 152 |
| Material, Services, Supplies | 31 | 30 | | 30 |
| Travel | 22 | 19 | | 19 |
| TOTAL | 205 | 201 | | 201 |
| PROGRAM MANAGEMENT | | | | |
| Personnel Costs | 1,238 | 1,229 | 15 | 1,244 |
| Material, Services, Supplies | 724 | 725 | | 725 |
| Travel | 126 | 116 | | 116 |
| TOTAL | 2,088 | 2,070 | 15 | 2,085 |
| CONTINGENCY/RESERVE | 1,733 | 1,000 | | 1,000 |
| COMMON COST | 1,961 | 2,035 | 79 | 2,114 |
| Subtotal Program | 77,709 | 78,292 | 412 | 78,704 |
| Funded by NSF | 334 | 326 | | 326 |
| TOTAL PROGRAM | 78,043 | 78,618 | 412 | 79,030 |



Figure 10

Figure 11

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM



BUDGET ANALYSIS BY PROGRAM YEAR
(in thousands)
Escalated Dollars

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | Total Escalated | Total Base | Escalation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SITE AND WYE | 964 | 875 | 4,924 | 4,882 | 2,310 | 5,273 | 4,631 | 2,915 | 26,774 | 26,545 | 229 |
| ANTENNA SYSTEMS | 315 | 2,453 | 2,740 | 7,717 | 4,103 | 3,762 | 1,536 | 98 | 22,724 | 22,707 | 17 |
| ELECTRONIC SYSTEMS | 816 | 1,460 | 2,292 | 2,512 | 3,285 | 3,897 | 2,651 | 711 | 17,624 | 17,566 | 58 |
| COMPUTER SYSTEMS | 29 | 412 | 1,289 | 660 | 782 | 740 | 1,587 | 683 | 6,182 | 6,168 | 14 |
| SYSTEMS INTEGRATION | - | 1 | 46 | 79 | 52 | 23 | - | - | 201 | 201 | 0 |
| PROGRAM MANAGEMENT | 158 | 236 | 499 | 684 | 102 | 109 | 115 | 182 | 2,085 | 2,070 | 15 |
| COMMON COST | - | - | - | - | 644 | 606 | 480 | 384 | 2,114 | 2,035 | 79 |
| SUBTOTAL | 2,282 | 5,437 | 11,790 | 16,534 | 11,278 | 14,410 | 11,000 | 4,973 | 77,704 | 77,292 | 412 |
| CONTINGENCY | - | - | - | - | - | 313 | 500 | 187 | 1,000 | 1,000 | - |
| TOTAL | 2,282 | 5,437 | 11,790 | 16,534 | 11,278 | 14,723 | 11,500 | 5,160 | 78,704 | 78,292 | 412 |
| | | | | | | | | | 326 | 326 | - |
| Add for cost of ECAC Study (16), Land Acquisition (293), and Ad Hoc Advisory Committee (17), funded directly by NSF and not carried in NRAO costs. | | | | | | | | | 79,030 | 78,618 | 412 |

Figure 11


12/01/78
Rev 03/01/79

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

BUDGET ANALYSIS BY PROGRAM YEAR
(in thousands)
Escalated Dollars

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | Total Escalation | Total Base | Escalation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SITE AND WYE | 964 | 875 | 4,924 | 4,876 | 2,299 | 5,281 | 5,320 | 2,135 | 26,674 | 26,445 | 229 |
| ANTENNA SYSTEMS | 315 | 2,453 | 2,740 | 7.717 | 4,102 | 3,725 | 1,549 | 98 | 22,699 | 22,682 | 17 |
| ELECTRONIC SYSTEMS | 816 | 1,460 | 2,292 | 2,511 | 3,283 | 3,819 | 2,764 | 711 | 17,656 | 17,598 | 58 |
| COMPUTER SYSTEMS | 29 | 412 | 1,289 | 660 | 782 | 562 | 1,392 | 593 | 5,719 | 5,705 | 14 |
| SYSTEMS INTEGRATION | - | 1 | 46 | 79 | 52 | 23 | - | - | 201 | 201 | 0 |
| PROGRAM MANAGEMENT | 158 | 236 | 499 | 682 | 99 | 112 | 120 | 282 | 2,188 | 2,173 | 15 |
| COMMON COST | - | - | - | - | 644 | 591 | 488 | 384 | 2,107 | 2,028 | 79 |
| SUBTOTAL | 2,282 | 5,437 | 11,790 | 16,525 | 11,261 | 14,113 | 11,633 | 4,203 | 77,244 | 76,832 | 412 |
| CONTINGENCY | - | - | - | - | - | - | 503 | 497 | 1,000 | 1,000 | - |
| TOTAL | 2,282 | 5,437 | 11,790 | 16,525 | 11,261 | 14,113 | 12,136 | 4,700 | 78,244 | 77,832 | 412 |
| Add for cost of ECAC Study (16), Land Acquisition (293), and Ad Hoc Advisory Committee (17), funded directly by NSF and not carried in NRAO costs. | | | | | | | | | 326 | 326 | - |
| | | | | | | | | | 78,570 | 78,158 | 412 |

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

12/01/78

## SUMMARY OF COMMON COST BUDGET

CY 1977 - CY 1980
(in thousands)
Escalated Dollars

| | | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|
| 18910 | Salary/Wages | 332 | 376 | 407 | 430 |
| 18920 | Benefits | 61 | 85 | 96 | 106 |
| 18930 | Travel | 8 | 9 | 8 | 9 |
| 18940 | Material, Services, Supplies | 118 | 182 | 188 | 210 |
| 18942 | Power | 112 | 165 | 260 | 335 |
| 18943 | GSA Vehicles | 38 | 46 | 52 | 56 |
| 18944 | Bus Operations/Maintenance | 14 | 10 | 15 | 19 |
| 18947 | Communications | 96 | 79 | 91 | 96 |
| 18952 | Cafeteria/Housing Expense | 17 | 18 | 19 | 21 |
| 18953 | Miscellaneous Income | (21) | (28) | (28) | (30) |
| | TOTAL - COMMON COST | 775 | 942 | 1,108 | 1,252 |



Figure 12

Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM


12/01/78

FINANCIAL PLAN - CY 1979
12/01/78
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | PLAN CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK I & V SITE FACILITIES/WYE | | | | | | | | | |
| Site Acquisition | - | - | - | - | - | - | - | - | - |
| Preliminary Design | 225 | 225 | - | - | - | - | - | - | - |
| Detailed Design | 506 | 443 | 30 | - | 11 | - | 12 | 10 | - |
| Construction Supervision | 139 | - | 30 | 51 | 14 | - | 32 | 12 | - |
| Survey/Soils | 322 | 223 | 4 | 34 | 33 | 1 | 11 | 10 | 6 |
| Construction Site Preparation | 77 | 15 | 33 | 8 | 11 | 2 | 2 | 4 | 2 |
| Construction Facilities | 145 | - | - | 141 | 4 | - | - | - | - |
| Construction Equipment | 161 | - | - | 16 | 55 | 28 | 7 | 55 | - |
| Computer/Site Trailers | 42 | - | - | 36 | 1 | 1 | 4 | - | - |
| Archaeological Preservation | 107 | - | - | - | - | 107 | - | - | - |
| Building Complex | 2,660 | - | - | 1,814 | 397 | 51 | 269 | 32 | 97 |
| Site Work/Utilities | 856 | - | - | 614 | 62 | 93 | 26 | 48 | 13 |
| Wye Construction | 14,039 | - | 616 | 838 | 3,472 | 497 | 3,546 | 2,638 | 2,432 |
| Waveguide Procurement | 4,859 | - | 60 | 1,114 | 413 | 1,100 | 738 | 1,434 | - |
| Waveguide Installation | 1,404 | - | - | 117 | 134 | 284 | 421 | 215 | 233 |
| Waveguide Antenna Stations | 422 | - | - | - | 121 | 81 | 134 | 42 | 44 |
| E.D.I.A. | 810 | 58 | 102 | 141 | 154 | 65 | 71 | 131 | 88 |
| TOTAL SITE FACILITIES/WYE | 26,774 | 964 | 875 | 4,924 | 4,882 | 2,310 | 5,273 | 4,631 | 2,915 |

Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1979
12/01/78
(thousands)



| TASK I & V SITE FACILITIES/WYE | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | ACTUAL CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| Site Acquisition | - | - | - | - | - | - | - | - | - |
| Preliminary Design | 225 | 225 | - | - | - | - | - | - | - |
| Detailed Design | 504 | 443 | 30 | - | 11 | - | 10 | 10 | - |
| Construction Supervision | 138 | - | 30 | 51 | 14 | - | 31 | 12 | - |
| Survey/Soils | 328 | 223 | 4 | 34 | 33 | 1 | 17 | 10 | 6 |
| Construction Site Preparation | 75 | 15 | 33 | 8 | 11 | 2 | - | 4 | 2 |
| Construction Facilities | 145 | - | - | 141 | 4 | - | - | - | - |
| Construction Equipment | 160 | - | - | 16 | 55 | 28 | 6 | 55 | - |
| Computer/Site Trailers | 42 | - | - | 36 | 1 | 1 | 4 | - | - |
| Archaeological Preservation | 107 | - | - | - | - | 107 | - | - | - |
| Building Complex | 2,581 | - | - | 1,814 | 397 | 51 | 280 | 32 | 7 |
| Site Work/Utilities | 845 | - | - | 614 | 62 | 92 | 23 | 41 | 13 |
| Wye Construction | 14,046 | - | 616 | 838 | 3,472 | 491 | 3,553 | 3,334 | 1,742 |
| Waveguide Procurement | 4,862 | - | 60 | 1,114 | 413 | 1,100 | 741 | 1,434 | - |
| Waveguide Installation | 1,393 | - | - | 117 | 128 | 280 | 420 | 215 | 233 |
| Waveguide Antenna Stations | 415 | - | - | - | 121 | 81 | 127 | 42 | 44 |
| E.D.I.A. | 808 | 58 | 102 | 141 | 154 | 65 | 69 | 131 | 88 |
| TOTAL SITE FACILITIES/WYE | 26,674 | 964 | 875 | 4,924 | 4,876 | 2,299 | 5,281 | 5,320 | 2,135 |

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1979
12/01/78
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL C&-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | ACTUAL CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK II ANTENNA SYSTEMS | | | | | | | | | |
| Antenna Element Design | 230 | 225 | - | - | - | 5 | - | - | - |
| Prototype Antennas | 1,623 | - | 1,623 | - | - | - | - | - | - |
| Production Models | 17,539 | - | - | 2,455 | 7,465 | 3,780 | 3,476 | 363 | - |
| Transporter Design | 120 | - | 83 | - | - | 37 | - | - | - |
| Transporter Prototype | 372 | - | 311 | 5 | 16 | 11 | 8 | 11 | 10 |
| Transportation Production Models | 800 | - | - | - | - | - | - | 800 | - |
| Assembly Structure | 413 | - | 312 | 86 | 5 | - | - | - | 10 |
| E.D.I.A. | 1,602 | 90 | 124 | 194 | 231 | 269 | 241 | 375 | 78 |
| TOTAL ANTENNA SYSTEMS | 22,699 | 315 | 2,453 | 2,740 | 7,717 | 4,102 | 3,725 | 1,549 | 98 |
| TASK IV SYSTEMS INTEGRATION | | | | | | | | | |
| Personnel Costs | 152 | - | - | 33 | 58 | 43 | 18 | | |
| Materials, Services, Supplies | 30 | - | - | 6 | 18 | 2 | 4 | | |
| Travel | 19 | - | 1 | 7 | 3 | 7 | 1 | | |
| TOTAL SYSTEMS INTEGRATION | 201 | - | 1 | 46 | 79 | 52 | 23 | | |



Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1979
12/01/78
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | PLAN CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK II ANTENNA SYSTEMS | | | | | | | | | |
| Antenna Element Design | 230 | 225 | - | - | - | 5 | - | - | - |
| Prototype Antennas | 1,623 | - | 1,623 | - | - | - | - | - | - |
| Production Models | 17,550 | - | - | 2,455 | 7,465 | 3,780 | 3,500 | 350 | - |
| Transporter Design | 120 | - | 83 | - | - | 37 | - | - | - |
| Transporter Prototype | 372 | - | 311 | 5 | 16 | 11 | 8 | 11 | 10 |
| Transportation Production Models | 800 | - | - | - | - | - | - | 800 | - |
| Assembly Structure | 413 | - | 312 | 86 | 5 | - | - | - | 10 |
| E.D.I.A. | 1,616 | 90 | 124 | 194 | 231 | 270 | 254 | 375 | 78 |
| TOTAL ANTENNA SYSTEMS | 22,724 | 315 | 2,453 | 2,740 | 7,717 | 4,103 | 3,762 | 1,536 | 98 |
| TASK IV SYSTEMS INTEGRATION | | | | | | | | | |
| Personnel Costs | 152 | - | - | 33 | 58 | 43 | 18 | | |
| Materials, Services, Supplies | 30 | - | - | 6 | 18 | 2 | 4 | | |
| Travel | 19 | - | 1 | 7 | 3 | 7 | 1 | | |
| TOTAL SYSTEMS INTEGRATION | 201 | - | 1 | 46 | 79 | 52 | 23 | | |



Figure 13

Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM



FINANCIAL PLAN - CY 1979
12/01/78
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | PLAN CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK IV COMPUTER SYSTEMS | | | | | | | | | |
| Synchronous Subsystem | 470 | - | 246 | - | 21 | 147 | 38 | 15 | 3 |
| Continuum Asynchronous Subsystem | 2,170 | - | - | 871 | 118 | 94 | 30 | 616 | 441 |
| Display I/O Equipment | 480 | - | - | 33 | 88 | 59 | 115 | 160 | 25 |
| Spectral Line Sorting/Mapping | 1,377 | - | - | - | - | 212 | 400 | 640 | 125 |
| Computer Maintenance | 166 | - | - | 48 | 62 | 19 | 22 | 15 | - |
| E.D.I.A. | 1,519 | 29 | 166 | 337 | 371 | 251 | 135 | 141 | 89 |
| TOTAL COMPUTER SYSTEMS | 6,182 | 29 | 412 | 1,289 | 660 | 782 | 740 | 1,587 | 683 |
| TASK III ELECTRONIC SYSTEMS DEVELOPMENT | | | | | | | | | |
| Feed System | 146 | - | 80 | 1 | 50 | 2 | 6 | 5 | 2 |
| Front End System | 321 | 97 | 64 | 81 | 23 | 19 | 13 | 14 | 10 |
| Local Oscillator System | 134 | 33 | 20 | 4 | 29 | 10 | 3 | 10 | 25 |
| Monitor/Control System | 85 | 74 | 9 | 2 | - | - | - | - | - |
| Waveguide System | 251 | 83 | 11 | 32 | 55 | 23 | 23 | 19 | 5 |
| IF Transmission System | 202 | 63 | 32 | 94 | 2 | 3 | 6 | 2 | - |
| Delay/Multiplier System | 21 | 7 | 14 | - | - | - | - | - | - |
| Spectral Processor | 142 | - | - | 4 | 25 | 96 | 7 | 8 | 2 |
| General Electronics | 13 | - | 13 | - | - | - | - | - | - |
| E.D.I.A. | 699 | 35 | 59 | 94 | 105 | 108 | 122 | 111 | 65 |
| SUBTOTAL DEVELOPMENT | 2,014 | 392 | 302 | 312 | 289 | 261 | 180 | 169 | 109 |

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM



FINANCIAL PLAN - CY 1979
12/01/78
(Thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL, CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | ACTUAL CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK IV COMPUTER SYSTEMS | | | | | | | | | |
| Synchronous Subsystem | 456 | - | 246 | - | 21 | 147 | 1 | 38 | 3 |
| Continum Asynchronous Subsystem | 1,146 | - | - | 871 | 118 | 94 | 13 | 25 | 25 |
| Display I/O Equipment | 869 | - | - | 33 | 88 | 59 | 90 | 339 | 260 |
| Spectral Line Sorting/Mapping | 1,306 | - | - | - | - | 212 | 324 | 636 | 134 |
| Mass Store | 280 | - | - | - | - | - | - | 198 | 82 |
| Computer Maintenance | 152 | - | - | 48 | 62 | 19 | 8 | 15 | - |
| E.D.I.A. | 1,510 | 29 | 166 | 337 | 371 | 251 | 126 | 141 | 89 |
| TOTAL COMPUTER SYSTEMS | 5,719 | 29 | 412 | 1,289 | 660 | 782 | 562 | 1,392 | 593 |
| TASK III ELECTRONIC SYSTEMS DEVELOPMENT | | | | | | | | | |
| Feed System | 141 | - | 80 | 1 | 50 | 2 | 1 | 5 | 2 |
| Front End System | 322 | 97 | 64 | 81 | 23 | 19 | 14 | 14 | 10 |
| Local Oscillator System | 133 | 33 | 20 | 4 | 29 | 10 | 2 | 10 | 25 |
| Monitor/Control System | 85 | 74 | 9 | 2 | - | - | - | - | - |
| Waveguide System | 263 | 83 | 11 | 32 | 55 | 23 | 35 | 19 | 5 |
| IF Transmission System | 202 | 63 | 32 | 94 | 2 | 3 | 6 | 2 | - |
| Delay/Multiplier System | 21 | 7 | 14 | - | - | - | - | - | - |
| Spectral Processor | 151 | - | - | 4 | 25 | 96 | 16 | 8 | 2 |
| General Electronics | 13 | - | 13 | - | - | - | - | - | - |
| E.D.I.A. | 701 | 35 | 59 | 94 | 105 | 108 | 124 | 111 | 65 |
| SUBTOTAL DEVELOPMENT | 2,032 | 392 | 302 | 312 | 289 | 261 | 198 | 169 | 109 |

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN -CY 1979
12/01/78
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | ACTUAL CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK III ELECTRONIC SYSTEMS PRODUCTION | | | | | | | | | |
| Feed System | 1,304 | - | 105 | 36 | 262 | 276 | 456 | 161 | 8 |
| Front End System | 3,336 | - | 214 | 384 | 395 | 467 | 999 | 835 | 42 |
| Local Oscillator System | 1,012 | - | 80 | 118 | 140 | 317 | 301 | 49 | 7 |
| Monitor/Control System | 592 | - | 15 | 85 | 97 | 133 | 151 | 79 | 32 |
| Waveguide System | 433 | 45 | 28 | 21 | 118 | 70 | 89 | 52 | 10 |
| IF Transmission System | 1,163 | - | 102 | 288 | 208 | 211 | 349 | 5 | - |
| Delay/Multiplier System | 302 | 24 | 63 | 122 | 21 | 17 | 10 | 45 | - |
| Spectral Processor | 1,089 | - | - | - | 3 | 540 | 52 | 494 | - |
| General Electronics | 1,418 | 108 | 135 | 254 | 232 | 228 | 333 | 85 | 43 |
| E.D.I.A. | 4,975 | 247 | 416 | 672 | 746 | 763 | 881 | 790 | 460 |
| SUBTOTAL PRODUCTION | 15,624 | 424 | 1,158 | 1,980 | 2,222 | 3,022 | 3,621 | 2,595 | 602 |
| TOTAL ELECTRONIC SYSTEMS | 17,656 | 816 | 1,460 | 2,292 | 2,511 | 3,283 | 3,819 | 2,764 | 711 |



Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1979
12/01/78
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | PLAN CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK III ELECTRONIC SYSTEMS PRODUCTION | | | | | | | | | |
| Feed System | 1,302 | - | 105 | 36 | 262 | 276 | 480 | 135 | 8 |
| Front End System | 3,348 | - | 214 | 384 | 395 | 467 | 1,058 | 788 | 42 |
| Local Oscillator System | 985 | - | 80 | 118 | 140 | 317 | 274 | 49 | 7 |
| Monitor/Control System | 589 | - | 15 | 85 | 97 | 133 | 148 | 79 | 32 |
| Waveguide System | 440 | 45 | 28 | 21 | 118 | 70 | 96 | 52 | 10 |
| IF Transmission System | 1,162 | - | 102 | 288 | 208 | 211 | 348 | 5 | - |
| Delay/Multiplier System | 304 | 24 | 63 | 122 | 21 | 17 | 12 | 45 | - |
| Spectral Processor | 1,085 | - | - | - | 3 | 540 | 67 | 475 | - |
| General Electronics | 1,432 | 108 | 135 | 254 | 232 | 228 | 368 | 64 | 43 |
| E.D.I.A. | 4,963 | 247 | 416 | 672 | 747 | 765 | 866 | 790 | 460 |
| SUBTOTAL PRODUCTION | 15,610 | 424 | 1,158 | 1,980 | 2,223 | 3,024 | 3,717 | 2,482 | 602 |
| TOTAL ELECTRONIC SYSTEMS | 17,624 | 816 | 1,460 | 2,292 | 2,512 | 3,285 | 3,897 | 2,651 | 711 |



Figure 13

Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM


12/01/78

FINANCIAL PLAN - CY 1979
12/01/78
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACTUAL CY-1976 | ACTUAL CY-1977 | PLAN CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK VIII PROGRAM MANAGEMENT | | | | | | | | | |
| Personnel Costs | 1,244 | 128 | 178 | 248 | 344 | 83 | 91 | 104 | 78 |
| Materials, Services, Supplies | 725 | 17 | 35 | 216 | 333 | 9 | 12 | 5 | 98 |
| Travel | 116 | 13 | 23 | 35 | 17 | 10 | 6 | 6 | 6 |
| TOTAL PROGRAM MANAGEMENT | 2,085 | 158 | 236 | 499 | 684 | 102 | 109 | 115 | 182 |
| Contingency/Reserve | 1,000 | | | | | | 313 | 500 | 187 |
| Common Cost | 2,114 | | | | | 644 | 606 | 480 | 384 |
| TOTAL PROGRAM | 78,704 | 2,282 | 5,437 | 11,790 | 16,534 | 11,278 | 14,723 | 11,500 | 5,160 |

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1979
(thousands)

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | ACUTAL CY-1976 | ACTUAL CY-1977 | ACTUAL CY-1978 | PLAN CY-1979 | PLAN CY-1980 |
|---|---|---|---|---|---|---|---|---|---|
| TASK VIII PROGRAM MANAGEMENT | | | | | | | | | |
| Personnel Costs | 1,245 | 128 | 178 | 248 | 344 | 83 | 92 | 104 | 78 |
| Materials, Services, Supplies | 629 | 17 | 35 | 216 | 331 | 6 | 12 | 10 | 198 |
| Travel | 118 | 13 | 23 | 35 | 17 | 10 | 8 | 6 | 6 |
| TOTAL PROGRAM MANAGEMENT | 2,188 | 158 | 236 | 499 | 682 | 99 | 112 | 120 | 282 |
| Contingency/Reserve | 1,000 | | | | | | | 503 | 497 |
| Common Cost | 2,107 | | | | | 644 | 591 | 488 | 384 |
| TOTAL PROGRAM | 78,244 | 2,282 | 5,437 | 11,790 | 16,525 | 11,261 | 14,113 | 12,136 | 4,700 |

Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)
12/01/78

| TASK | ITEM | PLAN 11/01/77 | ALLOCATION 12/01/78 | CHANGE |
|---|---|---|---|---|
| I & V | Site Facilities and Wye | 3,714 | 5,273 | + 1,559 |
| II | Antenna Systems | 3,618 | 3,762 | + 144 |
| III | Electronic Systems | 2,897 | 3,897 | + 1,000 |
| IV | Computer Systems | 958 | 740 | - 218 |
| VI | Systems Integration | 12 | 23 | + 11 |
| VII | Program Management | 122 | 109 | - 13 |
| | Common Cost | 579 | 606 | + 27 |
| | Contingency/Reserve | 600 | 313 | - 287 |
| | TOTAL PROGRAM | 12,500 | 14,723 (1) | + 2,223 |

(1) Includes $1,715 carryover and $375 additional 1978 funding.



Figure 14

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)

12/01/78

| | PLAN 11/01/77 | ALLOCATION 12/01/78 | CHANGE |
|---|---|---|---|
| TASK I & V SITE FACILITIES AND WYE | | | |
| Site Acquisition | - | - | |
| Archaeological Preservation | 7 | - | - 7 |
| Engineering - Preliminary | - | - | |
| - Detailed | 21 | 12 | - 9 |
| Construction Supervision | 12 | 32 | + 20 (1) |
| Survey/Soils | 20 | 11 | - 9 |
| Construction Facilities | 10 | 2 | - 8 |
| Computer/Site Trailers | 4 | 4 | |
| Construction Equipment | 35 | 7 | - 28 (2) |
| Building Complex | 190 | 269 | + 79 (3) |
| Site Work/Utilities | 37 | 26 | - 11 |
| Wye Construction | 2,820 | 3,546 | + 726 (4) |
| Waveguide Procurement | - | 738 | + 738 (5) |
| Waveguide Installation | 385 | 421 | + 36 (6) |
| Waveguide Antenna Stations | 101 | 134 | + 33 (7) |
| E.D.I.A. | 72 | 71 | - 1 |
| TOTAL | 3,714 | 5,273 | + 1,559 |

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)
12/01/78

TASK I & V SITE FACILITIES AND WYE

NOTES:

(1) For inspection work of all antenna foundations in lieu of only a portion planned in 1978.

(2) Purchase of dump truck ($20K) not needed in 1978. Decrease in tracked maintenance vehicles ($8K) now slated for 1979.

(3) Additional work done to Control and Garage buildings ($4K). 1977 carryover funds ($20K) used to complete required needs in equipment/furnishing account. 1978 contingency funds ($79K) used for Cryogenic facility. Decrease in funds ($24K) not needed for Cafeteria, VSQ, and Library-Office buildings.

(4) 1977 carryover funds ($800K) utilized to allow for the maximum work under Phase IV wye construction. June 1978 reallocation reduced allocation ($74K) to match known contract cost.

(5) 1977 carryover funds ($361K) used for advance procurement of waveguide purchased in 1977. Reallocation of funds in June 1978 ($42K) allowed for coating of waveguide ordered in 1977. Funds ($335K) allowed for advance procurement of waveguide in 1978 from contingency and fund transfer from Computer Systems.

(6) Transfer of decommitted funds from prior years.

(7) Funds provided from additional 1978 funding to provide for procurement of 1978 and 1980 waveguide couplers.



Figure 14

Figure 14

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)
12/01/78

| | PLAN 11/01/77 | ALLOCATION 12/01/78 | CHANGE |
|---|---|---|---|
| TASK II ANTENNA SYSTEMS | | | |
| Production Models | 3,306 | 3,453 | + 147 (1) |
| Field Modifications | 19 | 48 | + 29 (2) |
| Transporter Assembly/Test/Modifications | 16 | 8 | - 8 |
| E.D.I.A. | 277 | 253 | - 24 (3) |
| TOTAL | 3,618 | 3,762 | + 144 |

NOTES:

(1) Increase due to utilization of 1977 carryover in 1978 requested allocations ($136K), and to correction in amount of E-Systems contract ($11K).

(2) Increase due to modification of air conditioning system and walkways.

(3) Re-evaluation of travel and miscellaneous material, services, and supplies accounts.

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)

12/01/78

| | PLAN 11/01/77 | ALLOCATION 12/01/78 | CHANGE |
|---|---|---|---|
| TASK III ELECTRONIC SYSTEMS | | | |
| General Electronics | 234 | 368 | + 134(1) |
| Front End System | 650 | 1,071 | + 421(2) |
| Local Oscillator System | 249 | 277 | + 28(3) |
| Waveguide System | 66 | 119 | + 53(4) |
| IF Transmission System | 319 | 354 | + 35(5) |
| Delay/Multiplier System | 12 | 12 | |
| Feed System | 295 | 486 | + 191(6) |
| Monitor/Control System | 148 | 148 | |
| Spectral Processor | 125 | 74 | - 51(7) |
| E.D.I.A. | 799 | 988 | + 189(8) |
| TOTAL | 2,897 | 3,897 | + 1,000 |



Figure 14

Figure 14

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)
12/01/78

TASK III ELECTRONIC SYSTEMS

NOTES:

(1) Funds from 1978 additional funding ($33K) and from contingency ($113K) utilized for advance procurement of 1979 and 1980 metal fabricated parts.

(2) 1977 carryover funds ($53K) utilized in 1978 requested allocations; $94K from 1978 additional funding for CTI and AIL paramp retrofit; $39K in funds utilized in June 1978 reallocation; $34K in funds utilized from contingency for module production; $200K in funds utilized in November 1978 reallocation for AIL upconverters and FE filters.

(3) Increase due to utilization of 1977 carryover in 1978 requested allocations.

(4) Funds allocated from contingency to complete purchase of 20mm waveguide.

(5) 1977 carryover funds ($24K) utilized in 1978 requested allocations; funds from contingency ($192K) utilized for 1979 and 1980 modem and production; November 1978 reallocation transferred funds to Spectral Processor account ($120K) and decreased final cost of modems ($53K).

(6) November 1978 reallocation allowed for 1979 and 1980 advance procurement of subreflectors ($35K) and feeds ($179K), and decreases final costs for feed mount/deicer ($21K).

(7) Work to be done in 1979 instead of 1978.

(8) Increase due to utilization of 1977 carryover ($25K) in 1978 requested allocations; June 1978 reallocation provided for additional manpower needs ($87K), unforecast costs to miscellaneous materials and services ($41K), and 1978 spares ($36K).

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)
12/01/78

| | PLAN 11/01/77 | ALLOCATION 12/01/78 | CHANGE |
|---|---|---|---|
| TASK IV COMPUTER SYSTEM | | | |
| Synchronous Subsystem | 20 | 38 | + 18 |
| Asynchronous Subsystem | 684 | 145 | - 539 (1) |
| Spectral Line Computing Equipment | 85 | 400 | + 315 (2) |
| Computer Maintenance | 18 | 22 | + 4 |
| E.D.I.A. | 151 | 135 | - 16 |
| TOTAL | 958 | 740 | - 218 |

NOTES:

(1) 1977 carryover funds ($61K) utilized in 1978 requested allocations. Reduction due to utilization of unused computer funds for 1978 waveguide advance procurement ($160K) and map-making processor now combined under spectral line subsystem ($440K).

(2) 1977 carryover funds ($103K) utilized in 1978 requested allocations; map-making processor now combined with spectral line subsystem ($440K), some hardware procurement postponed to 1979 ($228K).

CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)

12/01/78

| | PLAN 11/01/77 | ALLOCATION 12/01/78 | CHANGE |
|---|---|---|---|
| TASK VI SYSTEMS INTEGRATION | | | |
| Personnel Costs | 10 | 19 | + 9 |
| Materials, Services, Supplies | 1 | 3 | + 2 |
| Travel | 1 | 1 | |
| TOTAL | 12 | 23 | + 11 |
| TASK VII PROGRAM MANAGEMENT | | | |
| Personnel Costs | 90 | 91 | + 1 |
| Materials, Services, Supplies | 18 | 12 | - 6 |
| Travel | 14 | 6 | - 8 |
| TOTAL | 122 | 109 | - 13 |
| COMMON COST | 579 | 606 | + 27(1) |
| CONTINGENCY/RESERVE | 600 | 313 | - 287(2) |

NOTES:

(1) Due to carryover of remaining 1977 commitments into 1978 and adjustment of common cost portion to construction after June 1978 reallocation of funds.

(2) Decrease due to utilization of funds for Cryogenic facility ($82K), 20mm waveguide procurement ($54K), module fabrication and certain other electronic accounts ($240K). Additional funds were added to contingency during the year due to a decommitment of funds from prior years ($90K).

## CY 1978 REVIEW OF FINANCIAL PLAN
(thousands)

12/01/78

| | PLAN 11/01/77 | ALLOCATION 12/01/78 | CHANGE |
|---|---|---|---|
| COMMON COST | | | |
| Personnel Costs | 435 | 461 | + 26 (1) |
| Travel | 8 | 9 | + 1 |
| Materials, Services, Supplies | 165 | 182 | + 17 (2) |
| Power | 175 | 165 | - 10 |
| Vehicles and Buses | 63 | 56 | - 7 |
| Communications | 76 | 79 | + 3 |
| Cafeteria and Housing (net) | (4) | (10) | - 6 |
| TOTAL | 918 | 942 | + 24 |
| PORTION TO CONSTRUCTION | 579 | 606 | + 27 (3) |

NOTES:

(1) To cover addition of accountant and increase in benefit costs.

(2) To cover an increase in freight costs due to increase in usage.

(3) Difference between total common cost change and portion common cost change due to change in salary base on which percentage split is figured.



Figure 14

# NRAO VLA
# PROGRAM REPORT
## EXPENDITURES AND COMMITMENTS
## CY-1978 CUMULATIVE ACTIVITY
## NOVEMBER 1, 1978

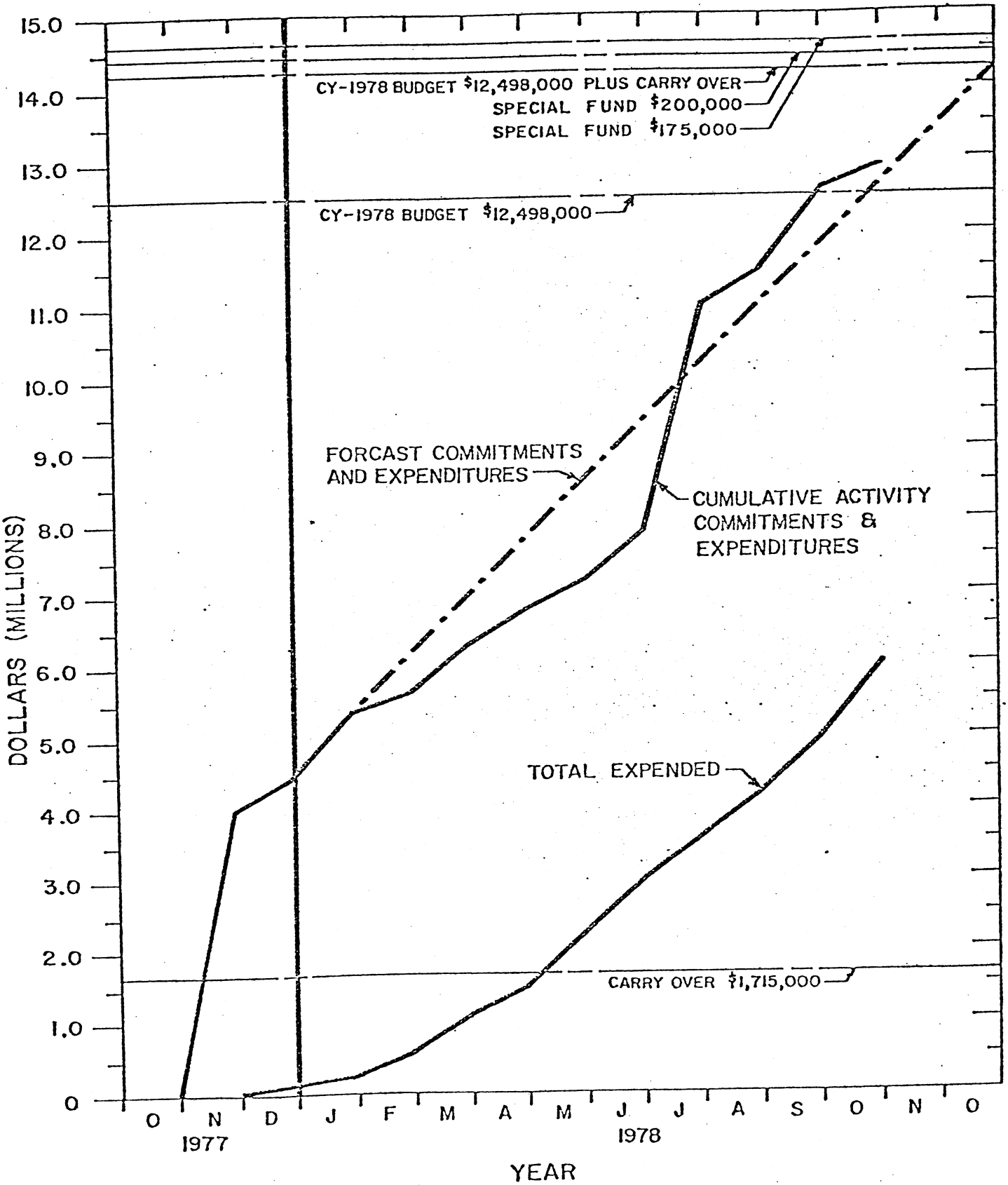



Figure 15

# NRAO VLA
# PROGRAM REPORT
## EXPENDITURES AND COMMITMENTS
## CY-1979 CUMULATIVE ACTIVITY

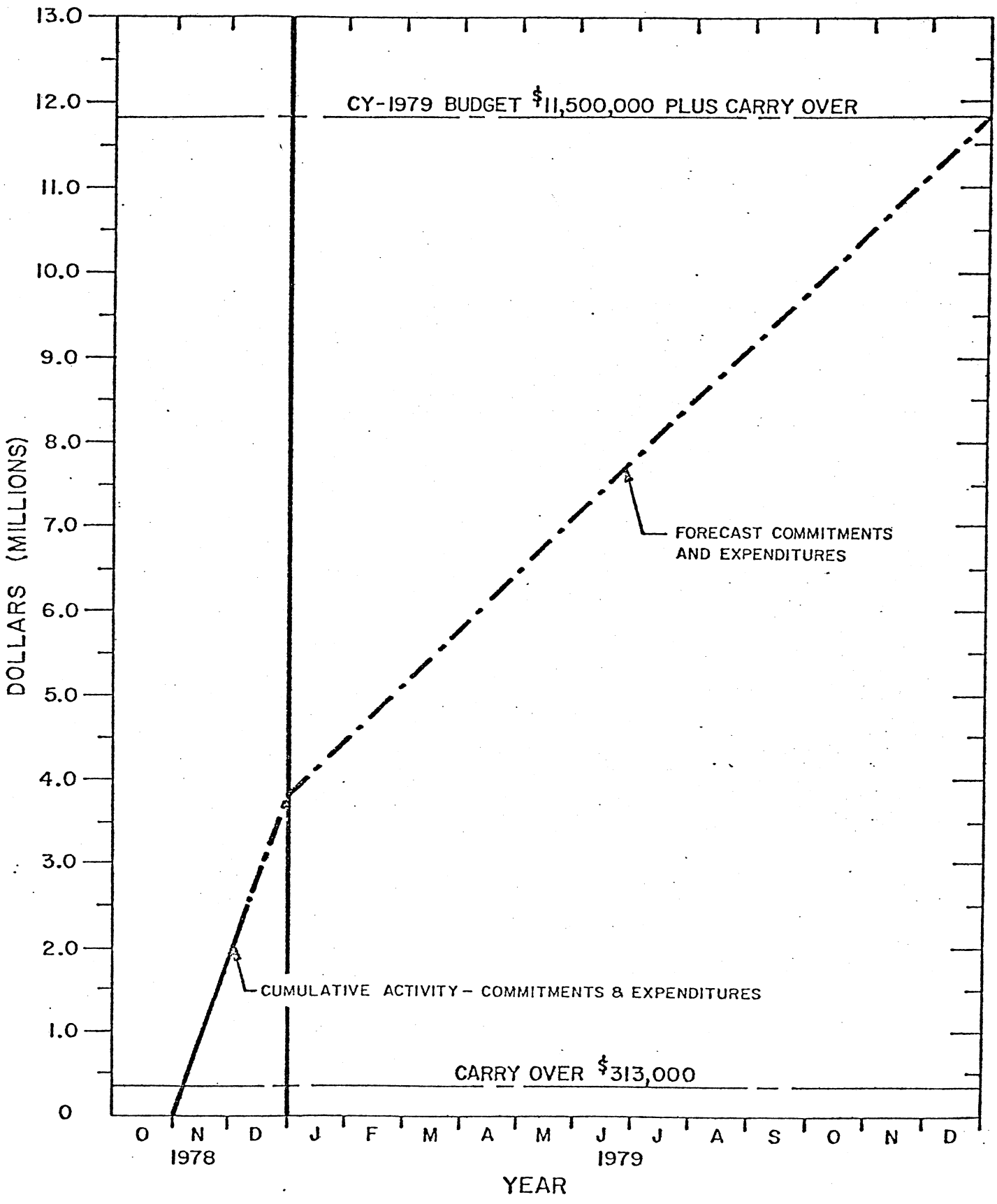





Figure 16

## REVIEW OF ESCALATION FORECAST

The Ad Hoc Advisory Panel for the Very Large Array (VLA), in their final report dated December 31, 1977, recommended that the NRAO make a review to identify more realistic escalation and contingency amounts. This review indicates the following:

### Antenna Mechanical Components

During 1978 a major upsurge in prices for fabricated metal components, such as the Sterling feed mounts and the feed towers, became evident. This movement is clearly shown on Figure 17. Using available contingency funds and advance funding, all mechanical items required for the antennas were bid and procured during the late months of 1978. The antenna contract is on a firm price basis and was fully committed using 1978 funds. A firm maximum bid is now available for the transporter. As all major procurements have been made, no escalation is included for 1979 and 1980 except for NRAO labor, where 4% is included for 1979 and 8% for 1980.

### Electronic Components

The cost of electronic components remained fairly stable until 1978, except for the metal components of racks, bins, and modules. In 1978, costs began to drift upward and so a determined effort was made to procure all items, particularly metal parts, for the remaining years of the program. Data from the Bureau of Labor Statistics indicate the following escalation from July 1977 to July 1978: semiconductors and devices, - 6.8%; electronic capacitors, + 4.9%; electronic resistors, + 7.0%; and electronic connectors, + 10.0%. As almost all major orders will be placed early in 1979, only a small amount of escalation funds is included for purchases in 1980. A figure of 8% was used for these items. Escalation costs for NRAO personnel are as set forth above.

Computer Hardware

In this area costs have continued to drop, as indicated by the index for semiconductors and devices, - 6.8%, in the last year. However, as "per-calculation" costs continue to drop, the need for more complex and higher capacity equipment continues to grow, offsetting any gain. Hence, in the computer hardware area no escalation has ever been included and this has proven to be proper. No escalation is included in this estimate except for NRAO personnel.

Site and Wye Construction

As the majority of costs in 1980 will be for site and wye construction, additional data was obtained for this area. Figure 18, Engineering News Record data, shows that heavy construction increased 7.6% nationwide; 8.4% in the Denver area; 2.9% in the Dallas area; and 14.5% in the Los Angeles area. The VLA is probably closer to the Dallas and Denver indexes. Figure 19, MEANS CONSTRUCTION COST INDEXES, indicates that all construction in the Albuquerque, New Mexico, area increased 10.9% from 7/1/77 to 7/1/78, but only 8.3% from 10/1/77 to 10/1/78. The remaining railroad work is closest to the site work category, which increased 8.1% in the same period. Figure 20, RAILROAD MATERIAL & SUPPLIES PRICE INDEXES, indicates that railroad supplies used for track construction increased 6.0% from October 1977 to October 1978. No comparable figure for railroad construction labor could be found.

An effort was made to compare the Phase III construction costs, bid on August 28, 1975, to Phase IV construction costs bid on May 11, 1978, some thirty-three months later. No realistic price data could be obtained as the Phase III prices varied from $2,913,000 to $5,523,000, and the Phase IV prices varied from $2,914,000 to $3,290,500. Also, the various contractors unweight their unit price bids severely in order to obtain up-front financing.

From the data obtained and the recommendations of the Engineer/Architect and the NRAO staff, an escalation factor of 8.5%

has been included for work to be done in 1980. NRAO staff escalation cost is as set forth above.

Program Management

This item is almost all salary costs and escalation factor is as set forth above.

Common Costs

These include all the housekeeping expenses of operating the VLA and maintaining its construction forces. Based on experience, an average figure of about 8.0% has been included for escalation on costs to be incurred in 1980, exclusive of NRAO staff costs, which are indicated above. The major exception to the average is for electric power, where an escalation factor of 15.5% has been included for 1979 and 11.7% for 1980.

General

It is interesting to note that, since March 1971, when the VLA cost estimate was made, to the present, the All Industrial Commodity Index has increased by 84.1% and the construction index by 73.4%. During this time the estimated construction cost of the VLA has increased from $76,000,000 to $79,030,000, a factor of 4.0%.

Contingency Allowance

As previously stated on page 49, a contingency allowance of $1,000,000 has been included within this estimate. This represents 6.3% of estimated 1979 and 1980 costs. As many of the 1979 costs are now known, the actual contingency allowance amounts to over 7.5% of uncommitted costs. Experience with a 6% contingency in previous years indicates that this contingency allowance should be sufficient.

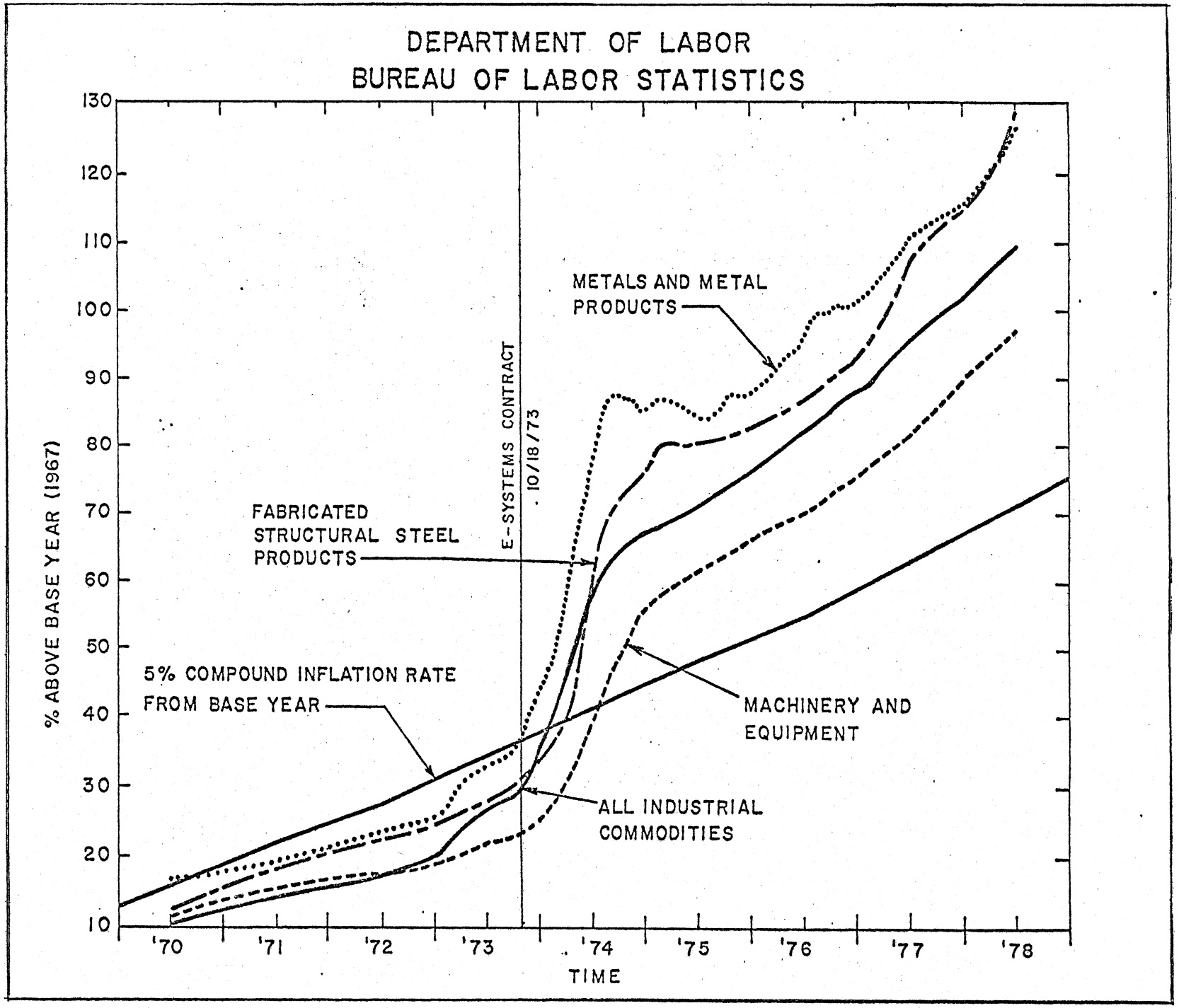

DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS
% ABOVE BASE YEAR (1967)
130
120
110
100
90
80
70
60
50
40
30
20
10
'70
'71
'72
'73
'74
'75
'76
'77
'78
TIME
E-SYSTEMS CONTRACT
10/18/73
METALS AND METAL PRODUCTS
FABRICATED STRUCTURAL STEEL PRODUCTS
5% COMPOUND INFLATION RATE FROM BASE YEAR
MACHINERY AND EQUIPMENT
ALL INDUSTRIAL COMMODITIES

Figure 17

Figure 18

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

12/01/78

## CONSTRUCTION COST INDEXES - WESTERN STATES

Data from "Engineering News Record"

| Item | | Index 09/15/77 | Index 09/14/78 | % Increase |
|---|---|---|---|---|
| U. S. Averages | Construction | 2650.4 | 2852.7 | 7.6 |
| | Building | 1592.9 | 1719.4 | 7.9 |
| | Common Labor | 5095.7 | 5442.1 | 6.8 |
| | Skilled Labor | 2315.8 | 2463.2 | 6.4 |
| | Materials | 1151.7 | 1265.5 | 9.9 |
| Denver, Colorado | Construction | 238.94 | 259.01 | 8.4 |
| | Building | 238.01 | 253.55 | 6.5 |
| | Common Labor | 247.58 | 266.36 | 7.6 |
| | Skilled Labor | 243.45 | 251.88 | 3.5 |
| | Materials | 236.42 | 260.72 | 10.3 |
| Dallas, Texas | Construction | 256.10 | 263.59 | 2.9 |
| | Building | 238.02 | 254.35 | 6.9 |
| | Common Labor | 259.56 | 259.56 | 0 |
| | Skilled Labor | 226.49 | 238.95 | 5.5 |
| | Materials | 236.00 | 255.39 | 8.2 |
| Los Angeles, California | Construction | 253.41 | 290.17 | 14.5 |
| | Building | 252.00 | 286.13 | 13.5 |
| | Common Labor | 252.24 | 288.34 | 14.3 |
| | Skilled Labor | 249.23 | 280.11 | 12.4 |
| | Materials | 267.32 | 307.69 | 15.1 |

## MEANS CONSTRUCTION COST INDEXES

YEAR TO YEAR
ALBUQUERQUE

| Year | Index | % Increase |
|---|---|---|
| July 1, 1971 | 68.4 | |
| 1972 | 72.5 | 6.0 |
| 1973 | 76.8 | 5.9 |
| 1974 | 86.2 | 12.2 |
| 1975 | 94.0 | 9.0 |
| 1976 | 97.0 | 3.2 |
| 1977 | 107.1 | 10.4 |
| 1978 | 118.8 | 10.9 |
| July 1, 1971 to July 1, 1978 . . . . . | | 73.4 |

BY TRADES
ALBUQUERQUE

| Item | 10/01/77 | 10/01/78 | % Increase |
|---|---|---|---|
| Site Work | 122.3 | 132.2 | 8.1 |
| Form Work | 125.1 | 132.6 | 6.0 |
| Reinforcing | 95.7 | 101.0 | 5.5 |
| Concrete | 110.2 | 117.2 | 6.4 |
| Masonry | 109.3 | 122.0 | 11.6 |
| Metals | 121.8 | 119.8 | - .2 |
| Electrical | 100.9 | 120.1 | 19.0 |
| Average Above Categories | 112.2 | 120.7 | 7.6 |
| Weighted Average All Construction | 113.8 | 123.3 | 8.3 |

## NATIONAL AVERAGE CONSTRUCTION TRADE LABOR RATES

| Date | Common Labor | | Equipment Operators | | Truck Drivers | | Electricians | |
|---|---|---|---|---|---|---|---|---|
| July 1973 | $ 7.05/hr | | $ 9.55/hr | | $ 6.80/hr | | $10.05/hr | |
| 1974 | 7.15 | 1.4% | 9.75 | 2.1% | 6.95 | 2.2% | 10.40 | 3.5% |
| 1975 | 8.33 | 16.5% | 10.86 | 11.4% | 8.45 | 21.6% | 11.49 | 10.5% |
| 1976 | 9.00 | 8.0% | 11.69 | 7.6% | 9.27 | 9.7% | 12.37 | 7.7% |
| 1977 | 9.58 | 6.4% | 12.44 | 6.4% | 9.94 | 7.2% | 13.61 | 10.0% |
| 1978 | 10.18 | 6.3% | 13.18 | 6.0% | 10.52 | 5.8% | 14.39 | 5.7% |

| Overall Labor: | | | |
|---|---|---|---|
| | 7/76 | 115.1 | |
| | 7/77 | 123.4 | 7.2% |
| | 7/78 | 129.7 | 5.1% |



Figure 19

Figure 20

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

12/01/78

RAILROAD MATERIAL & SUPPLIES PRICE INDEXES

Source: Association of American Railroads, Economics & Finance Division

Date: October 23, 1978

ANNUAL INDEXES OF SPOT PRICES

Base Year 1967

| | 10/73 | 10/74 | 10/75 | 10/76 | 10/77 | 10/78 |
|---|---|---|---|---|---|---|
| UNITED STATES | | | | | | |
| Forest, Iron & Steel, & Misc. Products | 128.5 | 176.7 | 196.6 | 209.6 | 224.4 | 239.1 |
| Percent Increase | - | 37.5 | 11.3 | 6.6 | 7.1 | 6.6 |
| WESTERN DISTRICT | | | | | | |
| Forest, Iron & Steel, & Misc. Products | 132.2 | 177.6 | 200.2 | 213.9 | 230.8 | 244.7 |
| Percent Increase | - | 34.3 | 12.7 | 6.8 | 7.9 | 6.0 |

## ALTERNATE ITEMS

There are two items which have not been included within the body of the 1978 cost estimate even though they are necessary for the future operation and safety of the Very Large Array. These items are:

### Visitors Center

Covers the construction of a 2,400 square foot building, 30'-0" by 80'-0" in size, to house exhibits, a forty-five seat auditorium, toilet rooms, and auxiliary spaces. The building would be of prefabricated wood stud construction, built in Albuquerque and trucked to the site. In design it would look like the Control and the Cafeteria buildings, with slump block brick exterior, flat roof, and stucco facia. It would be constructed just off the main access road, old U.S. 60, adjacent to the driveway to the Control Building. Site work would include access driveways, parking area for about twelve automobiles and two buses, concrete patio and walkways. It would be connected to the site water, sanitary sewer, electric, and telephone systems.

Its purpose is to exhibit various displays concerning astronomy and the VLA, which will reduce the amount of staff time now utilized for visitors, the use of toilet facilities in the main buildings, and the pressure of visitors who wish to enter the main buildings for inspection purposes. It would be the start of a self-guided tour of the central VLA site area. A self-activated film or slide show would be set up in the auditorium, or it could be used for a talk to a busload of a specific organization.

In 1978 over 2500 casual visitors stopped at the site, in addition to an organized bus trip for senior citizens, which came about six times during the year. There are no directional signs to the site and it is difficult for the tourist to find his

way in. To date, we have been successful in keeping the site off the New Mexico road maps because it is under construction. The New Mexico Department of Development has requested in the past that the VLA be shown and will in the future. In addition, the Director of the Albuquerque Chamber of Commerce wishes to have organized bus tours of the VLA, which they would market to potential tourists on an international basis. The VLA is on one of the few transcontinental U. S. highways and one can expect a very large increase in visitors over the years. The recent article in the "Smithsonian" magazine, the syndicated New York Times and Washington Post stories, the past TV programs, and the forthcoming "Reader's Digest" and "National Geographic" articles plus a series of CBS and other TV programs will interest a great many people in the VLA and add greatly to the visitor load.

Estimated cost of the Visitors Center is as follows:

| | | |
|---|---|---|
| Building, Foundation, Brick | | $ 87,000 |
| Site Work | | 23,000 |
| Utility Connections | | 20,000 |
| Initial Exhibits | | 20,000 |
| | Total | $150,000 |

Water Sprinkler Systems for Minor Buildings

Because of cost considerations, only the two major buildings, the Control and the Cafeteria buildings, have sprinkler systems for fire protection. The Technical Services Building, the Warehouse, and the Shop Building are prefabricated metal buildings. The Visiting Scientist Quarters, the Office-Library Building, and the Visitors Center are or will be wood frame buildings with slump block veneer. The three VSQs are covered by fire alarm systems which report to the VLA Control Building, but all eight of the smaller buildings which do not have sprinkler systems are subject to the possibility of serious damage or destruction by fire. We are training a fire brigade which should be effective during normal work hours, but this covers only 24% of total hours. The closest volunteer fire department is in

Datil, some 19-20 miles away, and it is very doubtful whether they could be effective during non-normal work hours. The loss of one of these buildings would result in a greater loss to the Government than the cost of water sprinkler systems for all of the eight buildings.

Estimated cost for the sprinkler systems is as follows:

| | |
|---|---|
| Sprinkler System, 32,000 SF @ $3.00/SF | $ 96,000 |
| Eight alarm valves & piping @ $1500.00 | 12,000 |
| Misc. and water main modifications | 12,000 |
| Total | $120,000 |

## DEFERRED ITEMS

### Third Antenna Transporter

A detailed time-motion study combined with scientific program decisions has resulted in the firm conclusion that the third antenna transporter is not necessary to the VLA Program and should be dropped from consideration.

Some of the considerations affecting this decision were: scientific programming pressures indicate that the array will be refigured about four times each year; the array can continue to do good science during a change; the time-motion study indicates that the four changes per year using two transporters ten hours per day would require fourteen days, while three transporters ten hours per day would shorten this yearly downtime to nine days. Given some scientific use during change, it is not thought that the nearly $800,000 cost of transporter No. 3 is cost effective; the downtime can be used for scheduled maintenance of electronics, computer hardware and software, waveguide runs, et cetera; and the manpower schedules for operation do not permit the effective manning of three transporters. Should electronic, site and wye, and other personnel be trained for transporter duty, it would be much more cost effective to utilize the two transporters for two eight or ten hour shifts per day. It would cost $25-30,000 yearly to maintain the third transporter in ready state as it would not be needed for maintenance activities on the antennas; and additional spare parts inventories would have to be maintained.

### Airstrip

In previous years the airstrip has been carried at an estimated cost of $268,000. During the past year an engineering study has shown that a shorter, 6,000 foot by 60 foot, runway would serve the site for single engine and light two-engine planes. An

unpaved, crushed aggregate surface runway, including parking area and approach road, could be constructed for $89,000. To pave this for all-weather use would cost an additional $83,000, making a total of $172,000. The necessary land for the airstrip has already been obtained from the State of New Mexico.

It is the conclusion of NRAO that the need for the airstrip must develop during the early years of operation and prove that it is an economic necessity before it is constructed.

Dichroic Reflector
for Simultaneous Operation at 6 and 2 cm Wavelengths

It was the intention of NRAO to include within the construction program a dichroic reflector over the 2 cm feed and an ellipsoidal reflector over the 6 cm feed on all antennas so that simultaneous observation could be made using two IF bands for each frequency. This system has been installed on antennas 1 and 2 and has been proven in operation. Its estimated cost for the remaining antennas is $101,000. Principally because of other priority demands on the manpower of the Electronics Group, it has been decided to defer procurement and installation of the dichroic reflector system until after 1981 and to finance it from OOE funds. Should manpower and contingency construction funds be available in 1980, the dichroic reflector system will be installed during the last months of 1980.

## PROGRAM SCHEDULES

From 1973 until July 1975, a detailed PERT network was used to plan, coordinate, and monitor the progress of the design, development, procurement, fabrication, and test of the various complex subsystems required for the VLA. This took about one and one-half man years per year to accomplish the mechanics of the system, plus considerable additional time of the scientists and engineers who had to input into the system. With the completion of the prototype electronics, the delivery of both computers, the delivery of the first two antennas, the move of the staff to New Mexico, and the start-up of the Systems Integration Group, it was decided to terminate the full PERT activity.

Work at the site is being coordinated by the Assistant to the Program Manager through the use of detailed bar schedules for the outfitting of each antenna. Weekly coordination meetings of approximately one hour duration are held each Monday morning, with department heads or designated representatives from all work areas present. Schedule achievements, problem areas, and specific plans for tasks to be accomplished during the week are reviewed. In Charlottesville, for the fabrication of the electronic components, PERT is still being used for scheduling and procurement purposes. There is attached, as Figure 21, a summary sheet for the 1978 fabrication of electronic modules, racks, and bins. The computer is also being used to gather data on the myriad electronic components for each module, coordinate the requirements, and deliver to the procurement staff consolidated lists. This saves multiple requisitions and purchase orders and results in quantity discounts, which in many cases are substantial.

There follows as Figure 22 a VLA ACTIVITY SCHEDULE Bar Chart dated 12/1/78, which is time-scaled to provide a concise, overall view of the entire Program. Several additions have been made to the chart

to show specific activities during 1979. These include the final design and construction of transporter No. 2, rail trackage currently under contract and planned for release during the year, upgrading of all telescope receivers to the desired selectivity by the addition of "front end filters", and the addition of the required IF circuits to provide for full spectral line capability. This chart is revised monthly to indicate the current status of the Program and is revised annually or at other times when major schedule changes occur.

The schedule as planned requires near maximum effort and facility utilization in the three principal work areas, Charlottesville equipment construction, antenna outfitting, and on-site maintenance, assembly, test, installation, and upgrading activity. New construction and installation proceed at a uniform rate which results in the well defined milestone of "first fringes" being achieved on Antenna 28 at the end of June 1980.

By following this schedule, the final six months of CY 1980 are available for testing of the full 27-element array and upgrading the instrument to provide four channel capability.

CYCLE CODE BAR CHART

PROGRAM 01NOV78 - REPORT DATE. ELECTRONICS - MODULES, RACKS ELCVLA RUN DATE 02NOV78
PROJECT VLA ELECTRONICS MODULES, RACKS, BINS FOR 1978 ELC007

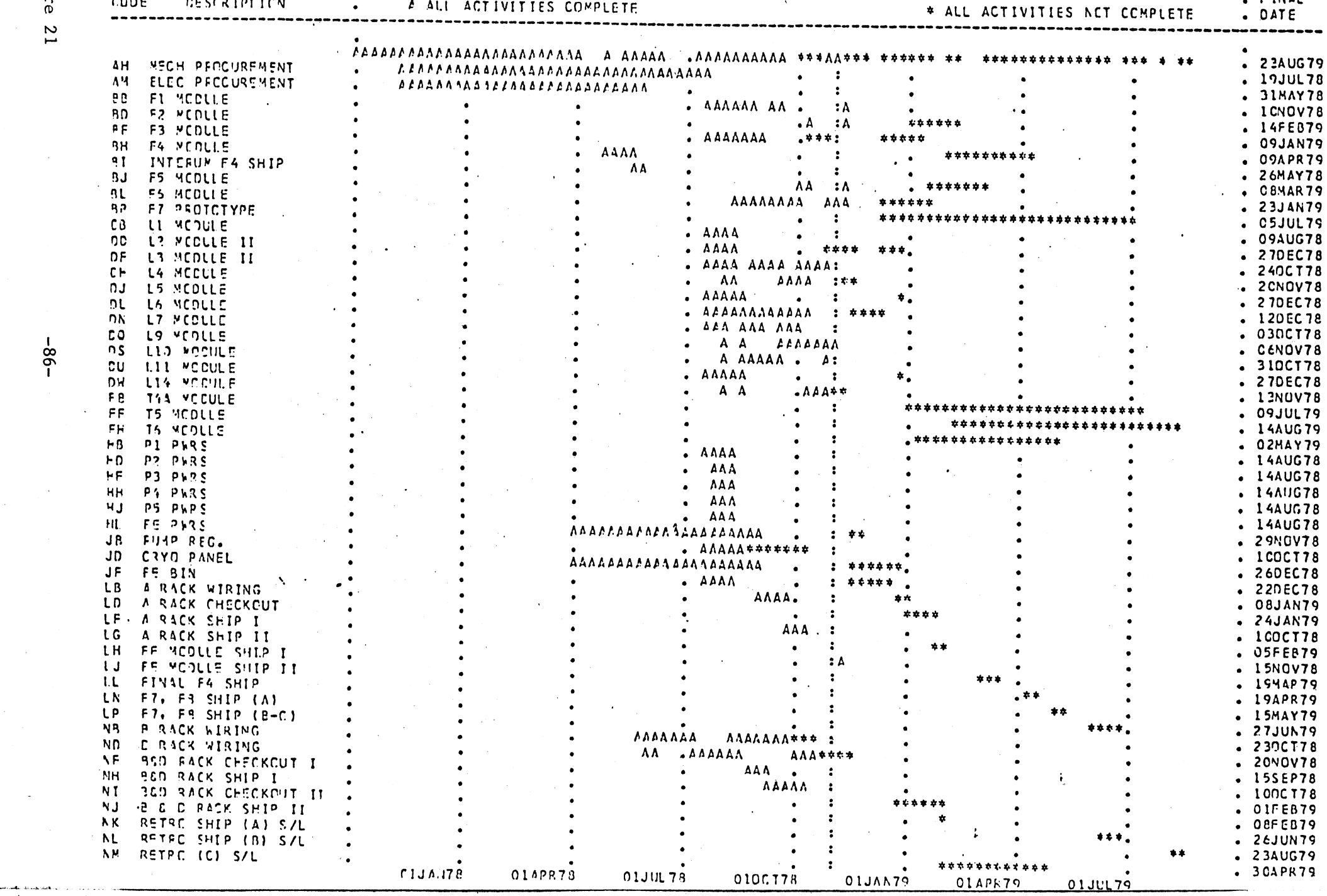
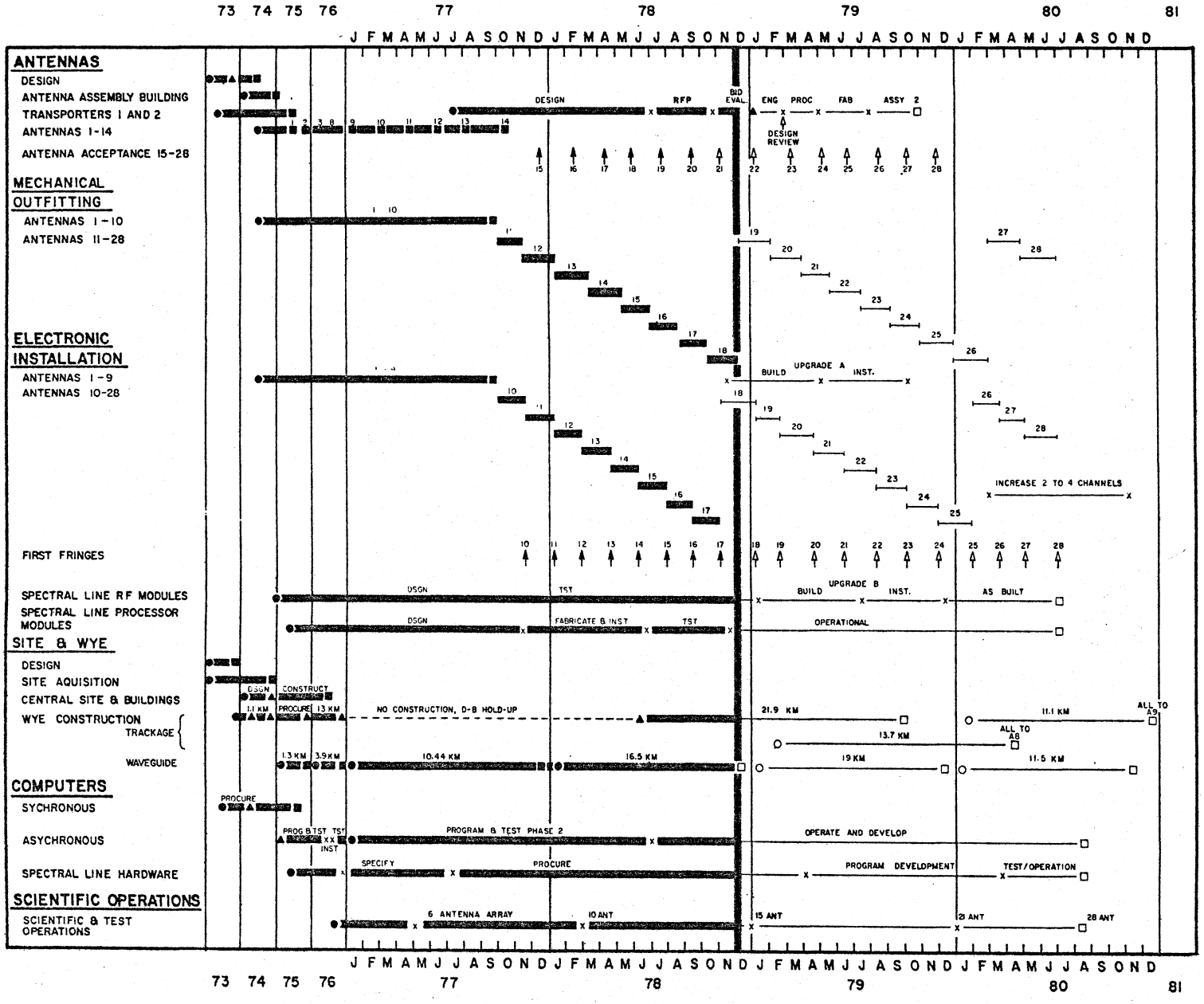



Figure 21

NATIONAL RADIO ASTRONOMY OBSERVATORY

# VLA ACTIVITY SCHEDULE

*UPDATE DATE:* 12/1/78




## TASKS

| | |
|---|---|
| UPGRADE A | RECEIVER FRONT-END FILTERS, MODULES F4, F7, F8. INSTALL 5 ANT/MO. (25 MODULES) |
| UPGRADE B | SPECTRAL LINE IF MODULES T3, T4, T5, T6. INSTALL 4 SYSTEMS (24 MODULES) PER MONTH. |
| INCREASE 2 TO 4 CHANNELS | ADDITIONAL MODULES OF ABOVE TYPES. TOTAL 224. INSTALL 36 PER MONTH. |

## ABBREVIATIONS

| | |
|---|---|
| DSGN — DESIGN | TST — TEST |
| LAB — LABORATORY | PRELM — PRELIMINARY |
| INST — INSTALL | OPNS — OPERATIONS |
| ANT — ANTENNA(S) | |

## SYMBOLS

| | |
|---|---|
| O START OF A PHASE | △ CONTRACT AWARD |
| X END OF AN ACTIVITY | □ END OF A PHASE |
| ↑ SCHEDULED | ↑ COMPLETED |

| REV. NO. | REV DATE | DESCRIPTION |
|---|---|---|
| 1 | 12/1/78 | UPDATE PROGRAM PLAN |
| | | |
| | | |
| | | |
| | | |



Figure 22

APPENDIX A

## NRAO COMMITTEES

There are four major committees involved with the VLA - the NRAO Visiting Committee, the NRAO Users Committee, the VLA Advisory Committee, and the VLA Steering Committee. The first of these provides the AUI Board of Trustees with an independent appraisal of NRAO performance, including the VLA. The Users Committee and the Advisory Committee provide broad overall review and guidance. These two committees furnish scientific input and are the Program's liaison with the scientific community, thus assuring broad participation in the Program. The Steering Committee is responsible for more detailed reviews and advice on scientific and technical aspects of the Program.

The Visiting Committee and the Users Committee have been in existence for many years and both have been involved with the VLA since its early design stages. The Steering Committee is an outgrowth of the design group, which was formed in the fall of 1972. Each of the committees is described below in more detail and the current membership of each is given.

In addition to the above standing committees, various ad hoc committees will be appointed as needed for specific tasks, such as the evaluation of proposals and the selection of contractors.

## NRAO VISITING COMMITTEE

This committee is appointed by the AUI Board of Trustees and formally reports to the AUI Board on an annual basis. Its function is to review the performance of the Observatory and advise the trustees on how well it is carrying out its function as a national center, the quality of the scientific work, and the adequacy of its instrumentation and facilities. A thorough review of the VLA Program will be conducted

by this committee each year. The current membership of the committee is:

| | |
|---|---|
| W. A. Fowler | California Institute of Technology |
| F. J. Kerr | University of Maryland |
| P. P. Kronberg | University of Toronto, Canada |
| R. B. Leighton | California Institute of Technology |
| J. M. Moran | Smithsonian Astrophysical Observatory |
| J. P. Ostriker | Princeton University Observatory |
| V. C. Rubin | Carnegie Institution of Washington |
| R. W. Wilson | Bell Telephone Laboratories |

## NRAO USERS COMMITTEE

This committee consists of users, and potential users, of NRAO facilities from throughout the scientific community. It advises the Director and Observatory staff on all aspects of Observatory activities that affect the users of the telescopes - development of radiometers and auxiliary instrumentation, operation of the telescopes, the computer and other support facilities, and major new instruments. This committee is appointed by the NRAO Director. It meets twice a year, and a broad review and discussion of the VLA will be a principal item for these meetings throughout the life of the Program. The present membership of this committee is:

| | |
|---|---|
| D. C. Backer | University of California, Berkeley |
| B. Balick | University of Washington |
| A. H. Barrett | Massachusetts Institute of Technology |
| J. J. Broderick | Virginia Polytechnic Institute |
| B. F. Burke | Massachusetts Institute of Technology |
| W. B. Burton | University of Minnesota |
| E. J. Chaisson | Center for Astrophysics, Harvard |
| F. O. Clark | University of Kentucky |
| T. A. Clark | NASA - Goddard Space Center |
| J. J. Condon | Virginia Polytechnic Institute |
| J. R. Dickel | University of Illinois |

| | |
|---|---|
| D. M. Gibson | New Mexico Institute of Mining & Technology |
| S. J. Goldstein | University of Virginia |
| S. Gottesman | University of Florida |
| C. E. Heiles | University of California, Berkeley |
| R. W. Hobbs | NASA - Goddard Space Center |
| D. R. Johnson | National Bureau of Standards |
| K. J. Johnston | Naval Research Lab |
| F. J. Kerr | University of Maryland |
| G. R. Knapp | California Institute of Technology |
| M. R. Kundu | University of Maryland |
| M. L. Kutner | Rensselaer Polytechnic Institute |
| R. A. Linke | Bell Telephone Labs (Crawford Hill) |
| J. M. Moran | Smithsonian Astrophysical Observatory |
| P. Palmer | University of Chicago |
| L. E. Snyder | University of Illinois Ovservatory |
| P. Solomon | State University of New York (Stony Brook) |
| J. H. Taylor | University of Massachusetts |
| P. Thaddeus | Institute for Space Studies of New York |
| N. Thonnard | DTM, Carnegie Institution of Washington |
| P. A. Vanden Bout | University of Texas |
| J. F. C. Wardle | Brandeis University |
| B. Zuckerman | University of Maryland |

## VLA ADVISORY COMMITTEE

The Advisory Committee will periodically review the status and progress of the VLA. Its particular concern is with the broad elements of the Program, and especially those that directly influence the scientific capabilities and performance characteristics of the Array. It will advise on broad aspects of design, scientific emphasis, and priorities, as well as on general progress, to assist the Director and the Program staff in assuring that the scientific and technical specifications are met and that the VLA will be as responsive to the needs of radio astronomy as is possible. When scientific observing commences, this group may advise also on general observing programs to be carried out.

The committee is appointed by the NRAO Director. It is composed of scientists whose interests encompass all areas of radio astronomy and technology of concern to the VLA. An attempt is made also to maintain, in the membership, reasonable geographic distribution and representation of the major radio astronomy centers. The committee generally meets twice a year, depending on the nature of current Program activities and their rate of progress. The current membership of the committee is:

| | |
|---|---|
| B. Balick | University of Washington |
| B. F. Burke | Massachusetts Institute of Technology |
| J. N. Douglas | University of Texas |
| F. D. Drake | Cornell University |
| R. D. Ekers | Kapteyn Laboratory |
| C. E. Heiles | University of California, Berkeley |
| P. P. Kronberg | University of Toronto |
| M. R. Kundu | University of Maryland |
| A. T. Moffet | California Institute of Technology |
| A. E. E. Rogers | Haystack Observatory |
| G. W. Swenson | University of Illinois |

## VLA STEERING COMMITTEE

The Steering Committee is the principal technical review committee for the Program. Its principal function is to continuously review technical designs, construction plans, et cetera, to assure that they are consistent with overall performance goals and that staff or contractor technical decisions do not unknowingly affect the system's performance. In addition, the committee advises on technical matters, such as systems design, components design and selection, et cetera.

The committee is appointed by the NRAO Director. It is composed principally of NRAO scientists and engineers who are thoroughly familiar both with the scientific requirements and uses of the VLA and with the techniques and instrumentation employed in the VLA.

The current membership of the committee is:

R. C. Bignell
R. L. Brown
W. R. Burns
B. G. Clark
L. R. D'Addario
J. W. Dreher
E. B. Fomalont
E. W. Greisen
R. M. Hjellming
D. E. Hogg
H. Hvatum
W. Jaffe
J. H. Lancaster
P. J. Napier
F. N. Owen
R. A. Perley
M. S. Roberts
L. Rudnick
R. P. Sinha
S. R. Spangler
R. A. Sramek
A. R. Thompson
C. M. Wade