# VERY LARGE ARRAY PROGRAM

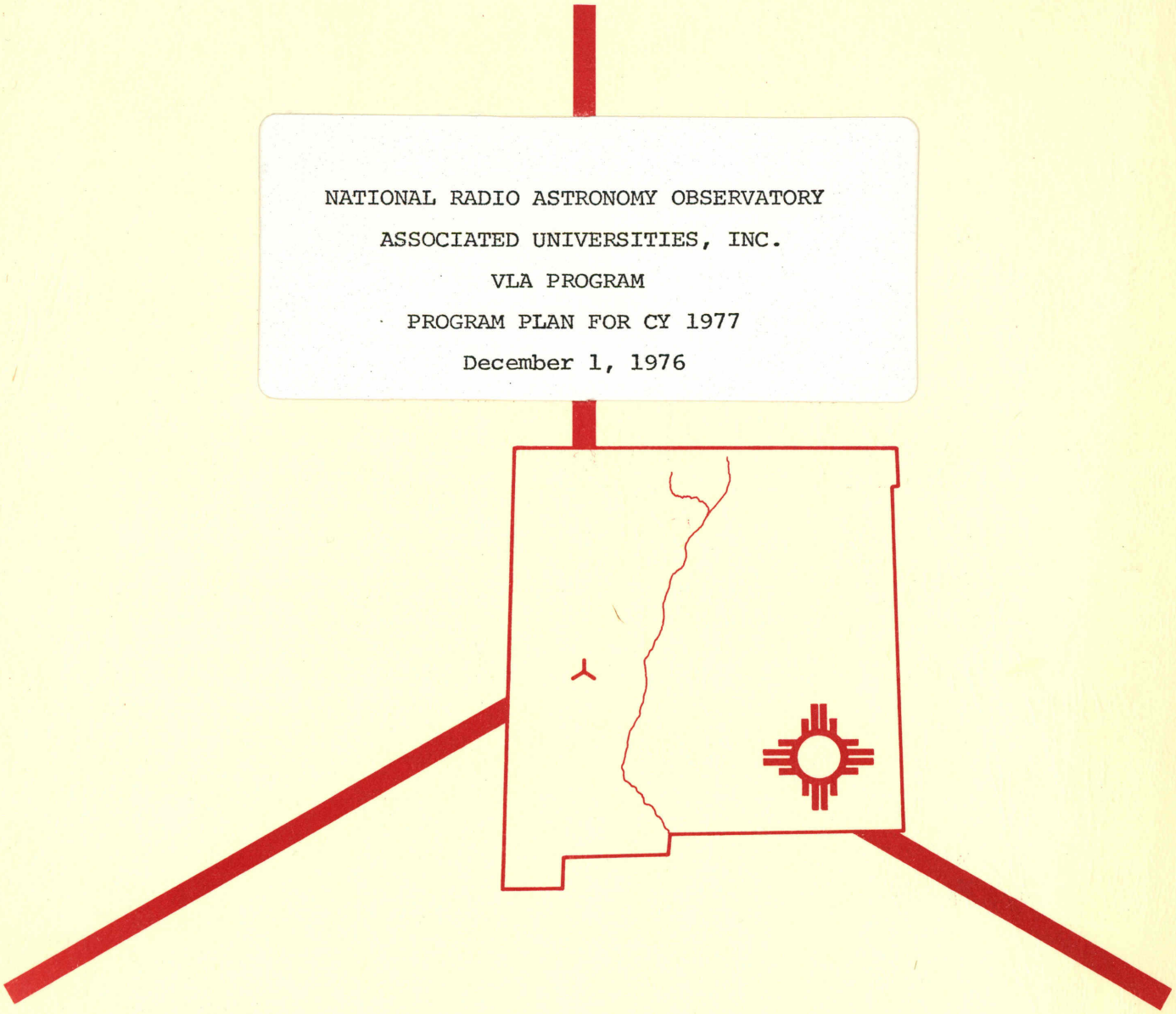
NATIONAL RADIO ASTRONOMY OBSERVATORY

ASSOCIATED UNIVERSITIES, INC.

VLA PROGRAM

PROGRAM PLAN FOR CY 1977

December 1, 1976



**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 1977

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# VLA PROGRAM PLAN FOR CY 1977

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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 1976 Program Plan was based on a funding level of $12,400,000 in CY 1976 and $13,000,000 in subsequent years. In March, $90,000 of additional CY 1976 funding was received; in July, $3,500,000 of transition quarter funds was received; and, in November, a $7,000,000 advance against CY 1977 was made available so that certain long-term delivery and key items of the CY 1977 program could be undertaken. This brought the total Program funding to $44,000,000, including $298,700 disbursed directly by the Foundation for land procurement and the ECAC study. In the fall, the Program staff was requested to prepare the CY 1977 program based on a funding level of $12,500,000, a reduction of $500,000, and a $13,000,000 level of funding in subsequent years. This plan is based on these funding levels and forecasts a total cost of $78,152,000, with final completion late in 1980.

It is the intention of the National Radio Astronomy Observatory that activities during CY 1977 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 1977 Plan will be revised.

## SUMMARY

CY 1976 was a transition year between construction and the start of scientific operations, during which the VLA first began to operate as an interferometer, the permanent buildings were completed and occupied, computers and electronics installed in the Control Building, additional wye trackage completed, and testing and calibration operations began on a regularly scheduled basis. In addition, fabrication and assembly of antenna elements continued, as did the manufacture, assembly, and testing of electronic components, and the work in development of the various software programs for the synchronous and the asynchronous computers.

CY 1977 will see the start-up of scientific operations of the instrument, using first a six element array, which will increase to ten elements by the end of the year. Work will continue in the antenna, electronics, computer, and site and wye areas.

DIC

## 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 required 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 equiangular 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 the equivalent of 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 basic different configurations planned for the array. The antennas will be moved



Original sheet used for 1978 Program Plan

between observing stations by a transport vehicle; one such transporter will be available in the early years of the Program, running on a double, standard gauge railroad track system. In later years, should funding permit, it is probable that ~~two~~ at least one additional transporters will be procured. A reconfiguration of the antenna system, using three transporters, is estimated to take twenty-four 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 will consist of several buildings. A 22,060 square foot Control Building will house 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 18,000 square feet, will house maintenance shops, the electronic and cryogenic shops, storage facilities, and office space. The subcontractor, who will fabricate and assemble 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 grouping of Visiting Scientists' Quarters will be constructed, as will necessary site work, water supply, sewage, electric utility, and similar facilities.



final check used for 1978 Program

## 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 implementation has been assigned to J. H. Lancaster, Assistant Director and VLA Program Manager.

### Program Implementation

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. The planned Program Management staff is shown on the accompanying Organization Chart (Figure 3).

On January 1, 1973, the Program was officially begun with the transfer of fifteen existing NRAO staff members to the VLA. This staff has been increased since then to the present level of ninety-seven members as shown below.

| | 1976 Program Plan Forecast 12/31/76 | Present Level 10/31/76 | Present Forecast 12/31/76 | Planned Level 12/31/77 |
|---|---|---|---|---|
| CONSTRUCTION GROUP | | | | |
| Antennas | 9 | 10 | 11 | 11 |
| Electronics | 36 | 38 | 47 | 42 |
| Computer | 16 | 14 | 16 | 14 |
| Systems Integration | 4 | 4 | 4 | 4 |
| Site and Wye | 7 | 7 | 8 | 3 |
| Program Management | 20 | 24 | 25 | 3 |
| Totals | 92 | 97 | 111 | 77 |

| | Planned Level for Operations 12/31/77 |
|---|---|
| OPERATING GROUP | |
| Antennas | 2 |
| Electronics | 5 |
| Data Processing | 4 |
| Array Operations | 4 |
| Totals | 15 |

| | Planned Level for Common Cost 12/31/77 |
|---|---|
| COMMON COST GROUP | |
| Business | 19 |
| Fiscal | 4 |
| Facility Maintenance | 7 |
| Totals | 30 |

TOTAL PERSONNEL 122

The projected peak construction staff shown by Figure 3 has increased from ninety-two to one hundred and eleven people scheduled for 12/31/76. This change provided additional staff in Antennas, Electronics, Site and Wye, and Program Management to support activation of the antennas, installation of the waveguide, and start-up of the cafeteria at the Site. An additional change, to be made in January 1977, will be the transfer of thirty people from the Construction and Operational Budgets to a Common Cost Budget. This allows the cost of support functions that cannot be placed entirely in either construction or operations to be fairly apportioned between these two activities. Figure 4 shows the projected operational and construction staffing through 1981 with the Common Cost personnel apportioned to each staff.

# NATIONAL RADIO ASTRONOMY OBSERVATORY
## ORGANIZATION CHART
## November 1, 1976

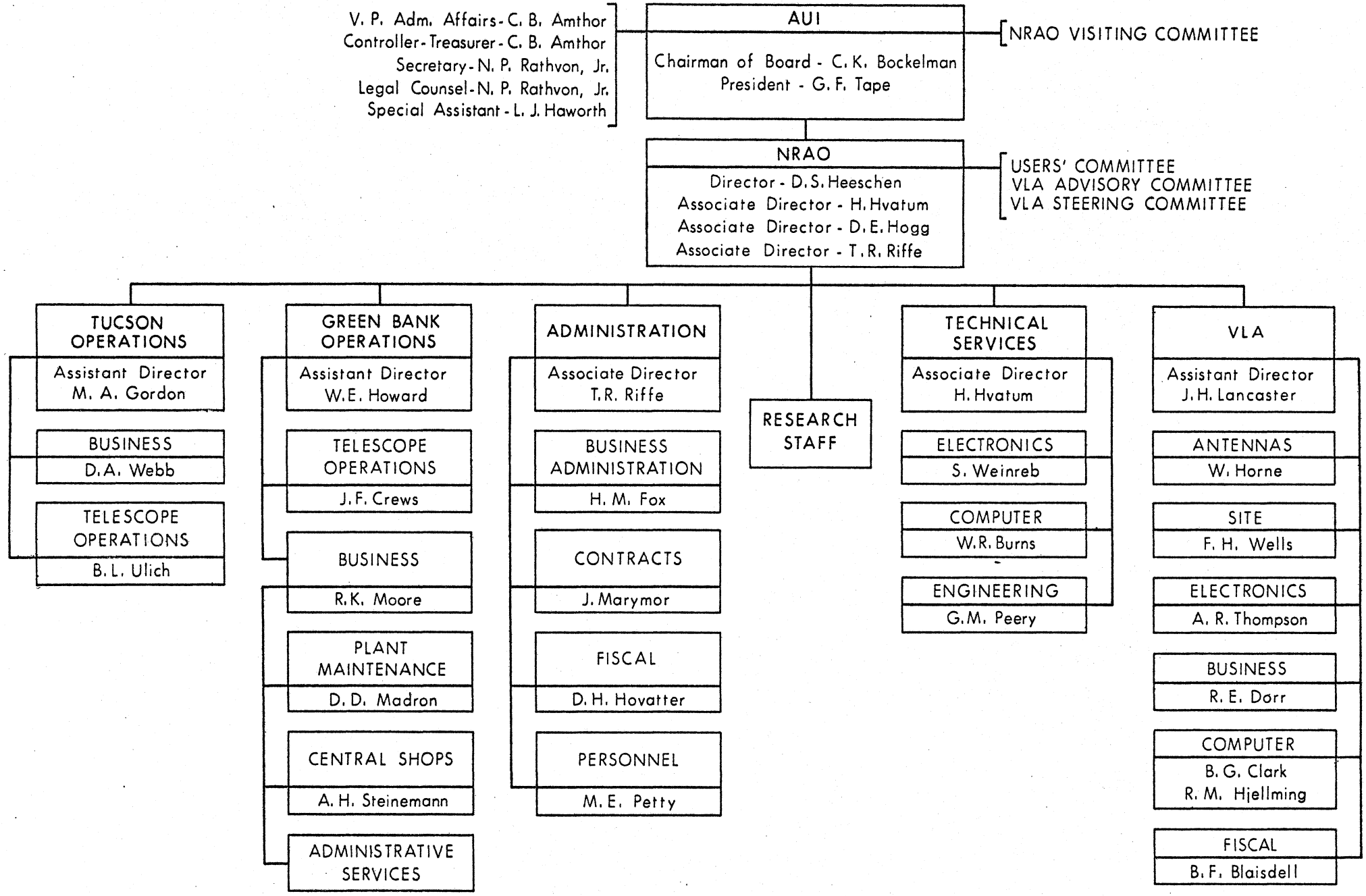





Figure 2

# NATIONAL RADIO ASTRONOMY OBSERVATORY
## VLA PROJECT ORGANIZATION
## PEAK STAFFING

**NRAO**

Director - D. Heeschen
Associate Director - H. Hvatum

**VLA PROJECT**

Manager - J. Lancaster
Deputy Manager - A. Thompson
Asst. to Project Mgr. - R. Mitchell

Exec. Secretary

| ANTENNAS | SITE AND WYE | SYSTEMS INTEGR. | ELECTRONICS | COMPUTER | ADMINISTRATION | FISCAL |
|---|---|---|---|---|---|---|
| W. Horne | F. Wells | V. Herrero | A. Thompson | B. Clark* R. Hjellming* | R. Dorr | B. Blaisdell |
| 3 Engineers | 1 Engineer | 3 Telescope Operators | 16 Engineers | 10 Programmers | 2 Clerks (Site) | 1 Accountant |
| 1 Draftsman | 1 Inspector | | 24 Technicians | 1 Technician | 1 Contract Admn. | 2 Clerks |
| 3 Telescope Mechanics | 1 Custodian | | 3 Draftsmen | 2 Operators | 2 Buyers | |
| 1 Machinist | 1 Maintenance Mechanic | | 2 Machinists | 2 Mathematicians | 1 Clerk-Typist | |
| 1 Equipment Operator | 1 Waveguide Foreman | | 1 Secretary | 1 Librarian | 1 Purch. Clerk (C'ville) | |
| 1 Electrician | 1 Mechanic | | | | 1 Staff Services Admn. | |
| | 1 Clerk-Typist | | | | 2 Driver-Messengers | |
| | | | | | 1 Storekeeper | |
| | | | | | 1 Clerk | |
| | | | | | 3 Guards | |
| | | | | | 2 Cafeteria | |
| 11 | 8 | 4 | 47 | 16 | 18 | |

TOTAL SHOWN 111
*NRAO Staff Scientists

12/01/76

Figure 3

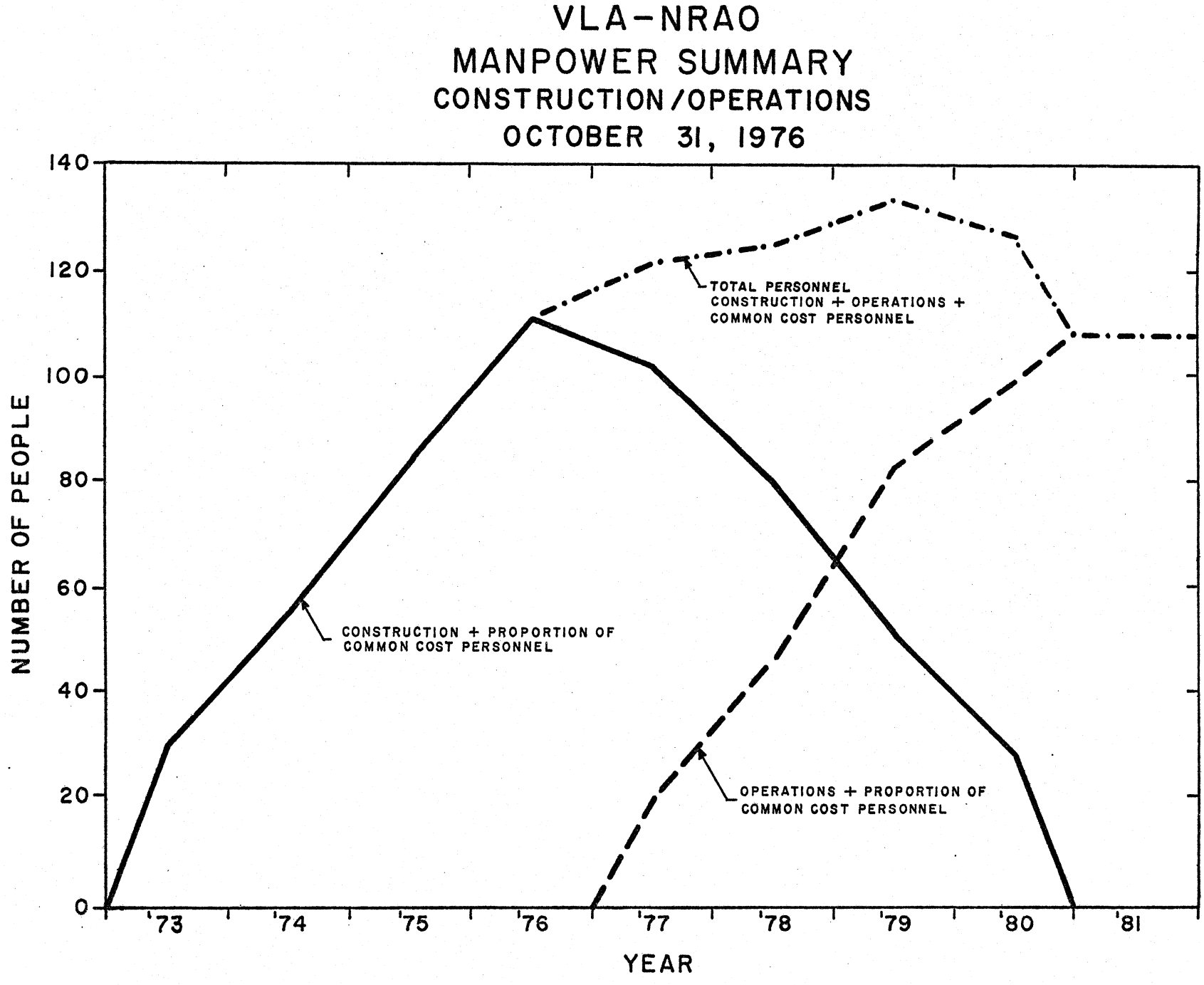

VLA-NRAO
MANPOWER SUMMARY
CONSTRUCTION/OPERATIONS
OCTOBER 31, 1976
NUMBER OF PEOPLE
140
120
100
80
60
40
20
0
'73
'74
'75
'76
'77
'78
'79
'80
'81
YEAR
TOTAL PERSONNEL
CONSTRUCTION + OPERATIONS +
COMMON COST PERSONNEL
CONSTRUCTION + PROPORTION OF
COMMON COST PERSONNEL
OPERATIONS + PROPORTION OF
COMMON COST PERSONNEL

Figure 4

## PROGRAM ACCOMPLISHMENTS 1976

### General

The fourth year of the Program saw: the placing in operating service of four antenna elements and the start of extensive debugging and calibration efforts; the acceptance of antenna elements No. 3 through No. 7; the successful negotiation with E-Systems for the balance of the twenty-eight antennas; the continuation of electronic production and the redesign of certain electronic modules whose performance needed upgrading; the continuation of synchronous and asynchronous software programs; the completion of the conceptual design for the spectral processor and the start of procurement efforts in this area; the completion and occupancy of the Control and Cafeteria buildings, utilities and site work; the completion and occupancy of the Warehouse Building and the Maintenance Shop Building; the completion of Phase III wye construction program; and the issuance of Phase IV construction documents.

### Contractual

Work continued under Prime Contract No. NSF-C-780. The record of funds received to date is as follows:

| | | | |
|---|---|---|---|
| Available 11/15/75 | | | $26,711,300 |
| Amendment No. 17 (CY-76) | 01/16/76 | $6,400,000 | 33,111,300 |
| Amendment No. 18 (CY-76) | 04/26/76 | 90,000 | 33,201,300 |
| Amendment No. 20 (IQF-76) | 07/02/76 | 3,500,000 | 36,701,300 |
| Amendment No. 23 (CY-77) | 11/02/76 | 7,000,000 | 43,701,300 |

The difference between $43,701,300 and $44,000,000 represents $283,000, which the Foundation has withheld for land acquisition, and $15,700 withheld for the ECAC study of radio interference.

### Legal

The Santa Fe, New Mexico, legal firm of Montgomery, Federici, Andrews, Hannahs, and Buell continued to represent Associated Universities, Inc. in New Mexico. There were no legal problems of any nature in New Mexico.

## New Mexico State Gross Receipts and Compensating Tax

In accordance with agreements among the AUI attorneys, the Foundation, and the AUI and NRAO staffs, no formal action was taken with the State of New Mexico. The Program continued paying this tax, through our construction contractors on construction services for conventional or "bricks and mortar" type construction.

During March, the New Mexico Bureau of Revenue made an audit of E-Systems work on antenna fabrication and assembly, which concluded that E-Systems, Inc. owed $140,800 in Gross Receipts Tax for the period through 12/30/75. To date no assessment has been filed, or other action taken, by the State revenue officials. It is still AUI policy to resist payment of any tax other than on "bricks and mortar" type construction.

## Land Acquisition

No significant action on land acquisition took place during 1976. The land situation, including that for the airstrip, appears to be in good shape, with no problems or difficulties forecast.

## Archaeological Approval

Early in 1976, it was determined by all concerned that Site II at the very end of the southwest arm was not of significant archaeological interest and it was dropped from consideration. On April 2, 1976, Site I was included on The National Register of Historic Places. In November, the Foundation intends to formally request the Advisory Council on Historic Preservation for permission to excavate the site under the direction of Dr. Stanley Bussey of the New Mexico State University. It is expected that approval will be received and the work will proceed next spring or summer. Estimated cost of the excavation, recovery, cataloging, and storage work is $96,800, which has been included in the 1976 Construction Cost Estimate.

Systems Integration

One of the major tasks during CY 1976 was the single dish testing of the antennas with their electronics and the integration of them into a working interferometer array. On August 5, 1976, Dr. Barry Clark, a senior, tenured, NRAO scientist, was selected to coordinate all test, integration, and scheduling activities.

During the year the following system highlights occurred:

| | | |
|---|---|---|
| December | 12 | Antenna No. 1 placed under computer control through waveguide. |
| January | | Began regularly scheduled 40-hour per week runs. |
| February | 18 | First fringes, using a two element array at 6 cm on the 1.24 km baseline. |
| June | 29 | First fringes - two element array at 2 cm. |
| July | 13 | First fringes - two element array at 1.3 cm. |
| August | 05 | Shutdown to move control center to Control Building. |
| August | 23 | Resumed operations. |
| September | 08 | First fringes - three element array at 6 cm. |
| September | 14 | First fringes - two element array at 18-21 cm. |
| September | 23 | Baseline increased to 1.9 km. |
| October | 19 | First fringes - four element array at 6 cm. |
| October | 26 | First operation of two independent subarrays. |
| November | | Began scheduled 88-hour operating runs. |

Antennas No. 3 through No. 10

Subsequent to E-Systems, Inc. agreement in April 1975 to produce Antennas No. 3 through No. 10, they proceeded to produce the antennas with considerable skill and diligence. The record of their deliveries is as follows:

| Antenna No. | Schedule Date | Actual Acceptance Date |
|---|---|---|
| 3 | 04/15/76 | 04/20/76 |
| 4 | 05/24/76 | 06/07/76 |
| 5 | 07/15/76 | 07/16/76 |
| 6 | 08/30/76 | 09/03/76 |
| 7 | 10/15/76 | 10/29/76 |
| 8 | 11/30/76 | - |

There follows as Figure 5 a table setting out the design and actual tolerances achieved on Antennas No. 3 through No. 7.

Transporter

The transporter continued to work well during the year and many times made the $90^{o}$ turn, fully loaded, within one or two minutes of the design goal of 15 minutes. Two defects in the design were found during the spring: one, that the connection between the wheels was too rigid and sheared hold-down bolts; and, second, that the trucks did not raise in a level position, making turning difficult. E-Systems, Inc. acknowledged responsibility for both these defects and corrected them without cost to NRAO.

Antennas No. 11 through No. 28

Discussions with E-Systems, Inc. concerning the completion of antennas beyond No. 10 began on January 10, 1976, and continued throughout the spring. In January E-Systems was forecasting a loss on Antennas No. 3 through No. 10 of $1,050,000, or $131,000 per antenna, and at least $150,000 per antenna beyond No. 10. On June 16, 1976, E-Systems requested forbearance on all remaining antennas unless NRAO made $9,000,000 immediately available for advance procurement and increased the lump sum price by $1,074,150.

On July 1, 1976, NRAO refused forbearance. Subsequent negotiations resulted in an agreement that E-Systems would complete all remaining antennas, that the sum of $5,000,000 would be made available for advance procurement,

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

ANTENNA MECHANICAL PARAMETERS

| ITEM | UNIT | SPEC. | ANTENNA NO. 3 | NO. 4 | NO. 5 | NO. 6 | NO. 7 |
|---|---|---|---|---|---|---|---|
| Panel Manufacture | in rms | 0.015 | - 0.011 to 0.015 - | | Avg. 0.0126 | Avg. 0.0123 | 0.013 |
| Panel Setting @ 50° El. | in rms | 0.018 | 0.0123 | 0.0113 | 0.0098 | 0.0096 | 0.011 |
| Az Center to Fdn Center | in | 0.500 | 0.250 | 0.500 | 0.250 | 0.250 | 0.375 |
| Azimuth Lean | arcsec | 18 | 17 | 17 | 14 | 5 | 8 |
| Elevation Orthogonality | arcsec | 18 | 4.0 | 4.1 | 5.0 | 10 | 10.5 |
| Elevation Offset | in | 0.100 | 0.040 | 0.060 | 0.020 | 0.010 | 0.010 |
| Collimation Orthogonality | arcsec | 18 | 6 | 10 | 12 | 10 | 11 |
| Collimation Offset | in | 0.250 | 0.060 | 0.125 | 0.020 | 0.060 | 0.040 |
| Alignment Focal Mount to Collimation Axis | arcsec | 18 | 9 | 5 | 12 | 8 | 9 |
| Servo Error | arcsec rms | 3.24 | - - - - - - - - - - - NOT MEASURED - - - - - - - - - - - | | | | |
| Resonant Frequency (Rocking | HZ | 2.07 | 2.5 | 2.3 | 2.3 | 2.4 | 2.25 |
| Resonant Frequency (Torsional | HZ | 2.15 | 2.3 | 2.2 | 2.4 | 2.35 | 2.2 |
| Slew Rate (Elevation | O/min | 20 | 20 | 20 | 20 | 20 | 20 |
| Slew Rate (Azimuth | O/min | 40 | 40 | 40 | 40 | 40 | 40 |



Figure 5

that the lump sum price would not be increased, that the discount for advance ordering would be waived, and that antennas would be delivered on an advanced schedule, which cut approximately fifteen months off the previous schedule. This agreement was fully executed on July 21, 1976.

Since then E-Systems has ordered nearly 100% of all materials and equipment required for the balance of the antennas.

Electronic Systems

The early part of the year was spent in adjusting, tuning, and debugging the electronics for the two prototype antennas as well as completing production of electronics for Antennas No. 3 through No. 6, and beginning production for Antennas No. 7 through No. 10. During this period it was found that, in order to improve performance in a number of areas, minor design changes should be made and, in two instances, the entire module should be redesigned.

These prototype studies led to the conclusion that the minor design changes should be made at once and the electronics for Antennas No. 1 through No. 6 would be completed and integrated into the array utilizing the existing design subject to these minor modifications. All design changes will be made before electronics for Antennas No. 11 and upward are fabricated. Antennas No. 7 through No. 10 will be an interim test group, which will test the new designs and be used for both astronomical and test operations. It is expected that this group will be in good working order in the fall of 1977 when the first group of six can be withdrawn from service and retrofitting started. Under this plan the full ten antennas should be operational as scheduled in January 1978.

Prototype tests of the 1.3 and 2.0 cm feeds showed them to have efficiencies of 44% and 53%, which met the design goals. However, the efficiency of the prototype 6.0 cm feed was a disappointing 53% compared to a design goal of 65%. A contract was awarded to J. J. Gustincic in April to develop a better 6 cm feed. The second prototype was installed on June 24 and found to have an efficiency of 65%, which meets the original design goal. The prototype 18-21 cm feed was tested in February and found to have an efficiency of only 40% versus 48% specified. A development contract was awarded to J. J. Gustincic and his prototype, when received and tested in September, showed an efficiency of 52% at 18 cm and 50% at 21 cm. In May it was found that, for the two circular polarizations, there is a pointing difference of 1/15 of the beamwidth for all wavelength bands due to the offset feed geometry. This problem is still under study.

The front end amplification equipment has in general worked well except in two areas. The parametric amplifiers supplied by Comtech have

given considerable difficulty and it was decided in April to switch to a two stage parametric amplifier furnished by AIL, followed by a room temperature GaAs FET transistor amplifier. The first FET amplifier was received in September and exceeds its design specifications. The second area was that of the helium compressors. Here, the Cryomech unit had to be discarded due to lack of capacity and a considerable number of minor changes were made in the Air Products compressor to make it more reliable.

Prototype tests in the spring showed that the local oscillator modules L2 and L3 needed redesign to improve phase stability and temperature coefficients. This redesign was completed and breadboard units tested during August. L2 and L3 modules now show a tenfold improvement in the temperature coefficient of phase.

The NRAO modem design was completed and parts received in January. These were assembled and tested with extremely good results. The modules are now being assembled by outside vendors without difficulty.

Completion of the Monitor and Control systems for the first six antennas went well although some minor changes to decrease the error rate were found to be necessary. Also completed during the year was a test set for all monitor and control modules using a minicomputer. No problems have been experienced with the Delay or Multiplier system and at present a twelve antenna system is close to completion.

Conceptual design of the Spectral Line System electronics was completed and detail design and procurement started. The design involves the development and production of two special integrated circuit chips. This procurement was bid in October and placed in November as soon as CY 1977 funds became available.

During the early spring, a concentrated effort was devoted to complete the design and order the materials for the walkways, cable trays, waveguide, coaxial and control cabling required to interconnect the electronics, computer and control equipment in the Control Building. Installation work began as soon as the building was accepted and was completed well ahead of schedule.

## Waveguide Communications System

The three complex waveguide signal distributors were received from Japan, installed in the Control Building in late May, thoroughly tested and accepted in June. They meet all required specifications.

Development work proceeded on the design of couplers required to remove and insert commands, signals, and scientific data from the 60 mm waveguide at antenna stations along the 21 km arms of the wye. Three different types, the helical, beam splitter, and sector, have been developed and tested with good results. The sector coupler, which is very broadband and has modest insertion loss, is thought to be the best for all stations except the last few on each arm.

During the year, the manufacturers of choice for the 20 mm antenna waveguide runs and the rotary joints declined to bid on future orders. Substitute vendors were found but the 20 mm waveguide is of inferior quality and must be improved.

Monitoring activities continued on the 1.24 km 60 mm prototype waveguide run buried in 1975. Attenuation losses in this run increased slightly from August 1975 until April 1976. From this date until mid-September an increase of .07 dB per km occurred, which is shown on Figure 6. Since then the increase seems to have stopped. Early in 1976 several alternate methods of direct waveguide burial were tried and one selected, which is now being used. It involves an eighteen-step procedure that gives much improved early results as shown on Figure 7. These runs will be carefully monitored. Late this year or early next year two test sections will be installed using a concrete base and a PVC outer sleeve.

## Computer Systems

The synchronous computer was used all year in the operation of the interferometer array. The group both operated and debugged the necessary programs and worked on additional software programs which will be required as the array grows in size and becomes more complex. In August, the system was moved out of the temporary trailer and into the computer room of the Control Building. Programs for all four receiver bands and for subarray operation were placed into operation.

# LOSS vs TIME-FREQUENCY

## (1.24 KM OF 60 MM HELIX WAVEGUIDE)

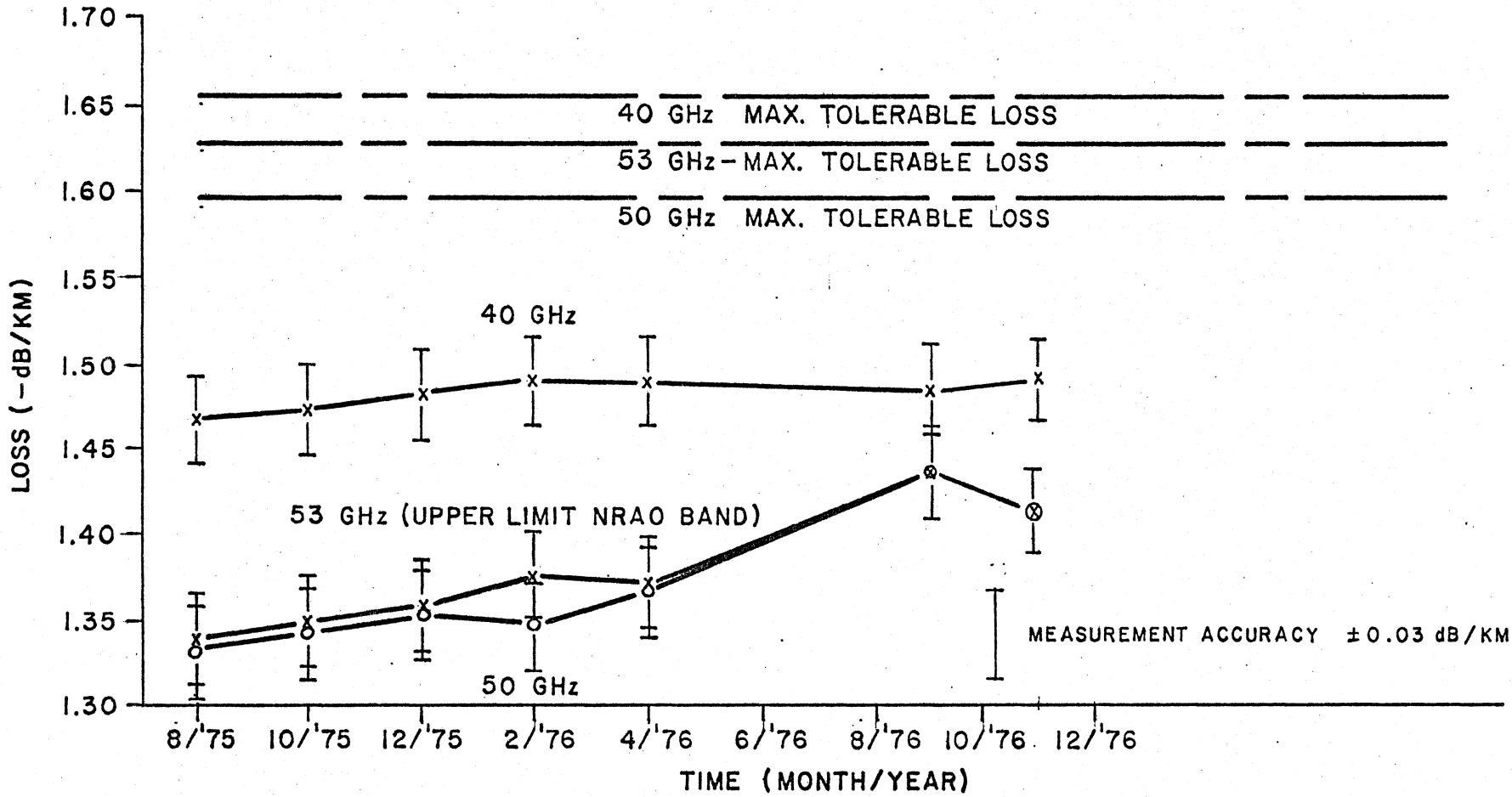



Figure 6

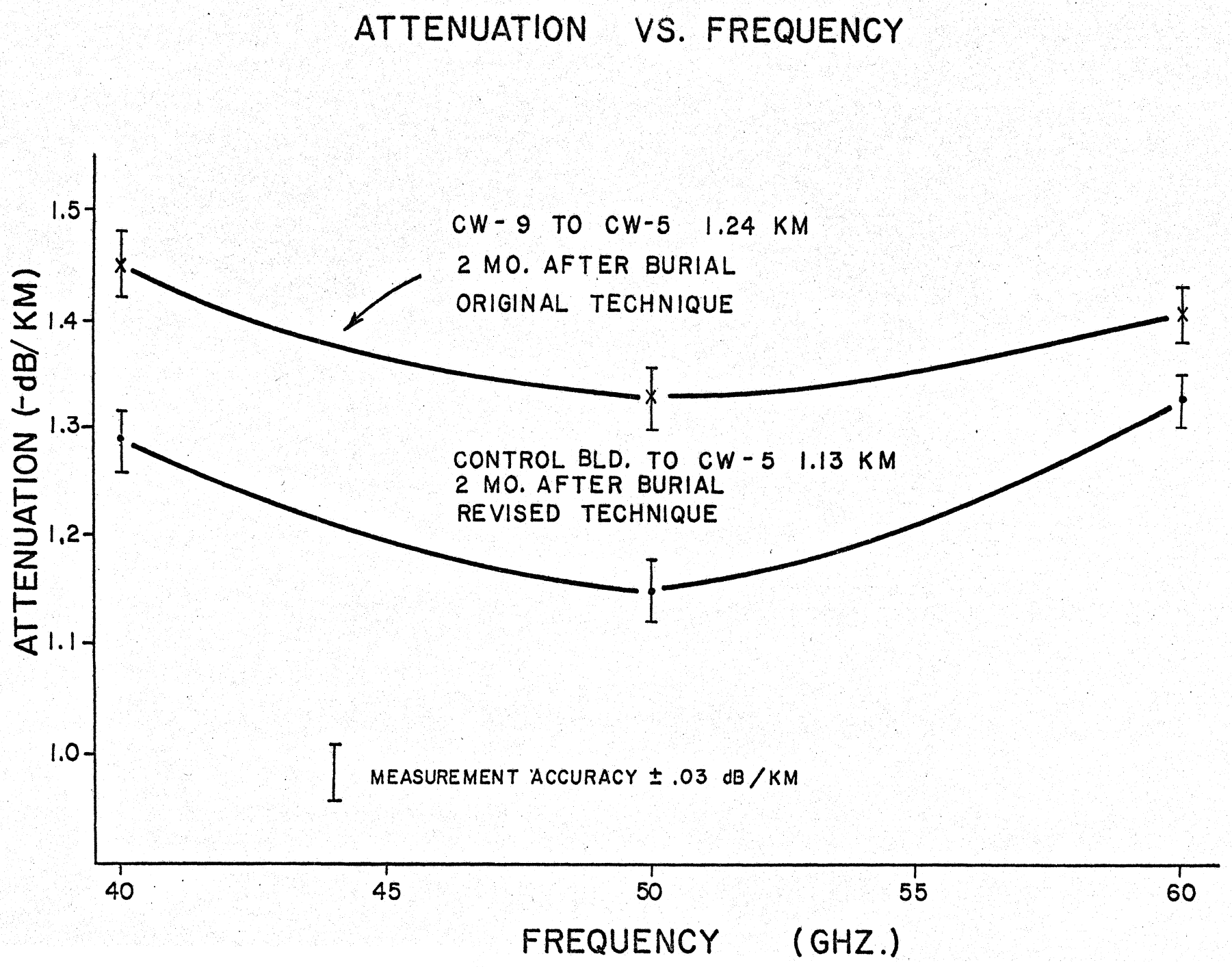

ATTENUATION VS. FREQUENCY
CW-9 TO CW-5 1.24 KM
2 MO. AFTER BURIAL
ORIGINAL TECHNIQUE
CONTROL BLD. TO CW-5 1.13 KM
2 MO. AFTER BURIAL
REVISED TECHNIQUE
MEASUREMENT ACCURACY ± .03 dB/KM
ATTENUATION (-dB/KM)
1.5
1.4
1.3
1.2
1.1
1.0
40
45
50
55
60
FREQUENCY (GHZ.)

Figure 7

The principal activity of the asynchronous group during the year was the continued development of software programs and their test and checkout with actual data from the Green Bank and VLA interferometers. Early in the year the initial graphics system, consisting of the Comtal raster display device, the Versatec electrostatic printer, the PDP-11, the line drawing CRT and ADDS graphics, was activated. On June 14th, the DEC system was shut down, shipped to the Site, assembled in the Control Building, and began operations on July 10th. The DEC FFT box received in December 1975 could not be made to meet its design specification and on May first was formally rejected. In September, an RFP for the addition of 128 K of memory core was issued and in November an RFP for two array processors was issued. Considerable effort has been expended toward speeding up the asynchronous system and making it more adapted to the developing array.

It was found during 1975 that electrical voltage swings and short power interruptions caused by lightning strikes on the some 600 miles of the SEC distribution network required the installation of a constant power motor generator set. This was ordered in January for a May 31 delivery. In April it was evident that the set would not be delivered in time for the move into the Control Building and a surplus set was obtained for temporary use. The final set did not arrive until November, when it was installed.

In April, the Associate Director of NRAO appointed an ad hoc committee headed by Dr. Campbell Wade to review the goals and progress of the VLA software computer work. This group completed their work and issued a report in July. The report has been discussed by the NRAO staff and the VLA Advisory Committee and many of its recommendations are being followed.

In February, the group looking into the advantages of utilizing a coherent optical processor for spectral-line map synthesis issued its report. After study and review, it was decided to engage a consultant to complete an engineering design, recommend components, demonstrate its performance, and to perform a system error analysis to confirm the performance. The firm of Environmental Research Institute of Michigan (ERIM) was selected and awarded a $95,000 contract in June 1976. The study is to be completed early next year.

Site and Wye Design and Construction

Phase II construction, consisting of the permanent buildings, site work and utilities, was accepted for occupancy on May 14, 1976, approximately two months ahead of schedule.

Phase III construction, consisting of 13.1 kilometers (8.1 miles) of wye trackage, 49 antenna foundations, and electrical utility system, is now 97% completed and will be accepted prior to the end of the year.

Phase IV construction, consisting of 12.4 kilometers (7.7 miles) of wye trackage and five antenna foundations, was issued for competitive bid on October 4, 1976. On October 29th the Washington Office of the Department of Labor issued a determination that this work should be constructed using the Heavy Engineering Construction wage classification. This will double the labor cost of the contract and result in an overall cost increase in VLA construction of approximately $2,000,000. The Department of Labor determination is being challenged and the bid due date has been postponed.

On January 6th, a contract in the amount of $147,805 for a 6,000 square foot Maintenance Shop Building and a 6,000 square foot Warehouse Building was awarded. This work went well and the buildings were both occupied in May. These two buildings replace the permanent 15,510 square foot maintenance/warehouse building bid in 1975 which had a construction cost of $508,000.

Installation of the 60 mm waveguide proceeded as soon as the weather was suitable. At the end of the year, in excess of 5,200 meters of waveguide had been installed.

On October 7th, a $28,123 contract was placed for the first four room, motel-type prefabricated Visiting Scientists Quarters building. This structure is being purchased without siding and will receive a slump block veneer to match the other permanent buildings.

On October 5th, a $72,980 contract was awarded to Executone Systems of New Mexico, Inc., covering the first phase of the wye communications system. Negotiations for this system have been under way for almost one year.

## Program Management

The principal activity of the Program Management group during 1976 was in the procurement field. In the year ending November 15th, 2,575 purchase orders and subcontracts were issued, having a total value of $8,733,000. Many of these actions required extensive negotiations which resulted in appreciable savings and in keeping the effects of inflation to a minimum.

The group also arranged for the transfer of the Asynchronous group and the DEC-10 computer from Charlottesville to the Site in June. The move of thirteen employees and their families from Virginia and West Virginia to New Mexico was arranged; and twenty-six new employees required for the Program were located, interviewed, and processed for hiring. The group assisted both transferred and new employees in obtaining housing. During the spring, the Control, Cafeteria, Maintenance, and Warehouse buildings were furnished and equipped.

Throughout the year a great deal of excess railroad trackage, accessories, and ties were found, removal and shipping contracted for, and the material stockpiled at the Site. Eleven thousand tons of rail material has been obtained from seventeen locations at an average total cost of $47.40 per ton. The current market price for relayer rail is $225.00 per ton and $305.00 per ton for new rail, exclusive of transportation. At the present time we have approximately 89% of all necessary rail and 68% of all necessary ties stockpiled, under contract, or under investigation. This is two to three years ahead of our original schedule.

In July, the Site cafeteria began operations, serving about fifty people at lunch and providing breakfast and an evening meal for the operating personnel.

## Fiscal Operations

Fiscal operations in 1976 were normal except that a considerable amount of time and effort was expended setting up the accounting system for the start of scientific operations during 1977. This involved establishing cost codes, coordination with the NRAO Fiscal Office, and establishing a common cost procedure which could properly allocate costs which were common to both construction and operations.

## PLANNED ACTIVITIES - 1977

### General

The main emphasis during the early months of the coming year will be to begin research operations, using at first a three element array which will gradually increase to six in the spring and to ten by January 1978. At the same time, production of additional antennas and electronics will proceed and these new antennas must be equipped with electronics, tested, and integrated into the array. Considerable difficulty is expected during the year in satisfactorily completing both these tasks and, as a result, a staff buildup is presently under way. This section of the Program Plan will discuss the events of major import planned to take place during CY 1977.

### Research Operations

On August 10, 1976, Dr. D. S. Heeschen invited research proposals from scientists throughout the country who have had interferometer observation experience. This is to be a cooperative program whereby observers will devote a portion of their time to test measurements and will make their results and their experience available promptly to the VLA staff in order to aid in further development of the system.

During CY 1977 fifteen people at the VLA will be charged to support of research operations. Summary details of personnel and costs of operations are included within this Program Plan for completeness, but details of scientific programs, objectives, personnel, and costs for this and future years are included within the regular NRAO Program Plans.

### Systems Integration

The Systems Integration group will remain at its present level during CY 1977 and continue with the work of checking out completed antennas and integrating them into the array. The planning and day-to-day coordination of the antenna outfitting, with both mechanical and electronic equipment, has

been shifted from this group and is now the responsibility of the Assistant to the Program Manager, Mr. Robert M. Mitchell.

The array operators assigned to Systems Integration will run the antennas during the single dish tests of feed and electronic efficiency and complete all necessary documentation. They will also be involved in the regularly scheduled research operations as necessary.

Antenna Systems

With the successful completion of negotiations with E-Systems, Inc. in 1976, we foresee no major problems connected with the fabrication and erection of the balance of the antenna elements. There remain a number of minor problems to resolve in the servo system and the air conditioning system for the Vertex Equipment room. We also intend to replace the vertical ladders at the base of the antennas with stairways for ease and safe access to the higher levels.

Antenna deliveries scheduled for the next year are as follows:

| | |
|---|---|
| Antenna No. 9 | January 17, 1977 |
| Antenna No. 10 | March 01, 1977 |
| Antenna No. 11 | April 29, 1977 |
| Antenna No. 12 | June 22, 1977 |
| Antenna No. 13 | August 12, 1977 |
| Antenna No. 14 | October 12, 1977 |
| Antenna No. 15 | December 09, 1977 |

One result of the speedup of antenna delivery by E-Systems, Inc. is that the VLA must purchase this year six sets, instead of five, of antenna outfitting items, such as the main feed support ring, feed support structures, Stirling focusing mounts, subreflectors, subreflector support barrel, cryogenic compressor platform, and miscellaneous trays and supports. These must be delivered in sufficient time as E-Systems is responsible for their installation.

Electronic Systems

During 1977 the major areas of activity in electronics will be: completing the redesign, prototyping, and testing of those few module elements whose performance needs improvement; continuing production of electronics for Antennas No. 11 and over; installation of electronics on completed antennas;

and testing and debugging completed systems prior to their final use on the array. In addition, a considerable amount of effort will be extended in maintaining and improving the efficiency of units already operating.

Of some forty-one different modules and power supply assemblies it has been found that two will require major redesign and that several others require minor revisions, such as the change of a malfunctioning switch. Several new modules will be designed. This work was started in 1976 and will be completed in 1977 when the early antennas will be retrofitted. It is planned that Antennas #11 and onward will be equipped with the final electronic components.

Considerable difficulty has been encountered during 1976 in keeping antennas operating due to the lack of spare modules, parts, and equipment. For this reason it has been decided to procure and fabricate seven sets of electronics during 1977 instead of the previously scheduled five sets. This will give us working spares and may enable us to equip six antennas instead of five during the coming year. To do this without excessive cost, the Charlottesville assembly operation will work on an efficient batch process, producing seven of each module at a time instead of one of each. This assembly method, plus the change in the fiscal year financing, will slow delivery of the first complete electronic set until November 1977, when it is expected that electronic sets No. 11 through No. 17 will be completed. This scheme also permits immediate assembly of the great majority of modules which do not require redesign, and their use as spares, and gives adequate time for complete design and testing of those that need redesign.

We now have acceptable vendors for all four feeds and will proceed to order additional models. An effort will be made to see if a corrugated horn will improve the efficiency of the 1.3 cm and 2.0 cm feeds. Additional work will also be done on the circular polarization offset matter. Five production models of the 18-21 cm feeds are on order for delivery in December - January 1977. These will be installed on the telescopes as soon as they are received.

It is believed that the problems of parametric amplifiers and reliability of the helium compressors will be solved in 1977 and completion of the front-end equipment will go ahead rapidly.

The balance of the electronic fabrication, assembly, and testing should go ahead in routine fashion.

Work will accelerate on the spectral processor delay and multiplier units, the control system, and the computer interface. This work has all been transferred to the VLA Site. The prototype, custom designed, integrated circuits will be received and tested in the late spring. If satisfactory, production will be ordered. The necessary multilayer boards, mother boards, cabinets and racks will also be ordered, with assembly to follow. By the end of 1977 a system which will handle two IF channels for all twenty-seven antennas will be nearing completion.

Waveguide Communication System

Development work on the waveguide couplers will continue during the first portion of the year, followed by the completion of detailed design drawings and specifications and procurement. Design will also be completed on the waveguide evacuation and nitrogen pressurization system, possible windows to sectionalize the waveguide, and waveguide monitoring devices of both pressure and electrical performance. Should it appear necessary, work begun in 1976 on a signal amplification device for the outer reaches of the waveguide will be continued.

In 1977 the determined procurement effort now under way to find a better source of 20 mm waveguide for the antenna runs will be continued.

The buried waveguide runs will be continuously monitored and new and potentially better schemes tried. This is a matter of considerable economic impact as it is estimated that to go to a burial scheme based on a concrete waveguide base will cost an additional $800,000.

Computer Systems

During 1977 the synchronous computer will continue to operate the increasing array and to initially process the data. Software programming will be continuously updated, expanded, and improved during this time. Time on the computer will be shared between regular scientific operations and the engineering requirements of debugging new antennas and integrating them into the array.

During the year several changes and additions will be made to the Modcomp system to improve its reliability and versatility. These are: the addition of core memory to two of the existing Modcomp computers, "Boss" and "Monty", and their conversion to multiport memory; the addition of an interface to the correlator Modcomp; and the acquisition of a repair system to prevent a complete VLA shutdown in the event that a Modcomp CPU unit failed. It is also intended that all Modcomp units be updated in 1977 by factory representatives.

Programming and development work on the asynchronous hardware and software packages will continue throughout CY 1977. This will occur while the system is being used for research operations and the programs expanded and adapted to the needs of the individual observations and the data flow from additional antennas.

During the year several items of additional equipment will be added to the asynchronous system. These are 128K words of additional DEC-10 memory core and modified data channels. An array processor and FFT subsystem will be integrated into the system. Procurement will start on sort/transpose equipment and a data base supervisor subsystem. The map display/analysis system will be upgraded by addition of a large disk unit, and XY plotter, and a passive video display system.

The contractor who is studying the practicability of using an optical processor will complete his study and make his report early in 1977. NRAO then must review the potential cost, advantages and risks of following this course and make a decision as to the best way for the VLA to proceed. Following this decision extensive work in the design of an optical or digital system must proceed.

Site and Wye Design and Construction

The Site and Wye group will supervise the construction of Phase IV construction with the assistance of the Engineer/Architect, who will continue weekly inspection visits to the Site and assist in other technical and administrative matters as requested. During the summer of 1977, when the level of CY 1978 funding is known, the E/A will be requested to prepare bid

documents for Phase V wye construction, which will be issued in October for award as soon as funds are available. Phase III bidding showed dramatically that large savings in construction cost can be made when the total price of the work is $3,000,000 or over.

Other activities that the Site and Wye group will accomplish during the year are the completion and placing into operation of the first Visiting Scientists Quarters and the emergency electric generation plant. The latter will consist of two 500 kW diesel generator units obtained through surplus channels. They are to be installed in a lean-to addition to the Maintenance Shop building and connected to the main switchgear. Site diesel and gasoline storage tanks will be installed as a portion of this project. One other miscellaneous project which will be completed during 1977 is a gravel road network to the antenna foundations within the central section of land owned by the Government.

Waveguide installation will proceed on all arms of the wye, with the goal of installing at least 10,000 meters during the year. Efforts will continue toward the improvement of the burial techniques as original or latent developing curvature rapidly increases attenuation.

Program Management

The Program Management group in CY 1977 will continue along the same lines as in 1976. Procuring, receiving and issuing will be the main chores and much effort must go into finding additional sources for waveguide components and other items. Transportation activities will continue at about their present level. As research activities increase, the cafeteria will have to open for breakfast and dinner and the Visiting Scientists Quarters will start operations.

During the year we will make another organized effort to find additional surplus railroad track, ties, and accessories. To date we have found approximately 89% of our total requirements for track and 68% of our tie requirements. By year's end we should have 100% of our track requirements in hand. Ties are of less urgent procurement need as we already have enough for the next two year's construction and supplies are not difficult to find in the local area.

Fiscal

In 1977 the Fiscal group will focus on accounting for funds budgeted for construction, operations, and common cost, utilizing the recently established procedures and the newly acquired Burroughs minicomputer. Implementation of the accounting system will allow a smooth flow of information into the existing NRAO financial reporting system while at the same time providing information to the VLA Project staff personnel.

The establishment of the Common Cost concept to account for expenditures common to both Construction and Operations will be implemented in 1977. Costs for such items as procurement, personnel, transportation, cafeteria and housing operation, facility maintenance, materials, warehousing and issue, fiscal operations, staff and administrative services and other related costs applicable to both operations and construction will be accumulated and prorated to construction and operations on an established formula basis.

Other areas of concentration during 1977 will include the internal control and audit support function, property accounting including fixed asset control, and inventory accounting.

## PLANNED ACTIVITIES - 1978

### Scientific Operations

Scientific operations will still be in the buildup stages, with ten antennas available early in the year, gradually building up to fifteen by the end of CY 1978.

### Systems Integration

Primary activities will be to assist in the systems integration task of combining the antennas, electronics, and computer systems. During the year this group will be disbanded and absorbed by the Operations Division.

### Antennas

As soon as CY 1978 funding becomes available, the options, contained in Amendment #18 of the E-Systems subcontract in the amount of $3,129,926, will be exercised. These provide for the manufacture, assembly, and test of Antennas No. 21 through No. 28. The subcontract provides for the delivery of Antennas No. 16 through No. 21 during 1978. VLA personnel will inspect the work of the subcontractor to insure compliance with the antenna specifications.

Other activities include the outfitting of all antennas received and the procurement of the NRAO-supplied antenna items. Mechanical maintenance of the operating array, increasing during the year from ten antennas, will require a considerable amount of effort.

### Transporters

Present plans provide for the bidding of Transporter No. 2 during late 1977 and the placement of a contract for its manufacture as soon as CY 1978 funds become available.

Electronics

Primary focus during 1978 will be the installation and testing of electronics on Antenna units 11 through 15. In addition, the balance of components for Antennas 16 through 20 must be ordered, fabricated, assembled and made ready for installation and testing on the antennas beginning in late 1978. Operational checkout of the first half of the spectral processor will be completed, and plans made for the procurement of the remainder of the system.

Computer

Primary objectives during 1978 will be the procurement, installation, and test of the remaining computing equipment needed to handle the spectral line data.

Site and Wye

The Site and Wye group will continue to oversee the construction of wye trackage and services. It is anticipated that a 12 kilometer package of wye trackage and services will be designed and bid during the summer of 1977, to be financed with 1978 funds. This work will be completed during 1978 by one or more general contractors.

Program Management

Primary focus will be on the procurement activities required to obtain the next group of antennas, antenna components, and electronic systems, as well as implementation of the operations budget.

## PLANNED ACTIVITIES - 1979

### Scientific Operations

Scientific operations will be in full swing in CY 1979, starting in January with fifteen antennas, which will build up to about twenty-one by the end of the year.

### Antennas

Antenna units No. 22 through No. 28 will be delivered during 1979 with the final unit received from E-Systems about November 30th. These units will be outfitted with all mechanical and waveguide items and prepared for the installation of electronics.

Mechanical maintenance of the operating antennas will require an ever-increasing effort.

### Transporter

The fabrication of transporter No. 2 should be completed about mid-year in 1979 and the vehicle placed in service.

### Electronics

The major emphasis during 1979 will be the installation and testing of electronics on Antenna units 16 through 20. In addition, electronic components for Antennas 21 through 25 must be ordered, fabricated, assembled and made ready for installation and testing on the antennas early in 1980. Fabrication of the second half of the spectral line processor will occur in 1979, at which time on-line testing of the full system will commence. Procurement of the additional modules required to implement all four IF channels will begin. During the early years only two IF channels are to be used.

Computer

Receipt of the remaining spectral line computing equipment will occur during 1978, at which time extensive testing and integration into the existing computer complex will take place.

Site and Wye

The Site and Wye group will continue to oversee the construction of wye trackage and services. It is anticipated that a major package of wye trackage and services will be designed and bid during the summer of 1978 and awarded as soon as 1979 funding becomes available.

Program Management

Major objective will be the supervision of procurement activities necessary to obtain the next group of antennas, antenna components, and electronic systems. Implementation of the operating budget will continue.

## PLANNED ACTIVITIES - 1980

### Scientific Operations

At the beginning of CY 1980 about twenty-one antenna elements should be operational, with this number increasing steadily during the year until all twenty-eight units are completed by January 1981.

### Antennas

All work on the mechanical outfitting of antennas will be completed early in the year and the antennas turned over for electronic outfitting.

### Electronics

The major focus during this year will be the installation and testing of electronics on Antenna units 21 through 25. In addition, electronic components for Antennas 26 through 28 must be ordered, fabricated, completed and made ready for installation and testing on the antennas in late 1980. Final testing of the spectral line processor will be completed and integration with the computer will begin and continue through the year. The implementation of all four IF channels will be completed.

### Computer

Development of programming and software will continue through the year.

### Site and Wye

The Site and Wye group will continue to oversee the construction of wye trackage and services.

### Program Management

Emphasis will be on procuring the required antenna components and electronics to complete the VLA construction. The operations budget will be fully implemented by the end of the year.

## FINANCIAL PLANNING

This section of the CY 1977 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 - 11/01/76 - Shows the current cost estimate for the Program and compares the present estimate with that presented in the CY 1976 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. Details current (escalated) and base (unescalated) cost and total Program escalation.

SUMMARY OF CONSTRUCTION/OPERATING BUDGETS - CY 1973 THROUGH CY 1980 - Shows the cost estimate by Program year for construction and operations, including distribution of Common Cost.

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

COMMITMENT SCHEDULE - CY 1973 THROUGH CY 1980 - A commitment schedule to show actual commitments through 1975 and how the estimated commitments will be divided among the various calendar years.

EXPENDITURE SCHEDULE - CY 1973 THROUGH CY 1981 - An expenditure schedule to show actual expenditures through CY 1975 and to forecast expenditures during the life of the program.

FINANCIAL PLAN - CY 1977 - The financial plan for CY 1977 broken down into various categories. For comparison, the actual allocation of CY 1973, 1974, 1975, and 1976 funds has also been included.

COMMITMENT/EXPENDITURE SCHEDULE BY QUARTERS CY 1977 - A commitment and expenditure schedule for CY 1977 broken down by quarters.

CY 1976 REVIEW OF FINANCIAL PLAN - A detailed analysis of the revisions that have been made to the CY 1976 Financial Plan, giving the reasons for the changes.

EXPENDITURES AND COMMITMENTS - CY 1976 CUMULATIVE ACTIVITY - A report in graph form, showing scheduled and actual expenditures and commitments by months.

EXPENDITURES AND COMMITMENTS - CY 1977 CUMULATIVE ACTIVITY - A graphic presentation, showing planned CY 1977 expenditures and commitments by months. This graph will be the basis of monthly reports.

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL STATUS REPORT
(in thousands)

As of: November 1, 1976

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|
| | | Allocation to Date | | | | Outlook | | | |
| 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 | 11,832 | 11,635 | 197 | 16,028 | 15,144 | 26,779 | 1,081 | |
| Antennas | 20,400 | 13,230 | 13,172 | 58 | 7,170 | 8,694 | 21,866 | (1,466) | |
| Electronics | 17,000 | 7,280 | 6,782 | 498 | 9,720 | 10,372 | 17,154 | (154) | |
| Computer | 4,850 | 2,529 | 2,339 | 190 | 2,321 | 3,187 | 5,526 | (676) | |
| Systems Integration | 400 | 139 | 111 | 28 | 261 | 150 | 261 | 139 | |
| Program Management | 2,650 | 1,569 | 1,478 | 91 | 1,081 | 490 | 1,968 | 682 | |
| Common Cost | - | - | - | - | - | 2,071 | 2,071 | (2,071) | |
| Subtotal | 73,160 | 36,579 | 35,517 | 1,062 | 36,581 | 40,108 | 75,625 | (2,465) | |
| Contingency | 2,840 | 122 | - | 122 | 2,718 | 2,527 | 2,527 | 313 | |
| TOTAL | 76,000 | 36,701 | 35,517 | 1,184 | 39,299 | 42,635 | 78,152 | (2,152) | |

Notes: (1) Basic estimate is that of August, 1976.

(2) Escalation included for future years for Site and Wye work (6%); National Radio Astronomy Observatory labor (6%); and certain antenna equipment items (6½%). Antenna estimate is based on the existing contract costs for fabrication of the antennas. No future escalation has been included for electronics or computer purchased equipment except for certain mechanical elements in the Electronic estimate (6%).

(3) Estimate excludes the following deferred item: Airstrip, $268K. Transporter #3 is not included within the estimated cost of the Program.

(4) Includes $293K withheld by NSF for land acquisition under Site/Wye and $15.7K withheld by NSF for ECAC under Electronics. These amounts were funded directly to the Corps of Engineers and ECAC.



Figure 8

NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA PROGRAM

VLA - FINANCIAL STATUS REPORT
As of: November 01, 1976

EXPLANATION TO ACCOMPANYING STATEMENT

Column (2) - Program Ceiling: Original estimates.

Column (3) - Allocated: Funded by NSF and included in total funds provided in Contract C-780.

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) - Estimated Total: Column (4) plus Column (7).

Column (9) - (Over) Under: Column (2) less Column (8).

NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA PROGRAM

## ESTIMATED COST - DESIGN AND CONSTRUCTION ON 11/01/76

(IN THOUSANDS)

| ITEM | CEILING | ESTIMATE 8/1975 | ESTIMATE 8/1976 | CHANGE 1975 vs. 1976 |
|---|---|---|---|---|
| SITE AND WYE | $27,860 | $27,811 | $26,779 | - 1,032 |
| ANTENNA SYSTEMS | 20,400 | 21,396 | 21,866 | + 470 |
| ELECTRONIC SYSTEMS | 17,000 | 17,226 | 17,154 | - 72 |
| COMPUTER SYSTEMS | 4,850 | 5,245 | 5,526 | + 281 |
| SYSTEMS INTEGRATION | 400 | 368 | 261 | - 107 |
| PROGRAM MANAGEMENT | 2,650 | 2,877 | 1,968 | - 909 |
| COMMON COST | - | - | 2,071 | + 2,071 |
| SUBTOTAL | $73,160 | $74,923 | $75,625 | + 702 |
| CONTINGENCY/RESERVE | 2,840 | 3,200 | 2,527 | - 673 |
| TOTAL PROGRAM | $76,000 | $78,123 | $78,152 | + 29 |
| EXCLUDES DEFERRED ITEMS - TRANSPORTERS #2 AND #3 | | 615 | TRANSP. #2 INC. ABOVE | |
| AIRSTRIP | | 268 | 268 | |



Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COST ESTIMATE - 11/01/76
(in thousands)

| | 3-5-13-12.4-13 Funding 1976 Program Plan 12/01/75 | 3-5-13-12.4-16-12.5-13 Funding PROGRAM 1976 BASE | COST ESCALATION | ESTIMATE TOTAL |
|---|---|---|---|---|
| ANTENNA SYSTEM | | | | |
| Antenna Element Design | 225 | 225 | - | 225 |
| Prototype Antennas | 1,624 | 1,624 | - | 1,624 |
| Production Antennas | 17,527 | 17,228 | 55 | 17,283 |
| Transporter Design | 83 | 83 | - | 83 |
| Transporter Prototype | 365 | 375 | - | 375 |
| Transporter Production Model | - | 525 | - | 525 |
| Assembly Structure | 397 | 403 | - | 403 |
| E.D.I.A. | 1,175 | 1,282 | 66 | 1,348 |
| TOTAL | 21,396 | 21,745 | 121 | 21,866 |
| ELECTRONIC SYSTEMS DEVELOPMENT | | | | |
| Feed System | 161 | 153 | - | 153 |
| Front End System | 281 | 329 | - | 329 |
| Local Oscillator System | 97 | 100 | - | 100 |
| Monitor/Control System | 93 | 85 | - | 85 |
| Waveguide System | 278 | 297 | - | 297 |
| IF Transmission System | 243 | 234 | - | 234 |
| Delay/Multiplier System | 22 | 21 | - | 21 |
| Spectral Processor | 25 | 127 | - | 127 |
| General Electronics | 13 | 13 | - | 13 |
| E.D.I.A. | 447 | 535 | 27 | 562 |
| SUBTOTAL DEVELOPMENT | 1,660 | 1,894 | 27 | 1,921 |



Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COST ESTIMATE - 11/01/76
(in thousands)

| | 3-5-13-12.4-13 Funding 1976 Program Plan 12/01/75 | 3-5-13-12.4-16-12.5-13 Funding PROGRAM 1976 BASE | COST ESCALATION | ESTIMATE TOTAL |
|---|---|---|---|---|
| ELECTRONIC SYSTEMS PRODUCTION | | | | |
| Feed System | 1,858 | 1,461 | 105 | 1,566 |
| Front End System | 2,989 | 2,842 | 108 | 2,950 |
| Local Oscillator System | 979 | 887 | - | 887 |
| Monitor/Control System | 654 | 601 | 18 | 619 |
| Waveguide System | 404 | 456 | 28 | 484 |
| IF Transmission System | 1,245 | 1,300 | - | 1,300 |
| Delay/Multiplier System | 799 | 320 | - | 320 |
| Spectral Processor | 1,310 | 1,236 | - | 1,236 |
| General Electronics | 1,498 | 1,444 | 45 | 1,489 |
| E.D.I.A. | 3,830 | 4,153 | 213 | 4,366 |
| SUBTOTAL PRODUCTION | 15,566 | 14,700 | 517 | 15,217 |
| TOTAL ELECTRONIC SYSTEMS | 17,226 | 16,594 | 544 | 17,138 |
| SITE FACILITIES AND WYE | | | | |
| Site Acquisition | 293 | - | - | - |
| Preliminary Design | 225 | 225 | - | 225 |
| Detailed Design | 513 | 507 | 3 | 510 |
| Construction Supervision | 217 | 163 | 12 | 175 |
| Survey/Soils | 301 | 332 | 8 | 340 |
| Construction Site Preparation | 104 | 76 | 2 | 78 |
| Computer/Site Trailers | 40 | 40 | - | 40 |
| Archaeological Preservation | - | 100 | - | 100 |
| Construction Facilities | 232 | 156 | - | 156 |



Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COST ESTIMATE - 11/01/76
(in thousands)

| | 3-5-13-12.4-13 Funding 1976 Program Plan 12/01/75 | 3-5-13-12.4-16-12.5-13 Funding PROGRAM 1976 BASE | COST ESCALATION | ESTIMATE TOTAL |
|---|---|---|---|---|
| SITE FACILITIES AND WYE (continued) | | | | |
| Equipment/Maintenance Vehicles | - | 122 | - | 122 |
| Building Complex | 2,358 | 2,274 | - | 2,274 |
| Site Work/Utilities | 1,152 | 857 | - | 857 |
| Wye Construction | 14,359 | 12,400 | 1,195 | 13,595 |
| Waveguide Procurement | 5,011 | 4,656 | 449 | 5,105 |
| Waveguide Installation | 1,587 | 1,356 | 131 | 1,487 |
| Waveguide Antenna Stations | 665 | 665 | 64 | 729 |
| E.D.I.A. | 754 | 667 | 26 | 693 |
| TOTAL | 27,811 | 24,596 | 1,890 | 26,486 |
| COMPUTER SYSTEMS | | | | |
| Synchronous Subsystem | 697 | 486 | - | 486 |
| Continuum Asynchronous Subsystem | 965 | 1,029 | - | 1,029 |
| Display I/O Equipment | 265 | 286 | - | 286 |
| Spectral Line Computing Equipment | 1,100 | 1,815 | - | 1,815 |
| Computer Maintenance | 315 | 200 | - | 200 |
| E.D.I.A. | 1,903 | 1,635 | 75 | 1,710 |
| TOTAL | 5,245 | 5,451 | 75 | 5,526 |



Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COST ESTIMATE - 11/01/76
(in thousands)

| | 3-5-13-12.4-13 Funding 1976 Program Plan 12/01/75 | 3-5-13-12.4-16-12.5-13 Funding PROGRAM 1976 BASE | COST ESCALATION | ESTIMATE TOTAL |
|---|---|---|---|---|
| SYSTEMS INTEGRATION | | | | |
| Personnel Costs | 148 | 148 | 5 | 153 |
| Material, Services, Supplies | 150 | 81 | - | 81 |
| Travel | 70 | 27 | - | 27 |
| TOTAL | 368 | 256 | 5 | 261 |
| PROGRAM MANAGEMENT | | | | |
| Personnel Costs | 1,406 | 1,173 | 49 | 1,222 |
| Material, Services, Supplies | 1,321 | 609 | - | 609 |
| Travel | 150 | 137 | - | 137 |
| TOTAL | 2,877 | 1,919 | 49 | 1,968 |
| CONTINGENCY/RESERVE | 3,200 | 2,527 | - | 2,527 |
| COMMON COST | - | 1,713 | 358 | 2,071 |
| SUBTOTAL PROGRAM | 78,123 | 74,801 | 3,042 | 77,843 |
| Add cost for ECAC Study ($16) and Land Acquisition ($293) | | | | |
| FUNDED DIRECTLY BY NSF | Inc. Above | 309 | - | 309 |
| TOTAL PROGRAM | 78,123 | 75,110 | 3,042 | 78,152 |



Figure 9

NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA PROGRAM

BUDGET ANALYSIS BY PROGRAM YEAR

(in thousands)

Current (Escalated) Dollars


08/31/76
10/01/76
11/01/76 Final

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | Total Current | Total Base | Escalation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SITE/WYE | 964 | 875 | 4,924 | 5,067 | 2,488 | 3,541 | 8,223 | 404 | 26,486 | 24,596 | 1,890 |
| ANTENNA SYSTEMS | 315 | 2,453 | 2,740 | 7,721 | 3,908 | 4,170 | 468 | 91 | 21,866 | 21,745 | 121 |
| ELECTRONIC SYSTEMS | 816 | 1,460 | 2,292 | 2,691 | 3,633 | 2,822 | 2,316 | 1,108 | 17,138 | 16,594 | 544 |
| COMPUTER SYSTEMS | 29 | 415 | 1,365 | 720 | 1,020 | 1,084 | 805 | 88 | 5,526 | 5,451 | 75 |
| SYSTEMS INTEGRATION | - | - | 46 | 93 | 82 | 40 | - | - | 261 | 256 | 5 |
| PROGRAM MANAGEMENT | 158 | 236 | 500 | 672 | 100 | 112 | 108 | 82 | 1,968 | 1,919 | 49 |
| COMMON COST | - | - | - | - | 691 | 631 | 450 | 299 | 2,071 | 1,713 | 358 |
| SUBTOTAL | 2,282 | 5,439 | 11,867 | 16,964 | 11,922 | 12,400 | 12,370 | 2,072 | 75,316 | 72,274 | 3,042 |
| CONTINGENCY | - | - | 27 | 122 | 578 | 600 | 630 | 570 | 2,527 | 2,527 | - |
| SUBTOTAL | 2,282 | 5,439 | 11,894 | 17,086 | 12,500 | 13,000 | 13,000 | 2,642 | 77,843 | 74,801 | 3,042 |
| Add for cost of ECAC study (16) and Land Acquisition (293) funded directly by NSF and not carried in NRAO costs | | | | | | | | | 309 | 309 | 0 |
| | | | | | | | | | $78,152 | $75,110 | $3,042 |



Figure 10

NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA PROGRAM

SUMMARY OF CONSTRUCTION/OPERATING BUDGETS
(in thousands)

Current (Escalated) Dollars

| | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| CONSTRUCTION: | | | | | | | | | |
| Site/Wye Task I & V | 964 | 875 | 4,924 | 5,067 | 2,488 | 3,541 | 8,223 | 404 | 26,486 |
| Antenna Task II | 315 | 2,453 | 2,740 | 7,721 | 3,908 | 4,170 | 468 | 91 | 21,866 |
| Electronics Task III | 816 | 1,460 | 2,292 | 2,691 | 3,633 | 2,822 | 2,316 | 1,108 | 17,138 |
| Computer Task IV | 29 | 415 | 1,365 | 720 | 1,020 | 1,084 | 805 | 88 | 5,526 |
| Systems Integration Task VI | - | - | 46 | 93 | 82 | 40 | - | - | 261 |
| Program Management Task VII | 158 | 236 | 500 | 672 | 100 | 112 | 108 | 82 | 1,968 |
| Contingency | - | - | 27 | 122 | 578 | 600 | 600 | 600 | 2,527 |
| Common Cost | - | - | - | - | 691 | 631 | 450 | 299 | 2,071 |
| Subtotal Construction | 2,282 | 5,439 | 11,894 | 17,086 | 12,500 | 13,000 | 13,000 | 2,642 | 77,843* |
| OPERATIONS: | | | | | | | | | |
| Site Operations | - | - | - | - | - | 8 | 181 | 228 | 417 |
| Data Processing | - | - | - | - | 75 | 180 | 190 | 201 | 646 |
| Array Operations | - | - | - | - | 57 | 133 | 158 | 167 | 515 |
| Electronic Maintenance | - | - | - | - | 72 | 132 | 407 | 557 | 1,168 |
| Antenna Maintenance | - | - | - | - | 27 | 95 | 101 | 169 | 392 |
| Subtotal Salary | - | - | - | - | 231 | 548 | 1,037 | 1,322 | 3,138 |
| Benefits | - | - | - | - | 50 | 120 | 232 | 303 | 705 |
| Travel | - | - | - | - | 7 | 17 | 35 | 48 | 107 |
| Misc. Material, Services, Supplies | - | - | - | - | 150 | 173 | 350 | 430 | 1,103 |
| Operating Equipment - New | - | - | - | - | 10 | - | 30 | 37 | 77 |
| Spares | - | - | - | 100 | 117 | - | 123 | 272 | 612 |
| Common Cost | - | - | - | - | 135 | 342 | 683 | 948 | 2,108 |
| Subtotal Operations | - | - | - | 100 | 700 | 1,200 | 2,490 | 3,360 | 7,850 |
| GRAND TOTALS | 2,282 | 5,439 | 11,894 | 17,186 | 13,200 | 14,200 | 15,490 | 6,002 | 85,693 |

*Does not include $293K withheld by NSF for Land Acquisition under Site/Wye and $15.7 withheld by NSF for ECAC under Electronics.



Figure 11

NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA PROGRAM

SUMMARY OF COMMON COST BUDGET

11/01/76

CY 1977 - CY 1980

(in thousands)

| | | 1977 | 1978 | 1979 | 1980 | TOTAL |
|---|---|---|---|---|---|---|
| 18100 | Transportation | 47 | 51 | 55 | 59 | 212 |
| 18300 | Utilities | 170 | 235 | 275 | 330 | 1,010 |
| 18910 | Salary/Wages | 345 | 392 | 471 | 497 | 1,705 |
| 18920 | Benefits | 74 | 86 | 105 | 114 | 379 |
| 18930 | Travel | 15 | 17 | 19 | 21 | 72 |
| 18940 | Material, Services, Supplies | 165 | 181 | 196 | 211 | 753 |
| 18950 | New Equipment | 10 | 11 | 12 | 15 | 48 |
| | TOTAL COMMON COST | 826 | 973 | 1,133 | 1,247 | 4,179 |



Figure 12

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COMMITMENT SCHEDULE - CY 1973 THROUGH CY 1980
(in thousands)

11/01/76

| | CY 1973 through CY 1976 | 1977 | 1978 | 1979 | 1980 | TOTAL |
|---|---|---|---|---|---|---|
| Site/Wye | 11,830 | 2,488 | 3,541 | 8,223 | 404 | 26,486 |
| Antenna Systems | 13,229 | 3,908 | 4,170 | 468 | 91 | 21,866 |
| Electronic Systems | 7,259 | 3,633 | 2,822 | 2,316 | 1,108 | 17,138 |
| Computer Systems | 2,529 | 1,020 | 1,084 | 805 | 88 | 5,526 |
| Systems Integration | 139 | 82 | 40 | - | - | 261 |
| Program Management | 1,566 | 100 | 112 | 108 | 82 | 1,968 |
| Common Cost | - | 691 | 631 | 450 | 299 | 2,071 |
| Contingency/Reserve | 149 | 578 | 600 | 630 | 570 | 2,527 |
| PROGRAM TOTAL | 36,701 (1) (2) | 12,500 | 13,000 | 13,000 | 2,642 | 77,843 |

Notes:

(1) Actual through 09/30/76; estimated through 12/31/76.

(2) Does not include $293K for Site acquisition funded directly to Corps of Engineers and $15.7 for ECAC Study funded directly by NSF.



Figure 13

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

EXPENDITURE SCHEDULE - CY 1973 THROUGH CY 1981
(in thousands)

11/01/76

| | CY 1973 through CY 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | TOTAL |
|---|---|---|---|---|---|---|---|
| Site/Wye | 10,856 | 3,082 | 3,490 | 7,702 | 1,207 | 149 | 26,486 |
| Antenna Systems | 11,942 | 4,624 | 4,219 | 881 | 200 | - | 21,866 |
| Electronic Systems | 6,461 | 3,844 | 2,779 | 2,371 | 1,113 | 570 | 17,138 |
| Computer Systems | 2,301 | 1,111 | 1,087 | 939 | 88 | - | 5,526 |
| Systems Integration | 132 | 84 | 45 | - | - | - | 261 |
| Program Management | 1,488 | 169 | 114 | 111 | 86 | - | 1,968 |
| Common Cost | - | 691 | 631 | 450 | 299 | - | 2,071 |
| Contingency/Reserve | - | 727 | 600 | 600 | 600 | - | 2,527 |
| PROGRAM TOTAL | 33,180 (1) (2) | 14,332 | 12,965 | 13,054 | 3,593 | 719 | 77,843 |

Notes:

(1) Actual through 09/30/76; estimated through 12/31/76.

(2) Does not include $293 for Site acquisition funded directly to Corps of Engineers and $15.7 for ECAC Study funded directly by NSF.



Figure 14

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1977
11/01/76

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | PLAN CY-1976 | PLAN CY-1977 |
|---|---|---|---|---|---|---|
| TASK I & V SITE FACILITIES/WYE | | | | | | |
| Site Acquisition | - | - | - | - | - | - |
| Preliminary Design | 225 | 225 | - | - | - | - |
| Detailed Design | 510 | 443 | 30 | - | 10 | 12 |
| Construction Supervision | 175 | - | 30 | 51 | 48 | 10 |
| Survey/Soils | 340 | 223 | 4 | 34 | 18 | 20 |
| Construction Site Preparation | 78 | 15 | 33 | 8 | 6 | 5 |
| Construction Facilities | 156 | - | - | 141 | 10 | - |
| Construction Equipment | 122 | - | - | 16 | 61 | 45 |
| Computer/Site Trailers | 40 | - | - | 36 | 2 | 1 |
| Archaeological Preservation | 100 | - | - | - | - | - |
| Building Complex | 2,274 | - | - | 1,814 | 392 | 31 |
| Site Work/Utilities | 857 | - | - | 615 | 50 | 82 |
| Wye Construction | 13,595 | - | 616 | 837 | 3,591 | 1,449 |
| Waveguide Procurement | 5,105 | - | 60 | 1,114 | 410 | 372 |
| Waveguide Installation | 1,487 | - | - | 116 | 171 | 275 |
| Waveguide Antenna Stations | 729 | - | - | - | 147 | 110 |
| E.D.I.A. | 693 | 58 | 102 | 142 | 151 | 76 |
| TOTAL SITE FACILITIES/WYE | 26,486 | 964 | 875 | 4,924 | 5,067 | 2,488 |



Figure 15

FINANCIAL PLAN - CY 1977
11/01/76

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | PLAN CY-1976 | PLAN CY-1977 |
|---|---|---|---|---|---|---|
| TASK IV SYSTEMS INTEGRATION | | | | | | |
| Personnel Costs | 153 | - | - | 33 | 57 | 46 |
| Materials, Supplies, Services | 81 | - | - | 6 | 30 | 25 |
| Travel | 27 | - | - | 7 | 6 | 11 |
| TOTAL SYSTEMS INTEGRATION | 261 | - | - | 46 | 93 | 82 |
| TASK II ANTENNA SYSTEM | | | | | | |
| Antenna Element Design | 225 | 225 | - | - | - | - |
| Prototype Antennas | 1,624 | - | 1,623 | - | - | - |
| Production Models | 17,283 | - | - | 2,455 | 7,462 | 3,615 |
| Transporter Design | 83 | - | 83 | - | - | - |
| Transporter Prototype | 375 | - | 311 | 5 | 24 | 25 |
| Transporter Production Models | 525 | - | - | - | - | - |
| Assembly Structure | 403 | - | 312 | 86 | 5 | - |
| E.D.I.A. | 1,348 | 90 | 124 | 194 | 230 | 268 |
| TOTAL ANTENNA SYSTEM | 21,866 | 315 | 2,453 | 2,740 | 7,721 | 3,908 |



Figure 15

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1977
11/01/76

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | PLAN CY-1976 | PLAN CY-1977 |
|---|---|---|---|---|---|---|
| TASK III ELECTRONIC SYSTEMS DEVELOPMENT | | | | | | |
| Feed System | 153 | - | 80 | - | 55 | 17 |
| Front End System | 329 | 96 | 64 | 81 | 30 | 47 |
| Local Oscillator System | 100 | 33 | 20 | 4 | 18 | 15 |
| Monitor/Control System | 85 | 74 | 9 | 2 | - | - |
| Waveguide System | 297 | 83 | 11 | 32 | 90 | 51 |
| IF Transmission System | 234 | 63 | 32 | 94 | 25 | 20 |
| Delay/Multiplier System | 21 | 7 | 14 | - | - | - |
| Spectral Processor | 127 | - | - | 4 | 40 | 83 |
| General Electronics | 13 | - | 13 | - | - | - |
| E.D.I.A. | 562 | 188 | 117 | 109 | 127 | 76 |
| SUBTOTAL - DEVELOPMENT | 1,921 | 544 | 360 | 326 | 385 | 309 |
| TASK III ELECTRONIC SYSTEMS PRODUCTION | | | | | | |
| Feed System | 1,566 | - | 105 | 36 | 371 | 293 |
| Front End System | 2,950 | - | 214 | 384 | 367 | 529 |
| Local Oscillator System | 887 | - | 80 | 118 | 136 | 268 |
| Monitor/Control System | 619 | - | 15 | 85 | 73 | 188 |
| Waveguide System | 484 | 46 | 28 | 21 | 97 | 81 |
| IF Transmission System | 1,300 | - | 103 | 289 | 187 | 236 |
| Delay/Multiplier System | 320 | 24 | 62 | 122 | 38 | 19 |
| Spectral Processor | 1,236 | - | - | - | 40 | 617 |
| General Electronics | 1,489 | 108 | 135 | 254 | 234 | 272 |
| E.D.I.A. | 4,366 | 94 | 358 | 657 | 763 | 821 |
| SUBTOTAL - PRODUCTION | 15,217 | 272 | 1,100 | 1,966 | 2,306 | 3,324 |
| TOTAL ELECTRONIC SYSTEMS | 17,138 | 816 | 1,460 | 2,292 | 2,691 | 3,633 |



Figure 15

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

FINANCIAL PLAN - CY 1977
11/01/76

| | ESTIMATE | ACTUAL CY-1973 | ACTUAL CY-1974 | ACTUAL CY-1975 | PLAN CY-1976 | PLAN CY-1977 |
|---|---|---|---|---|---|---|
| TASK IV COMPUTER SYSTEM | | | | | | |
| Synchronous Subsystem | 486 | - | 248 | - | 21 | 155 |
| Continuum Asynchronous Subsystem | 1,029 | - | - | 923 | 16 | 90 |
| Display I/O Equipment | 286 | - | - | 34 | 113 | 100 |
| Spectral Line Computing Equipment | 1,815 | - | - | - | 95 | 320 |
| Computer Maintenance | 200 | - | - | 71 | 83 | 23 |
| E.D.I.A. | 1,710 | 29 | 167 | 337 | 392 | 332 |
| TOTAL COMPUTER SYSTEM | 5,526 | 29 | 415 | 1,365 | 720 | 1,020 |
| TASK VIII PROGRAM MANAGEMENT | | | | | | |
| Personnel Costs | 1,222 | 128 | 178 | 248 | 321 | 85 |
| Materials, Supplies, Services | 609 | 17 | 35 | 216 | 20 | 2 |
| Travel | 137 | 13 | 23 | 36 | 331 | 13 |
| TOTAL PROGRAM MANAGEMENT | 1,968 | 158 | 236 | 500 | 672 | 100 |
| Contingency/Reserve | 2,527 | - | - | 27 | 122 | 578 |
| Common Cost | 2,071 | - | - | - | - | 691 |
| TOTAL PROGRAM | 77,843 | 2,282 | 5,439 | 11,894 | 17,086 | 12,500 |



Figure 15

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

COMMITMENT/EXPENDITURE SCHEDULE BY QUARTERS CY-1977
(in thousands)

11/01/76

| | 1st QUARTER | | 2nd QUARTER | | 3rd QUARTER | | 4th QUARTER | | TOTAL CY-1977 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | COMMIT. | EXPEND. | COMMIT. | EXPEND. | COMMIT. | EXPEND. | COMMIT. | EXPEND. | COMMIT. | EXPEND. |
| Site/Wye | 2,039 | 1,067 | 202 | 1,176 | 107 | 585 | 140 | 254 | 2,488 | 3,082 |
| Antenna Systems | 3,667 | 1,862 | 81 | 985 | 80 | 953 | 80 | 824 | 3,908 | 4,624 |
| Electronic Systems | 1,163 | 914 | 1,054 | 1,383 | 763 | 1,055 | 653 | 492 | 3,633 | 3,844 |
| Computer | 532 | 205 | 311 | 314 | 89 | 367 | 88 | 225 | 1,020 | 1,111 |
| Systems Integration | 18 | 18 | 28 | 25 | 18 | 27 | 18 | 14 | 82 | 84 |
| Program Management | 25 | 81 | 25 | 38 | 25 | 26 | 25 | 24 | 100 | 169 |
| Common Cost | 229 | 121 | 187 | 162 | 154 | 187 | 121 | 221 | 691 | 691 |
| Contingency/Reserve | - | 149 | 347 | 300 | 231 | 278 | - | - | 578 | 727 |
| Total Planned | 7,673 | | 2,235 | | 1,467 | | 1,125 | | 12,500 | |
| | | 4,417 | | 4,383 | | 3,478 | | 2,054 | | 14,332 |



Figure 16

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY -1976 REVIEW OF FINANCIAL PLAN
(in thousands)

11/01/76

| | | 12/01/75 | 11/01/76 | | Change |
|---|---|---|---|---|---|
| I & V | Site Facilities & Wye | 4,586 | 5,067 | (1) + | 481 |
| II | Antenna Systems | 2,964 | 7,721 | + | 4,757 |
| III | Electronic Systems | 2,762 | 2,691 | - | 71 |
| IV | Computer Systems | 606 | 720 | + | 114 |
| VI | Systems Integration | 171 | 93 | - | 78 |
| VII | Program Management | 635 | 672 | + | 37 |
| | Contingency/Reserve | 676 | 122 | - | 554 |
| | TOTAL PROGRAM | 12,400 | 17,086 | (1) (2) + | 4,686 |

Notes: (1) Does not include $10.0K withheld by NSF and funded directly to Army Corps of Engineers.

(2) Increase resulting from transition quarter funding ($3,500K), increase of CY-1976 funding by NSF ($90K) and carryover of funds from previous years ($1,096K).



Figure 17

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY-1976 REVIEW OF FINANCIAL PLAN
(in thousands)

11/01/76

| TASK I & V - SITE FACILITIES & WYE | 12/01/75 | 11/01/76 | Change | |
|---|---|---|---|---|
| Site Acquisition | - | - | | - |
| Engineering - Preliminary | - | - | | - |
| - Detailed | 12 | 11 | - | 1 (1) |
| Construction Supervision | 24 | 48 | + | 24 (2) |
| Survey/Soils | 16 | 18 | + | 2 (3) |
| Construction Facilities | 26 | 16 | - | 10 (4) |
| Computer/Site Trailers | 7 | 2 | - | 5 (5) |
| Construction Equipment | - | 61 | + | 61 (6) |
| Building Complex | 427 | 392 | - | 35 (7) |
| Site Work/Utilities | 73 | 50 | - | 23 (8) |
| Wye Construction | 3,506 | 3,591 | + | 85 (9) |
| Waveguide Procurement | - | 410 | + | 410 (10) |
| Waveguide Installation | 200 | 170 | - | 30 (11) |
| Waveguide Antenna Stations | 152 | 147 | - | 5 (12) |
| E.D.I.A. | 143 | 151 | + | 8 (13) |
| TOTAL | 4,586 | 5,067 | + | 481 |



Figure 17

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY-1976 REVIEW OF FINANCIAL PLAN
(in thousands)

11/01/76

TASK I & V - SITE FACILITIES & WYE

NOTES:

(1) Required detailed design work accomplished within existing subcontract authorization.

(2) Increase required to cover additional supervision by Joint Venture of Phase III construction.

(3) Increase required to cover reimbursables in conjunction with Joint Venture effort on supervision of Phase III construction.

(4) Allocation reduced after reëvaluation of CY-1976 requirements.

(5) Allocation reduced after reëvaluation of CY-1976 requirements.

(6) Additional requirements that were not estimated in 12/01/75 Program Plan. Includes tracked maintenance vehicles, loader, forklift truck.

(7) Allocation reduced after reëvaluation of CY-1976 requirements.

(8) Allocation reduced after reëvaluation of CY-1976 requirements.

(9) Increase required to cover additional earthwork/drainage and stockpiling effort on relayer rail, ties, and track materials for future wye construction.

(10) Increased to cover option to procure 5,300 meters of waveguide before price increase went into effect.

(11) Allocation reduced after reëvaluation of CY-1976 requirements. Required waveguide installation work for CY-1976 will be accomplished under existing subcontract.

(12) Allocation reduced after reëvaluation of CY-1976 requirements.

(13) Allocation increased to cover the additional personnel service required for a waveguide installation foreman.

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY-1976 REVIEW OF FINANCIAL PLAN
(in thousands)

11/01/76

| | 12/01/75 | 11/01/76 | Change |
|---|---|---|---|
| TASK II - ANTENNA SYSTEMS | | | |
| Production Model Antennas | 2,670 | 7,462 | + 4,792 (1) |
| Field Modifications | - | - | - |
| Assembly Structure | - | 5 | + 5 (2) |
| Transporter Assembly/Test/Modification | 50 | 24 | - 26 (3) |
| E.D.I.A. | 244 | 230 | - 14 (4) |
| TOTAL | 2,964 | 7,721 | + 4,747 |

NOTES:

(1) Reflects the cost of authorizing advance procurement of materials by E-Systems for Antennas 11 - 28.

(2) Reflects increased cost of completing the Antenna Assembly Building.

(3) Allocation reduced after reëvaluation of CY-1976 requirements.

(4) Allocation reduced after reëvaluation of CY-1976 requirements for personnel service and travel.



Figure 17

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY-1976 REVIEW OF FINANCIAL PLAN
(in thousands)

11/01/76

| TASK III - ELECTRONIC SYSTEMS | 12/01/75 | 11/01/76 | Change | |
|---|---|---|---|---|
| General Electronics | 259 | 234 | - 25 | (1) |
| Front End System | 476 | 397 | - 79 | (2) |
| Local Oscillator System | 189 | 154 | - 35 | (3) |
| Waveguide System | 172 | 187 | + 15 | (4) |
| IF Transmission System | 250 | 212 | - 38 | (5) |
| Delay/Multiplier System | 110 | 38 | - 72 | (6) |
| Feed System | 333 | 426 | + 93 | (7) |
| Monitor/Control System | 114 | 73 | - 41 | (8) |
| Spectral Processor | 67 | 80 | + 13 | (9) |
| E.D.I.A. | 792 | 890 | + 98 | (10) |
| TOTAL | 2,762 | 2,691 | - 71 | |

NOTES:
(1) Decrease in required test units for CY-1976 requirements.

(2) Decrease in allocation is a result of system change from 3-stage to 2-stage design on the parametric amplifiers.

(3) Decrease in allocation is a result of system modification to existing L6 and L7 modules, allowing a reduction from four to two per antenna.

(4) Increase required for more extensive test evaluation of waveguide components.

(5) Decrease resulting from reëvaluation of modem development requirements for CY-1976 program.

(6) Decrease resulting from decision to build two IF channels only on first twelve antennas.

(7) Increase resulted from not procuring 18-21 cm feeds for Antennas 2-6, uncommitted carryover reprogrammed in CY-1976 Program.

(8) Decrease resulting from reëvaluation of CY-1976 requirements for Control Room equipment.

(9) Increase required for added CY-1976 program development and evaluation in Spectral Processor, including IF, Delay/Multiplier, and Control/Interface.

(10) Increased to cover additional manpower for Front End group; Local Oscillator group.



Figure 17

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY-1976 REVIEW OF FINANCIAL PLAN
(in thousands)

11/01/76

| | 12/01/75 | 11/01/76 | Change | |
|---|---|---|---|---|
| TASK IV - COMPUTER SYSTEMS | | | | |
| Synchronous Subsystem | 21 | 21 | - | |
| Asynchronous Subsystem | 40 | 140 | + 100 | (1) |
| Display I/O Equipment | 80 | 80 | - | |
| E.D.I.A. | 465 | 479 | + 14 | (2) |
| TOTAL | 606 | 720 | + 114 | |

NOTES: (1) Reflects cost of the optical processor feasibility study.

(2) Reflects increase in estimate to maintain synchronous and asynchronous computer hardware.

| | | | | |
|---|---|---|---|---|
| TASK VI - SYSTEMS INTEGRATION | | | | |
| Personnel Costs | 62 | 57 | - 5 | (1) |
| Materials, Services, Supplies | 71 | 30 | - 41 | (2) |
| Travel | 38 | 6 | - 32 | (3) |
| TOTAL | 171 | 93 | - 78 | |

NOTES: (1) Decrease in allocation is the result of reëvaluation of CY-1976 program requirements.

(2) Decrease in allocation is a result of reëstimate of materials, services, and supplies funds required in Systems Integration CY-1976 Program Plan.

(3) Decrease in allocation is a result of reëstimate of travel funds required in Systems Integration CY-1976 Program Plan.



Figure 17

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLA PROGRAM

CY-1976 REVIEW OF FINANCIAL PLAN
(in thousands)

11/01/76

| | 12/01/75 | 11/01/76 | Change | |
|---|---|---|---|---|
| TASK VIII - PROGRAM MANAGEMENT | | | | |
| Personnel Costs | 294 | 321 | + 27 | (1) |
| Materials, Services, Supplies | 311 | 331 | + 20 | (2) |
| Travel | 30 | 20 | - 10 | (3) |
| TOTAL | 635 | 672 | + 37 | |

NOTES: (1) Reflects increase due to additional manpower requirement for clerk, cook, and cafeteria helper which were not budgeted in the Program Plan at 12/01/75.

(2) Reflects increase due to cafeteria operations requirements which were not budgeted in the Program Plan at 12/01/75.

(3) Decrease in allocation is a result of reëstimate of travel funds required in program management in CY-1976 Program Plan.

| | | | | |
|---|---|---|---|---|
| Contingency/Reserve | 676 | 122 | - 554 | (1) |

NOTES: (1) Decrease in allocation is a result of authorizing advance procurement of materials by E-Systems, Inc. for Antennas 11 - 28.



Figure 17

# EXPENDITURES AND COMMITMENTS
## CY-1976 CUMULATIVE ACTIVITY

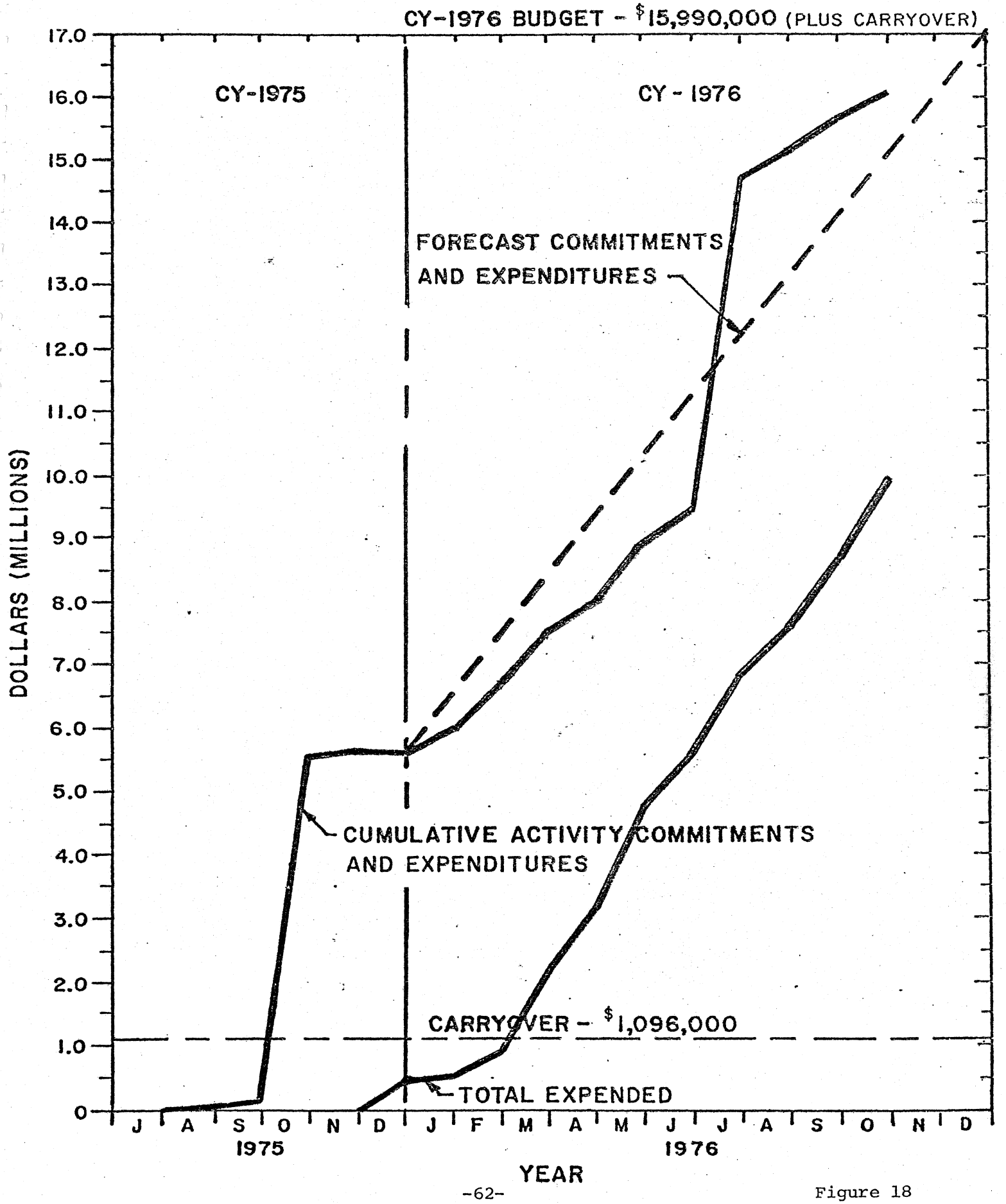





Figure 18

# VLA-NRAO
# PROGRAM REPORT
## EXPENDITURES AND COMMITMENTS
## CY-1977 CUMULATIVE ACTIVITY

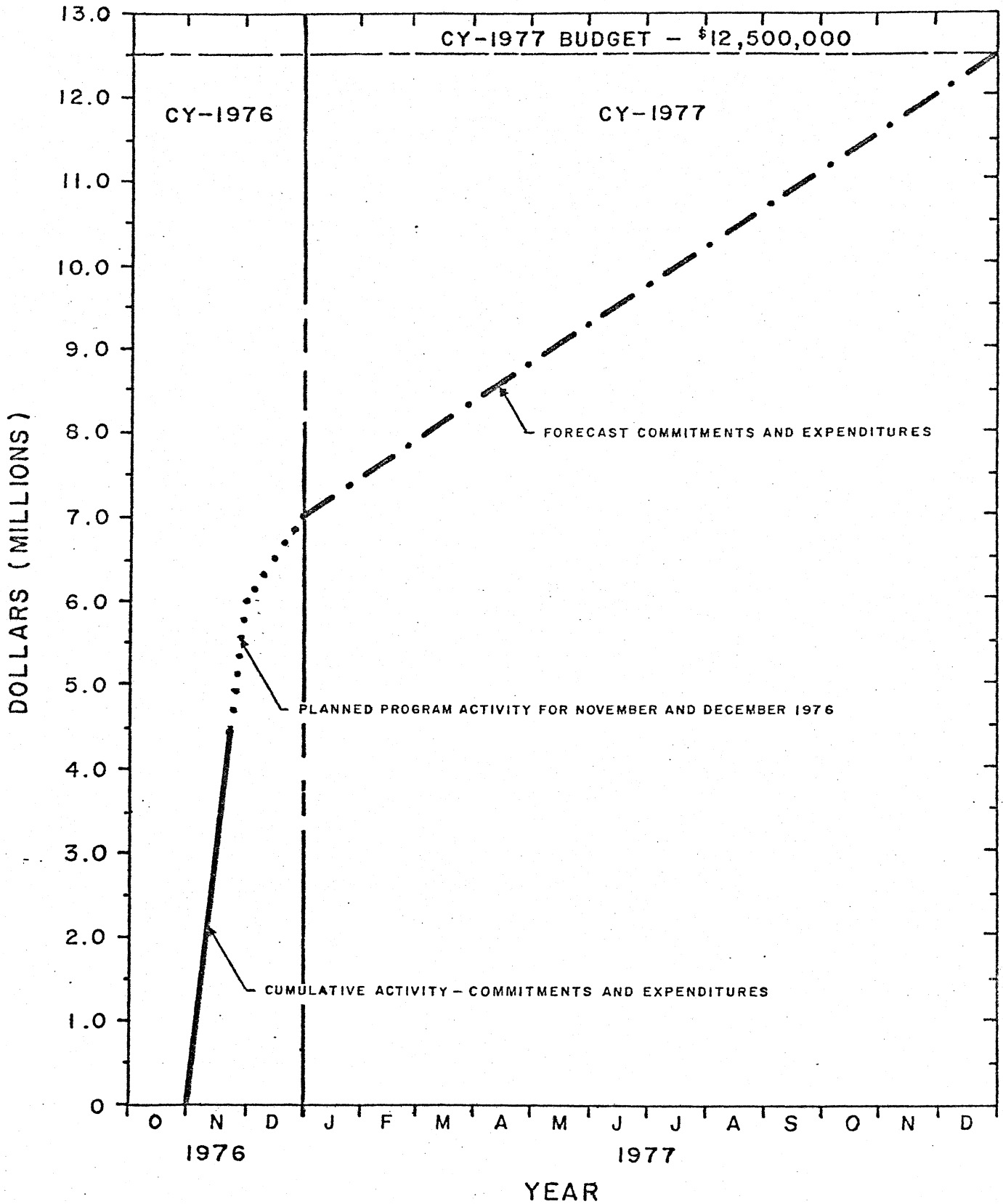





Figure 19

## 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 an assistant to the Program Manager under the supervision of the Deputy Program Manager through the use of detailed bar schedules for the outfitting of each antenna. In Charlottesville, for the fabrication of the electronic components, PERT is still being used for scheduling and procurement purposes. There is attached, as Figure 20, a summary sheet for the 1976 fabrication of electronic modules, racks and bins. The computer is also being used to gather data on the myriads of 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 21 a VLA ACTIVITY SCHEDULE Bar Chart dated 11/15/76, which is time-scaled to provide a concise, overall view of the entire Program. 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.

NATIONAL RADIO ASTRONOMY OBSERVATORY
CYCLE CODE BAR CHART

PROGRAM 15NOV76 REPORT DATE. ELECTRONICS – MODULES, RACKS ELC002 RUN DATE 18NOV76
PROJECT VLA ELECTRONICS MODULES, RACKS, BINS FOR 1976(1) 06SEP75 EL0076

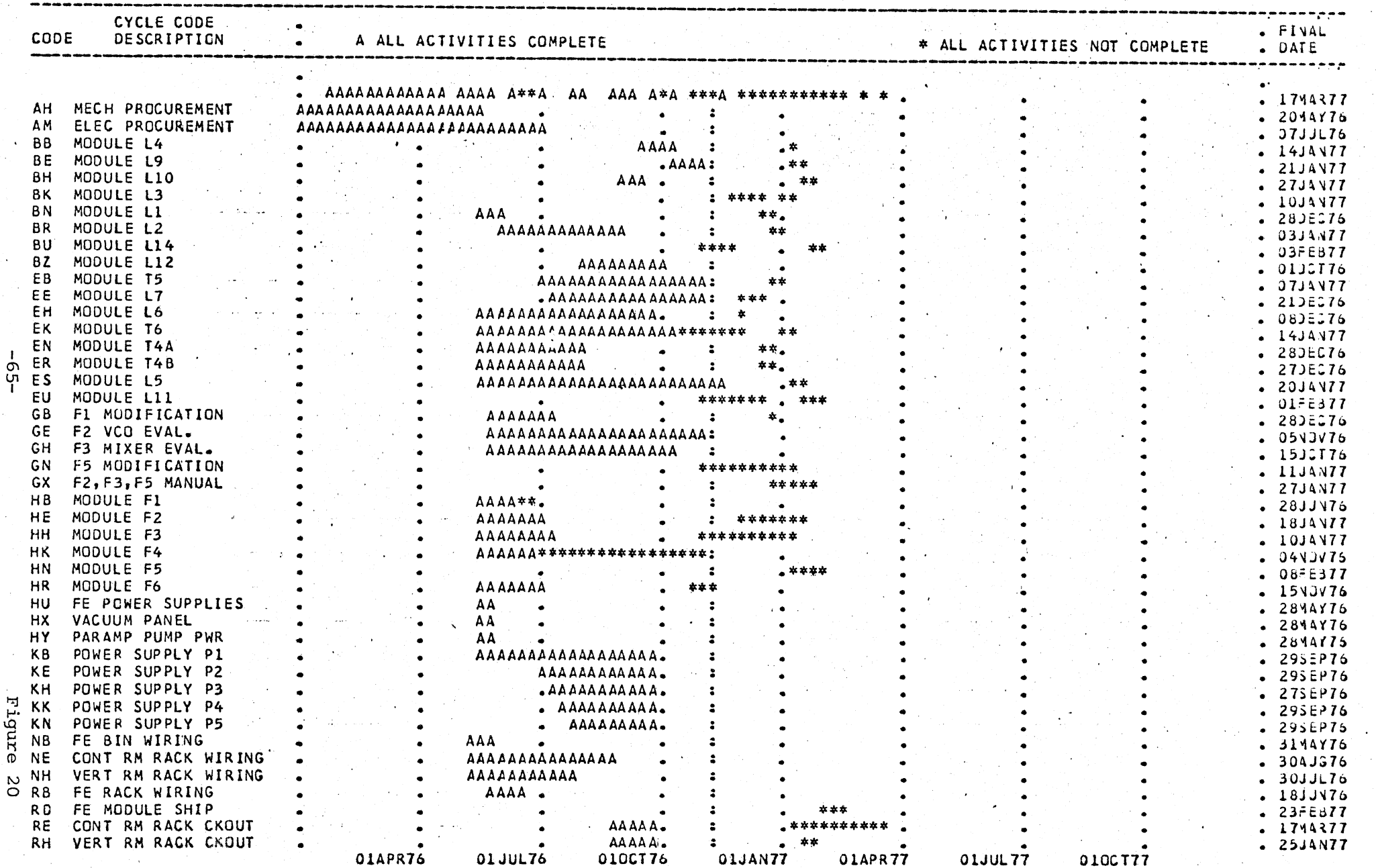




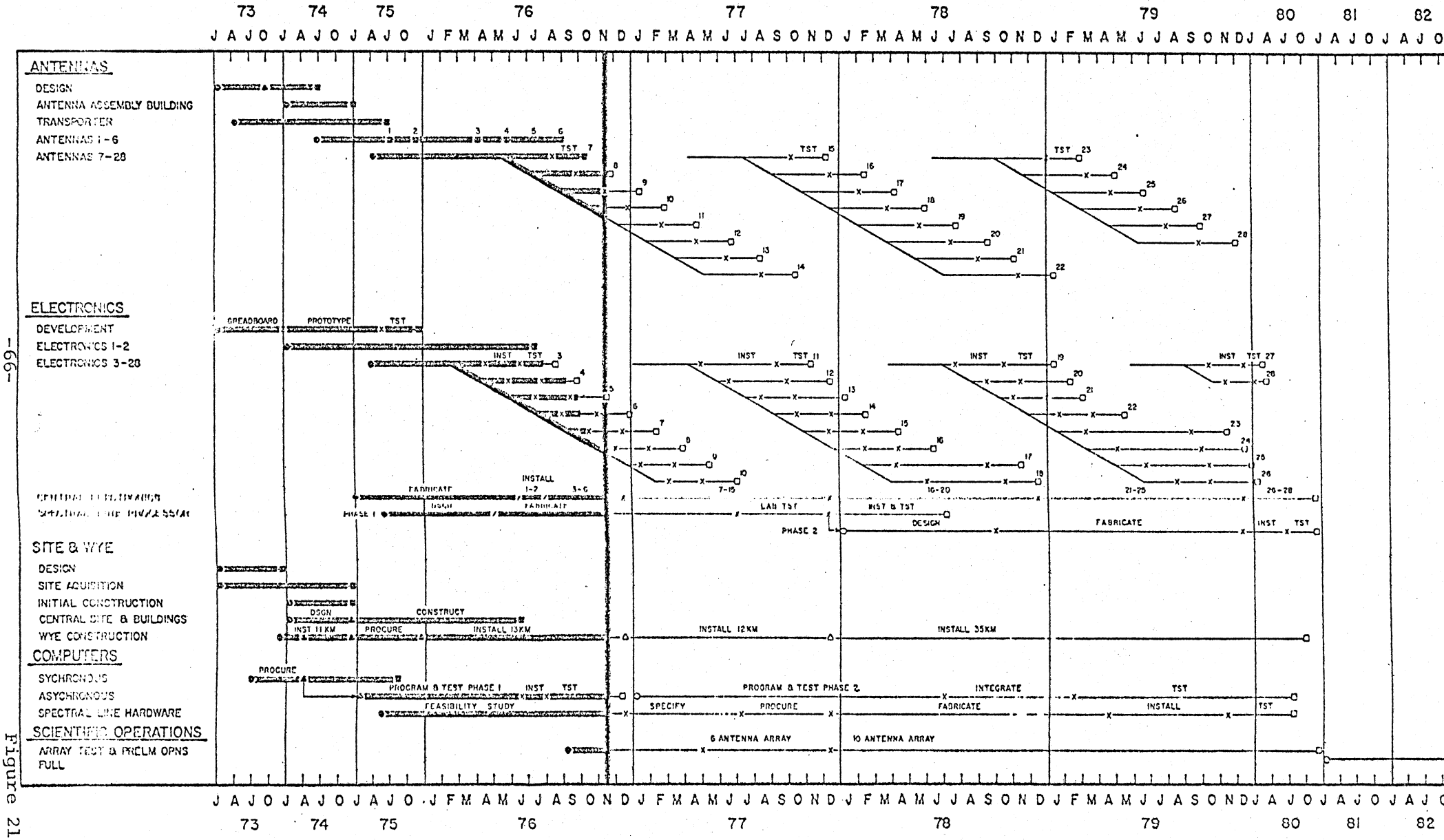

Figure 20

NATIONAL RADIO ASTRONOMY OBSERVATORY

# VLA ACTIVITY SCHEDULE

11/15/76

UPDATE DATE: 11/15/76




SYMBOLS

- O START OF A PHASE
- X END OF AN ACTIVITY
- Δ CONTRACT AWARD
- □ END OF A PHASE

ABBREVIATIONS

- DSGN - DESIGN
- LAB - LABORATORY
- TST - TEST
- PRELM - PRELIMINARY

| REV. NO. | REV. DATE | REVISION |
|---|---|---|
| | | |
| | | |
| | | |

Figure 21

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 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:

| | |
|---|---|
| E. J. Blum | Meuden Observatory |
| R. D. Ekers | Kapteyn Laboratory |
| W. A. Fowler | California Institute of Technology |
| C. E. Heiles | University of California, Berkeley |
| F. J. Kerr | University of Maryland |
| V. C. Rubin | Carnegie Institution of Washington |
| E. E. Salpeter | Cornell University |
| 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:

| | |
|---|---|
| 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 |
| F. O. Clark | University of Kentucky |
| T. A. Clark | NASA - Goddard Space Center |
| J. J. Condon | Virginia Polytechnic Institute |
| M. M. Davis | Arecibo Observatory |
| W. A. Dent | University of Massachusetts |
| J. R. Dickel | University of Illinois |
| J. N. Douglas | University of Texas, Austin |
| F. D. Drake | Cornell University |
| W. C. Erickson | University of Maryland |
| S. J. Goldstein | University of Virginia |
| C. E. Heiles | University of California, Berkeley |
| D. R. Johnson | National Bureau of Standards |
| F. J. Kerr | University of Maryland |
| G. R. Knapp | California Institute of Technology |
| H. C. Ko | Ohio State University |
| M. R. Kundu | University of Maryland |
| A. E. Lilley | Harvard University |
| C. H. Mayer | U. S. Naval Research Laboratory |
| P. Palmer | University of Chicago |
| K. W. Riegel | University of California, Los Angeles |
| A. G. Smith | University of Florida |

| | |
|---|---|
| L. E. Snyder | University of Illinois Observatory |
| P. Solomon | State University of New York (Stony Brook) |
| G. W. Swenson | University of Illinois |
| J. H. Taylor | University of Massachusetts |
| P. Thaddeus | Institute for Space Studies of New York |
| G. L. Verschuur | University of Colorado |
| J. F. C. Wardle | Brandeis University |
| J. W. Warwick | University of Colorado |
| G. Westerhout | University of Maryland |
| D. R. W. Williams | University of California, Berkeley |
| R. W. Wilson | Bell Telephone Laboratories |
| W. J. Wilson | University of Texas, Austin |
| 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 also advise on the 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 also made 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. 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 |
| 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, etc. 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. L. Brown | D. E. Hogg |
| W. R. Burns | H. Hvatum |
| B. G. Clark | J. H. Lancaster |
| L. R. D'Addario | P. J. Napier |
| E. B. Fomalont | F. N. Owen |
| E. W. Greisen | L. Rudnick |
| D. S. Heeschen | A. R. Thompson |
| V. Herrero | N. Vandenberg |
| R. M. Hjellming | C. M. Wade |