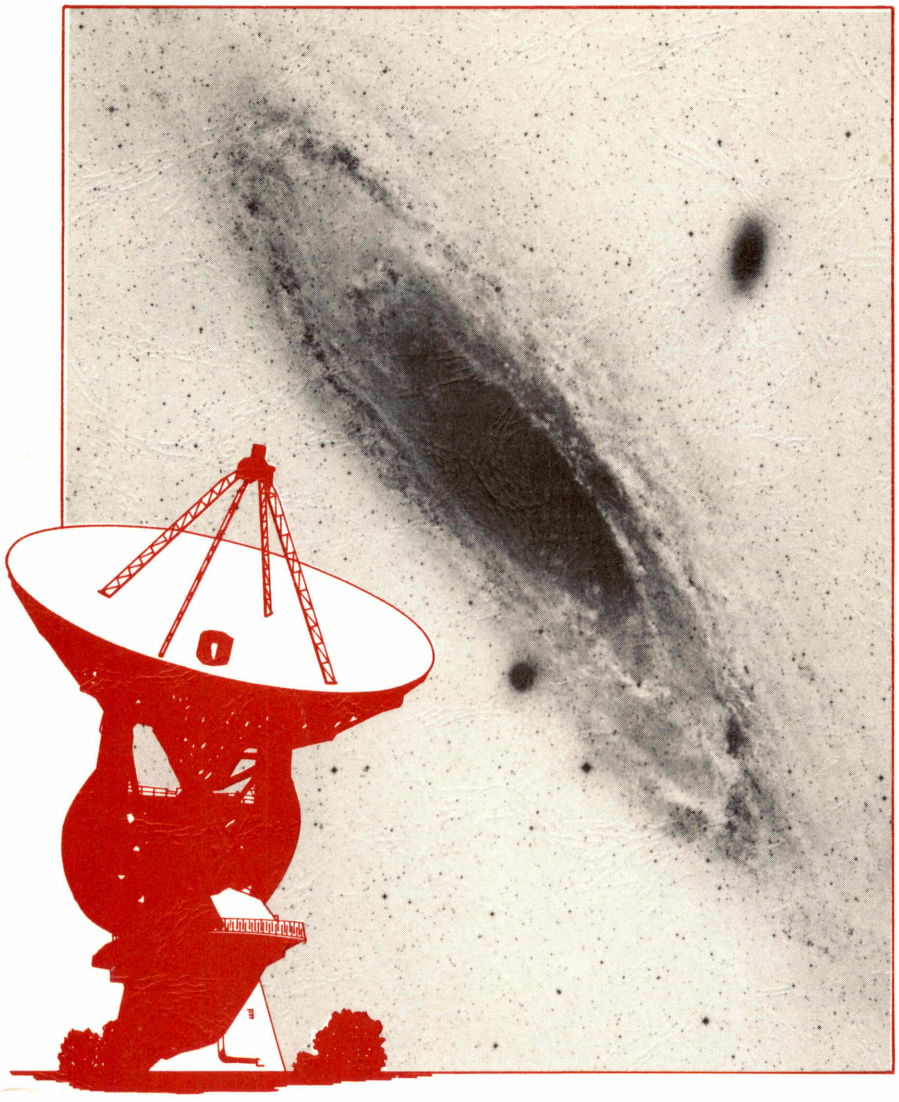
NATIONAL RADIO ASTRONOMY OBSERVATORY



PROGRAM PLAN 1979

NATIONAL RADIO ASTRONOMY OBSERVATORY

CALENDAR YEAR 1979 PROGRAM PLAN

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NATIONAL RADIO ASTRONOMY OBSERVATORY

CALENDAR YEAR 1979 PROGRAM PLAN

I. INTRODUCTION

The National Radio Astronomy Observatory is funded by the National Science Foundation under a management contract with Associated Universities, Inc. The role of the Observatory as a center for basic research in radio astronomy is implemented both by the operation of its major telescope systems and by research and development in the fields of advanced electronics and data processing systems.

During this year the available time on the completed portion of the VLA will be under heavy observing pressure, as an increasing number of scientists begin to use it in their research. The operation of the three single dishes--the 36-foot millimeter wavelength telescope, the 140-foot telescope, and the 300-foot meridian transit telescope--will continue. The research planned for this period by the NRAO permanent staff and the visiting investigators is summarized in the following section. More than 60 percent of the observing time required for this research will be used by visiting investigators.

Section III of the Plan presents a program for the development of new research instrumentation for use on the telescopes. Particular emphasis this year is placed on the development of techniques and devices to be used at frequencies above 120 GHz, and on the continuation of the construction of low-noise systems for Green Bank. An investigation of various techniques that will be useful in the analysis of radio maps (VLA, VLBI, or single-dish line data) will be continued.

Subsequent sections give the detail of the expenditures required for operations and maintenance of the Observatory. A summary of the allocation of funds is given in Section IX, the Financial Plan.

Appendices to this Plan include a summary of the scientific program of the NRAO permanent staff, a list of the staff and their principal research interests, an organizational chart for the NRAO, and a list of the various committees associated with the NRAO.

II. SCIENTIFIC PROGRAM

Since proposals for the use of the NRAO telescopes will be received throughout 1979, it is not possible to describe the scientific program in complete detail. However, the proposals in hand span a wide range of investigations and are undoubtedly typical of the observations that will be made. Perhaps the most useful summary is one made by instrument, although a number of the programs request time on more than one telescope.

The VLA - Even though the VLA is only partially completed, it has commanded wide interest in the community and is already heavily oversubscribed. Its capability will grow markedly during 1979, as the number of antennas available for scientific programs increases from twelve to twenty, and as the maximum baselines along the two southern arms are increased to 17 km. Some observations with the VLA have already been made of strong H_2O and OH maser sources, using a bandwidth of 1.5 MHz; tests of the multichannel spectral-line system will be made towards the end of the year.

Solar system work planned includes studies of most of the planets, a number of their satellites, and of the sun, the latter in coordination with the Solar Maximum Mission beginning in October, 1979. The VLA has proven to be very powerful in the study of radio stars, x-ray sources, and stellar envelopes, where it can reach very low flux density levels without fear of confusion. The high positional accuracy which can be achieved will be exploited in the identification of stellar radio sources, in the measurement of parallax and proper motion of the stronger radio stars, and in the search for expansion of novae and supernovae shells.

The pressure for time to map the distribution of the Stokes' parameters of the radio emission from selected radio galaxies is very great. Observers in this field have been encouraged by the high quality of some of the early maps. For example, the detail found in the inner regions of the head-tail galaxy NGC 1265 has placed serious constraints on the mechanism by which energy can be transmitted outwards from the active nucleus, and a preliminary map of M87 (Virgo A) shows that the radio jet breaks up into small condensations coincident with the features seen optically.

The 36-ft Telescope - An increasing number of proposals deal with the general morphology of the interstellar medium. The recently discovered large molecular clouds appear to be sufficiently numerous to influence the dynamics of the stellar population in the galaxy. Studies will address such questions as the mass of these clouds, and the lifetimes and dynamics of them. Interstellar chemistry is still of wide interest, and attempts will be made to detect ring molecules. There is some discouragement about the apparent complexity of the chemical reactions which must be occurring; the search for

small free radicals such as C_2H may be a promising avenue. A number of investigations will attempt to determine if there are significant differences in isotope ratio from one region of the galaxy to another.

Continuum observations will likely concentrate on compact extragalactic objects, both to monitor selected objects for time variability as well as to determine the millimeter wavelength spectrum, for comparison with data from longer wavelength, infrared, and optical observations.

The 140-ft Telescope - This telescope continues to be attractive for a wide range of problems, and the advent of the new maser-based receivers will stimulate even greater interest. The requests for galactic line work are the most numerous, and include studies of neutral hydrogen and CH in the galactic center, measurements of OH in stellar envelopes, formaldehyde observations in dark clouds made in an attempt to estimate the physical conditions in the clouds as well as to measure the abundances of carbon and oxygen isotopes, and various studies of heavy molecules including the long chain molecules HC_nN. Some work on neutral hydrogen and OH in external galaxies is planned.

Approximately twenty-five percent of the observing time on this telescope will be used for Very Long Baseline (VLBI) programs. Continuum observations will concentrate on mapping of superluminal sources, on the study of compact components in normal and radio galaxies, and on astrometric and geodetic measurements. Line observations will attempt to follow up the suggestion that compact HII regions exhibit Zeeman pairs of "hot spots".

Continuum work with the 140-ft will primarily be directed towards mapping of the larger galactic sources. One particularly interesting extragalactic program will be the attempt to detect the diminution of the background radiation as it passes through the intergalactic medium in x-ray clusters of galaxies.

The 300-ft Telescope - This telescope is particularly well suited to surveys or to studies of a large number of selected objects, since in these cases the limitation imposed by the fact that the 300-ft is a transit instrument is of lesser importance. It is also useful to note that with the current 6-cm receiver, the telescope is confusion limited, at a level of about 5 mJy, in one transit.

Active continuum programs include completion of a pulsar survey in the northern sky, searches for variable galactic sources, monitoring the variation of flux density of extragalactic sources, mapping the faint extended structure in radio galaxies, and a survey of the properties of galaxies in selected clusters of galaxies. The number-flux density relationship for faint sources is being developed both from direct counts and from

an analysis of the probability of a given deflection in a confusion limited survey.

Line work envisioned for the next year includes extensive surveys of neutral hydrogen in selected types of galaxies and studies of the distribution of faint hydrogen features, especially those at high velocity, in our own Galaxy. Some observations of hydrogen at large redshifts (found in absorption against extragalactic continuum sources) will be undertaken, but the peak in activity in this subfield has, for the moment, passed.

All proposals for telescope time, whether by visitor or staff, are sent for evaluation to referees who are not on the NRAO staff. The programs that are run on the telescopes represent the best of the proposals. It is anticipated that approximately 300 visitors will use the NRAO telescopes during 1979.

The program of the NRAO staff, which comprises about thirty percent of the total program, is described in greater detail in Appendix A.

III. RESEARCH INSTRUMENTS

The research instruments at the National Radio Astronomy Observatory consist of (1) the 140-foot telescope; (2) the 300-foot telescope; (3) the 36-foot telescope; and (4) the Very Large Array. At this time the bulk of the program of new instrumentation is in support of the first three telescopes. The VLA, still under construction, requires little equipment money at this point, although in the future it will become a major factor in this budget.

The CY 1979 program for new instrumentation has three categories, with budget allocations as follows (in thousands of dollars):

Item 1.	Other Observing Equipment.....	780
Item 2.	Research Equipment.....	219
Item 3.	Test Equipment.....	35
	Total.....	1034

The estimated funds for research instruments will provide auxiliary instrumentation and equipment to maintain and improve the capabilities of the telescopes, including new systems development and modifications and upgrading of existing systems. The ability of the NRAO to maintain an active research and development program in electronic and computer hardware is essential if the Observatory is to continue in its role as the nation's principal center for research in radio astronomy. Because of rapid and unpredictable changes in "state-of-the-art" electronics hardware and unforeseen

short notice requirements of the scientific community, it is desirable that flexibility within the general area of the program be maintained. The following table shows the planned distribution of funds for the "Other Observing Equipment" account. The NRAO continually updates this table as scientific priorities change. These estimates provide funds for the completion of already started projects, new development, and funds for items of continuing and general development.

Item

1. Other Observing Equipment (in thousands of dollars)

	Estimate to Complete (k$)	Estimate New Development (k$)	Estimate Continued Development (k$)
140-foot Telescope			
Maser, upconverter system			120
Autocorrelator	10		
40-50 GHz maser/maser development			20
300-foot Telescope			
300-foot low-noise system			45
Traveling feed	10		
36-foot Telescope			
130-170/200-230 GHz receiver			50
Varactor downconverter			40
Millimeter tube development		100	
1-3 mm bolometer		40	
Other			
VLA map processor			90
VLBI			75
Diode and Josephson development			65
Computer equipment		115	
Subtotal	20	255	505
Total			780

A. Other Observing Equipment: Items to Complete

The items expected to be completed in 1979 include:

1. 1024-Channel Autocorrelator. The present 413-channel autocorrelator at the 140-foot telescope is one of the most heavily used instruments at NRAO. It will be replaced with a unit providing 20 percent more sensitivity (through three-level quantization), 2.5 times more channels, and a larger bandwidth. This autocorrelator will be available for use by mid-1979.

2. Traveling Feed. An improved traveling feed assembly for the 300-foot telescope will be installed which will be capable of supporting the new cryogenic cooled receivers.

B. Other Observing Equipment: New Development Items

The following new items are planned for 1979:

1. Millimeter Tube Development. This will cover development of backward wave oscillator tubes for atmospheric windows above 130 GHz. To be used as local oscillators for fundamental mixers to 390 GHz.

2. 1-3 mm Bolometer Receiver. One millimeter and three millimeter bolometer receiver for 36-foot telescope. Bolometer will be cooled to 0.36 K using ^{3}He.

3. Computer Equipment. Covers Calcomp plotter and Modcomp for Charlottesville for processing single-dish data.

C. Other Observing Equipment: Continuing Development Items

1. Maser, Upconverter System for the 140-Foot Telescope. There will be continued development of a dual-channel upconverter-maser system giving very low noise temperature covering the frequency range 5-25 GHz.

2. 40-50 GHz Maser. There will be continuing maser development; initial plans are for a maser covering 40-50 GHz.

3. 300-Foot Low-Noise Systems. A dual-channel upconverter-maser system giving low-noise performance in the frequency range 1000-5000 MHz will be started. A second upconverter-FET system will give low-noise coverage at 300-1000 MHz.

4. 130-170/200-230 GHz Receiver. This receiver will cover 130-170/200-230 GHz frequency ranges with cooled resistive mixers.

5. Varactor Downconverter. Tests will be made on a varactor downconverter from 80-120 GHz frequency range to 25 GHz, which will give

considerable improvement in noise temperature for millimeter wavelength observations at the 36-foot telescope.

6. VLA Map-Processor. Further work will be done on a VLA map-processor to enable observers to analyze VLA data.

7. VLBI. The plan includes the continuing development of Mark III VLBI recording terminals.

8. Diode and Josephson Junction. Development work on Schottky diodes and Josephson junctions will continue. Both these developments are important for further improvements of millimeter receivers.

2. Electronic Research Equipment

Items funded under this part of the program are the numerous, smaller experiments and development projects--usually costing less than $10k each. These funds are made available in response to visitor and staff requests for minor modifications to existing observing equipment and relatively inexpensive "off-the-shelf" new items.

3. Electronic Test Equipment

These funds are used to add to and update the Observatory's general bank of test equipment for use in the laboratories and also for monitoring and testing the complex observing systems on the telescopes.

Millimeter-Wavelength Instrumentation

The 25-meter millimeter wavelength telescope project has been described in two volumes of a report, the second volume of which was sent to the NSF in July, 1977. The project is now awaiting favorable action by the Foundation. In the meantime, a contract has been awarded for the study of carbon fiber techniques in the fabrication of surface plates. This contract will be completed in 1979. A program of soil samples will be started to provide the data necessary for specifications of the foundations of the astrodome and telescope.

IV. EQUIPMENT

No major equipment acquisitions are planned for 1979. The distribution of funds (in thousands of dollars) in the various equipment accounts is as follows:

Item 1.	Maintenance, Shop and Repair Equipment.....	15.0
Item 2.	Office and Library Furnishings and Equipment..	10.0

Item 3.	Living Quarters Furniture	5.0
Item 4.	Building Equipment	10.0
Item 5.	Scientific Services and Engineering Equipment	15.0
	Total	55.0

Item

1. Maintenance, Shop and Repair Equipment

Funds planned in this account provide for the replacement and/or acquisition of items for the shops at Green Bank, Charlottesville, and Tucson, and for the Green Bank maintenance division. Items included in this account are: tractors and mowers, replacement trucks and other vehicles, machine shop equipment, and several auxiliary items and accessories to be used with existing equipment.

2. Office and Library Furnishings and Equipment

These funds provide for replacement, updating and acquisition of typewriters, adding machines, desk calculators, desks, chairs, and other office furnishings for the Green Bank, Charlottesville, and Tucson sites.

3. Living Quarters Furnishings

These funds provide for replacement of household appliances and furnishings, such as beds, tables, lamps, draperies, carpets, etc., used in the residences at the sites.

4. Building Equipment

These funds provide for items that are generally attached to and become a part of the buildings. Included are such items as small air conditioners, small heating units, water heaters, etc.

5. Scientific Services and Engineering Equipment

These funds provide for small equipment additions in the darkroom, public education, and engineering divisions. Items such as cameras, film processing units, projectors, measuring equipment, etc., are included in this amount.

V. OPERATIONS AND MAINTENANCE

Because the NRAO now has significant operations at four sites, we have found it desirable to adopt a presentation which more clearly reflects the estimated costs of the principal activities at the Observatory. These activities have been grouped into six operations units, as follows:

I. Research Support - This group is composed of the scientific research staff and the students (summer, co-operative, and Ph.D.). As well as undertaking research, the staff assists visiting observers in gaining familiarity with the NRAO telescopes, advises the technical divisions about modifications to equipment or the design of new equipment, and participates in the checkout and calibration of instrumentation.

II. Technical Support and Development - This unit has the general responsibility for the Observatory-wide technical and instrumental programs. The Central Development Laboratory explores new concepts in radiometers, and has provided design support for very long baseline and correlator development. The Computer Division operates the central computer and the VLB MK II processor, and assists in the development of programs for computers at the telescopes. The Engineering Division provides engineering assistance to the operating sites, and undertakes the design of new facilities and telescopes. The Scientific Services Group maintains the central and branch libraries, and provides technical illustration and drafting.

The Materials, Supplies, and Services (MS&S) budgets for the Central Lab, Computer, Engineering, and Scientific Services are 62k, 311k, 90k, and 113k, respectively, with an additional 224k required for personnel benefits.

III. Green Bank Operations - There are five divisions with the responsibility of maintaining and operating the 300-foot telescope, the 140-foot telescope and the four-element interferometer, with developing new instrumentation for the single dishes, and with maintaining the Green Bank site. These divisions, and the 1979 MS&S budgets, are: Telescope Operations (117k); Electronics (139k); Shops (22k); Plant Maintenance (167k); and Administrative Services (128k). An additional 641k is required for personnel benefits, communications, and utilities, and miscellaneous revenue is estimated to amount to 80k.

IV. Tucson Operations - This smaller group maintains and operates the 36-foot millimeter wavelength telescope at Kitt Peak, and develops new instrumentation for the telescopes. An important aspect of the recent work is the effort to obtain state-of-the-art radiometers at 2 millimeters and 1.3 millimeters. The MS&S budgets for this group includes 180k for Operations and Maintenance, 130k for Electronics, and 110k for Personnel Benefits.

V. VLA Operations - This group continues to expand as the array approaches completion. The number of operational antennas by the end of 1979 will be approximately 22, and the number of people in VLA operations will reach 60 by the end of the year. At this year-end period, the array will be making astronomical observations at least 75 percent of the time. The four divisions--Array Operations, Scientific Services, Electronics Maintenance, and Antenna Maintenance--will require MS&S in the amount of 22k, 154k, 87k, and 48k, respectively. An additional 251k is required for personnel benefits, and the Operations's share of common cost is 656k.

VI. General and Administration - Included in this unit are the Director's Office, the Fiscal Office, and the Business Office, with total MS&S budget of 143k. Rent and maintenance of the Charlottesville buildings, including utilities, will require 245k, and 122k is allocated to personnel benefits. The management fee will be 165k subject to current negotiations.

A summary of the CY 1979 budget for these Operation Units is provided in the following table.

CY 1979 Budget--Operation Units
(in thousands of dollars)

	Operation Unit	Salaries and Wages	Materials, Supplies & Services	Travel	Total
I.	Research Support	805	185	150	1140
II.	Technical Support & Development	975	800	45	1820
III.	Green Bank Operations	1875	1134	32	3041
IV.	Tucson Operations	475	420	35	930
V.	VLA Operations	1065	1218	45	2328
VI.	General & Administration	535	675	60	1270
	Total Operations	5730	4432	367	10529

VI. INTERFEROMETER OPERATIONS

Under a Memorandum of Understanding between the National Science Foundation and the U.S. Naval Observatory (dated September 26, 1978), the NRAO will operate the four-element interferometer in Green Bank for a period of one year, beginning October 1, 1978. The agreement may be extended for successive one-year terms at the mutual agreement of the parties.

The costs of this operation are included in the budget summary of Section V, and will total $316,000 for the nine months of 1979. Of this approximately $161,000 will be required for salaries and benefits of employees associated with this operation.

VII. CONSTRUCTION

The construction of the Very Large Array (VLA) will continue in 1979 with new funds in the amount of $11,500,000. A detailed description of this program will be found in the VLA Project Plan submitted separately.

VIII. PERSONNEL

Personnel Services and Benefits (Level = Full-Time at December 31).

	1978			1979		
Category	Level	Salaries	Benefits	Level	Salaries	Benefits
Operations						
Scientific & Engineering	63	1,574,100	337,600	79	2,111,000	485,600
Technical	89	1,366,400	293,000	102	1,589,000	365,500
Administrative & Clerical	60	1,166,200	250,100	58	1,231,000	283,100
Operations & Maintenance	46	638,800	137,000	59	799,000	183,800
Total Operations	258	4,745,500	1,017,700	298	5,730,000	1,318,000
VLA Common Costs	31	365,500	87,800	32	407,000	95,000
VLA Construction	63	1,023,100	209,200	44	812,000	191,000
Total Personnel	352	6,134,100	1,314,700	374	6,949,000	1,604,000

The Personnel Levels shown for 1979 include ten persons directly associated with Interferometer Operations.

The major part of the increase in level arises in VLA Operations, where the staff will grow from 34 to 60. Eight positions will be filled by scientists and engineers, while the remaining six are for electronic technicians and other support staff.

IX. PRELIMINARY FINANCIAL PLAN - 1979

(in thousands of dollars)

	(a) Actual Exp. 1978	(b) Comm. Carried to 1979	(c) Uncomm. Funds Carried to 1979	(d) New Funds 1979	(e) Available for Exp. & Comm. (b,c,d) 1979
I. SCIENTIFIC RESEARCH					
A. Operations †					
Personnel Compensation	$ 4,745.5			$ 5,730.0	$ 5,730.0
Personnel Benefits	1,017.7			1,318.0	1,318.0
Travel - Domestic	331.3			332.0	332.0
Travel - Foreign	30.3			35.0	35.0
Other Materials, Supplies & Services	2,324.5	$ 250.0	$ 43.0	2,906.0	3,199.0
Management Fee	165.0			165.0	165.0
Subtotal	$ 8,614.3	$ 250.0	$ 43.0	$10,486.0	$10,779.0
B. Equipment					
Research Equipment	$ 854.9	$ 450.0	$ 254.0	780.0	1,484.0
Operating Equipment	389.9	5.0	5.0	50.0	60.0
Subtotal	$ 1,244.8	$ 455.0	$ 259.0	$ 830.0	$ 1,544.0
TOTAL - SCIENTIFIC RESEARCH	$ 9,859.1	$ 705.0	$ 302.0	$11,316.0	$12,323.0
II. CONSTRUCTION					
Very Large Array	$ 7,796.2	$10,429.3*	$(2,350.0)*	$11,500.0	$19,579.3
TOTAL - CONSTRUCTION	$ 7,796.2	$10,429.3	$(2,350.0)	$11,500.0	$19,579.3
TOTAL	$17,655.3	$11,134.3	$(2,048.0)	$22,816.0	$31,902.3

* $3.7M of the CY 1979 VLA funds were made available in CY 1978, and commitments were made against these funds.

† Includes additional funding for operation of the interferometer for the USNO of $105k in CY 1978 and $316k in CY 1979.

Note: This is a preliminary plan based on estimated 1978 figures. The final Financial Plan, reflecting actual year-end figures, will be submitted early in 1979.

NRAO OPERATIONS - 1979
(in thousands of dollars)

	(a) Actual Exp. 1978	(b) Comm. Carried to 1979	(c) Uncomm. Funds Carried to 1979	(d) New Funds 1979	Available for Exp. & Comm. (b,c,d) 1979
I. SCIENTIFIC RESEARCH					
A. Operations †					
1. Excluding VLA					
Personnel Compensation	$4,189.0	-	-	$ 4,665.0	$ 4,665.0
Personnel Benefits	901.3	-	-	1,067.0	1,067.0
Travel	333.7	-	-	322.0	322.0
Other Materials, Supplies & Services	1,797.7	$225.0	$ 15.0	1,967.0	2,207.0
Management Fee	165.0	-	-	165.0	165.0
Subtotal	$7,386.7	$225.0	$ 15.0	$ 8,186.0	$ 8,426.0
2. VLA Only					
Personnel Compensation	$ 556.5	-	-	$ 1,065.0	$ 1,065.0
Personnel Benefits	116.4	-	-	251.0	251.0
Travel	27.9	-	-	45.0	45.0
Other Materials, Supplies & Services	219.9	$ 15.0	$ (1.6)	311.0	324.4
Common Costs	306.9	10.0	29.6	628.0	667.6
Subtotal	$1,227.6	$ 25.0	$ 28.0	$ 2,300.0	$ 2,353.0
TOTAL OPERATIONS	$8,614.3	$250.0	$ 43.0	$10,486.0	$10,779.0

† Includes additional funding for operation of the interferometer for the USNO of $105k in CY 1978 and $316k in CY 1979.

APPENDIX A

RESEARCH PROGRAMS OF THE NRAO SCIENTIFIC STAFF

The permanent staff at the NRAO has planned for 1979 to work in a number of research areas, as described below. Some of the research will be done in collaboration with visiting scientists.

A. GALACTIC STUDIES

1. The Structure of the Milky Way and the Galactic Center

A study will be made of the $^{12}C^{34}S$ and $^{13}C^{32}S$ emission in sources covering a range of galactocentric radii, in order to investigate the variation of $^{12}C/^{13}C$. Additional observations will be made to confirm the tentative detection of C ≡ CD and it, with other deuterated molecules, will be used to explore whether the apparently low deuterium-to-hydrogen ratio in the galactic center can be explained solely by chemical effects or if it has cosmological implications.

An analysis of a 120-point map of CH in the galactic center will be made in terms of current models (tilted spinning disks) of the central region. The molecular cloud in Sgr B2 will be analyzed using data from HNCO, CH_3CN, OH, HC_3N, and NH_3 observations. Continuum work on Sgr A will include VLA maps of the object as well as VLBI measurements at short wavelengths, the latter with a view towards separating the actual structure of the source from the effects of interstellar broadening.

A number of avenues in the study of the interstellar medium are being followed. The NAIC telescope will be used to study the occurrence and distribution of OH in dense self-absorbed HI clouds that appear to represent the transition phase between fully atomic and fully molecular clouds. Of particular interest is the distribution and excitation of OH in the Taurus Molecular Complex, the unusual region in which the heavy cyanopolyyne molecues (HC_nN) have been discovered. HI profiles obtained with the NRAO line interferometer in the direction of extragalactic sources seen through the Galactic plane will be used to estimate the Galactic velocity field at large Galactocentric distances. In an attempt to obtain estimates of the magnetic field in dense interstellar matter, the structure in the radio continuum seen toward isolated interstellar clouds will be analyzed, and theoretical models will be developed. Finally, CO observations will be undertaken to establish the size spectrum of molecular clouds.

2. HII Regions, Infrared Sources, and Planetary Nebulae

A VLBI experiment to synthesize the OH emission from four star-forming (HII) region regions, W3(OH), W75(N), W75(S), and ON1, is presently underway.

This experiment would extend the results of the first OH synthesis project which was highly successful. These observations should yield new and exciting information on star formation, magnetic fields, and maser processes. These regions will also be mapped using the VLA. Initial results on one source, W75N, suggest a strong correlation between the position and structure of the masers and the HII regions. These observations should provide strong constraints on models of masers and the formation of massive stars.

Theoretical work on the formation and transfer of radio recombination lines in HII regions will be continued. The temperatures of HII regions will be measured by comparing the widths of hydrogen and helium recombination lines, a procedure which is independent of line intensity.

The VLA will be used to study the angular sizes and to determine the positions of the OH masers associated with IR stars. Past attempts to conduct this experiment with VLBI techniques demonstrated that baselines from 10-50 km are required to map the OH maser emission.

High-resolution maps of four planetary nebula have been made at 6 cm using the VLA, and will be compared in detail with optical observations made in various forbidden and permitted emission lines. The goal is to determine the nature of the absorbing matter within and surrounding the nebulae and to improve our understanding of the physical conditions within the nebulae. The program to measure continuum fluxes of planetaries at millimeter wavelengths will continue, and will be extended to include lower frequencies.

Twenty-four evolved stellar objects have now revealed CO and other molecules. These comprise mostly carbon-rich stars. Analysis of this data is being made with a view of consolidating the picture that most red giant stars with large mass loss rates are carbon-rich, and that these stars evolve into planetary nebulae. Emphasis will be placed on the photochemistry of these objects.

3. Radio Stars, Pulsars, Novae, and Supernovae

It is expected that the VLA will be used in conjunction with satellite observations in the study of radio stars. A search will be made for radio counterparts of SAS-3 x-ray sources. Observations of RS CVn stars will be made with the IUE satellite, in an attempt to correlate changes in the appearance of intense ultraviolet resonance lines with simultaneous changes in the radio emission from these stars. A theoretical investigation of stellar winds with application to thermally emitting star "shells" and other radio stars will be made.

A number of novae are now known to be radio sources. Sufficient data exist to begin the analysis and model fitting for the radio light curves of

the novae HR Delphini, FH Serpentis, and V1500 Cygni. Monitoring of the radio light curve of nova NQ Vulpecula will continue.

There are theoretical reasons for believing that as pulsars age and spin down the magnetic and rotational axes become aligned. Thus one might expect a class of long period, large duty cycle pulsars to exist. The possibility that some of the steep spectrum, compact radio sources discovered in low-frequency surveys are in fact this type of pulsar will be investigated. Roughly two hundred candidates have been selected from the literature.

The long series of measurements of the flux of Cas A at frequencies near 1400 MHz will be continued, and the accuracy will be improved by using a two-element interferometer. From studies of the radio structure and HI absorption, an attempt will be made to determine the nature of several compact radio sources that are possibly associated with supernova remnants.

An investigation of turbulent, stochastic, and geometric models for the acceleration of cosmic rays will be started.

4. Molecular Line Studies

The VLA has been successfully used in continuum mode to detect and measure accurate positions of OH masers detected in the Green Bank survey. Analysis of this data is underway. Observations with the 140-ft telescope will be made to confirm the tentative detection of maser emission from a new rotationally-excited state of OH. Studies, including polarization, will continue of a new quasi-thermal excited-state absorption source, first detected at 5 cm.

Searches will be undertaken for silylethene (H_2CSi) for which new laboratory measures are available, and for vibrationally-excited ammonia, for which recent laboratory results suggests an identification with a U-line. Detailed calculations of the millimeter-wave spectra of SiN and SiO^+ have been made, and searches for these are planned. Analysis of the interstellar chemistry of CH in terms of a survey of CH in many regions of the galaxy will be made.

Detailed computer programs have been written to predict accurate millimeter-wavelength spectra for several hundred laboratory-measured molecular species which may be relevant astrophysically. Attempts to identify the $\sim$120 U-lines observed in the past four years are nearly completed, with reasonably secure identifications of half a dozen new species. Collaboration with laboratory spectroscopists is planned.

B. EXTRAGALACTIC STUDIES

1. Normal Galaxies

Although a considerable amount of work is planned in the traditional field of extragalactic hydrogen, especially with regard to hydrogen satellites and bridges, there is growing interest in the study of molecules in external galaxies. Studies using CO will include completion of maps of the distribution of CO in M51 and M83, which will be correlated with a variety of other data (radio and optical), and of NGC 253, NGC 6946, and IC 342. Searches will be made for new CO emitters (including a follow-up of two tentative detections) and for ^{13}CO emission.

An attempt to detect and measure the position of the OH maser in M82 has been made with the VLA. If analysis yields useful information, other such masers in other galaxies will be observed with the VLA. Searches for OH emission from galaxies with nuclear continuum sources, using the NAIC telescope, will be continued, and the tentative detection of NGC 660 will be re-examined. A survey of intense OH maser emission in nearby, hydrogen-rich galaxies will be initiated, in an attempt to investigate the correlation of the stellar formation rate with gas content in low mass galaxies. HCO^+ will also be of importance, in the study of the variation of the average cosmic ray densities within and among galaxies.

Continuum work on spiral galaxies will concentrate on the nuclei of these objects, and will include not only VLBI and VLA maps but millimeter observations as well. The program on elliptical galaxies will include regular observations at several wavelengths to determine the continuum spectrum, which is variable in several of these objects, and observations of their structure. The object of the study is to try and understand the nature and physics of the radio emitting properties of these galaxies and how they fit in the general picture of extragalactic radio sources.

Work will continue on the development of 3-dimensional finite-size-particle hydrodynamic codes in order to explore the early evolution of protogalaxies, in particular the effect of early conditions upon the final rotation curve.

2. Radio Galaxies and Quasars

A three-part program will be started to study the variability of extragalactic sources. The program entails the investigation of very short time-scale variability (< 1 day) of a small number of sources by observations with the VLA and/or the 36-ft telescope; the investigation of short time-scale variability (1-30 days) of the same sources by frequent observations with the 300-ft telescope; and the study of a complete sample of sources

drawn from the 5 GHz strong source surveys done a few years ago at Green Bank. This will involve observations with the 300-ft telescope to determine which sources are variable, the amplitudes and time scales of the variability and then an attempt to relate the variability characteristics to other source characteristics. In another program, the KPNO 2-m telescope will be used to monitor the optical variability of selected radio sources.

Detailed studies of the spectra of compact sources over a wide range of radio wavelengths, in coordination with optical and infrared observations, will be continued. For several of the sources observed so far, it appears that a single emission mechanism is responsible for the emission in the different regimes. There is little, if any, nonrelativistic component to the electron distribution. Other spectra appear to be consistent with models of inhomogeneous synchrotron sources, and the inhomogeneity parameters are what would be expected of a wind. Other models, in which the energetic electron spectrum is a relativistic Maxwellian (rather than a power law) also appear in agreement with the observations for many sources.

Observations will be made of selected Area 57 which is near the north galactic pole, with the VLA at 21 cm. Since carefully studied deep plates are available for this region, deeper identifications of faint radio sources should be possible in this region with existing data than in any other. Accurate positions for sources with flat radio spectra found in a recent 6-cm survey with the 300-ft telescope will be determined. These data, along with data from the Texas 365-MHz survey, are being used to identify the sources from the 6-cm survey. This study and associated optical work at McDonald Observatory should allow the properties of weak sources with flat radio spectra to be studied in detail.

General studies of source structure and polarization will primarily be done with the VLA. Radio jets are currently of great interest and sources such as NGC 7385 and M87 (Virgo A) will be observed in order to study the relationship of optical jets and knots to the radio emission from these sources. From these data it may be possible to learn more about the role of the magnetic field and thermal plasma in the creation and evolution of the jets. The galaxy NGC 4374 will be studied for evidence that it is in a binary orbit with M87. Searches will be made for compact nuclear components in 3C sources and for radio emission coincident with optical features in extended extragalactic radio sources. The initial goal is to determine the emission mechanisms in the two-frequency domains. The work with the VLBI on compact objects in radio galaxies and on quasars will be continued, and, at the other end of the angular scale, the 300-ft telescope will be used to search for large radio galaxies, similar to NGC 315, among the sources included in the Jodrell Bank survey.

A number of 4C sources lying outside clusters of galaxies have been mapped. The associated optical fields will be examined to determine the

density of nearby galaxies, since this was recently shown to be important for the morphology of 3C sources.

Active x-ray galaxies will be studied, including an attempt to confirm a suggested eight-day periodicity in the radio emission of Centaurus A by using the VLA. This result has important implications for the central powerhouse, as well as the mechanism for generating the X-radiation. The x-ray galaxy III Zw2 is now undergoing an exceptionally strong radio event, and the evolution of its spectrum will be monitored. Conversely, a number of strong millimeter sources will be observed with the HEAO-B satellite to search for soft x-rays produced by the inverse Compton effect.

A program designed to detect the relative proper motion of a close pair of QSO's will be conducted. An initial study using the NRAO 140-ft telescope and the Bonn 100-m antenna will investigate the ultimate accuracy of differential VLBI position work for two objects separated by only 33 arcseconds on the sky. If the expected accuracy of better than 10^{-4} arcsec in relative position is achieved, such observations carried out over some years may provide a significant test of the cosmological intepretation of redshift distances.

An investigation will be made of the number and distribution of radio sources in the 1-10 mJy level by means of confusion-limited statistical deflection (P(D)) observations.

Theoretical studies of the origin of the relativistic particles in radio sources are considering several possibilities. The evidence for *in situ* acceleration of these particles is being evaluated. Alternatively, it is possible that the absence of spectral steepening in extended extragalactic sources is due to particle resupply from a low pitch angle "reservoir" This model would eliminate the necessity for exotic mechanisms for particle reacceleration. The theory of charged particle transport in a stochastic magnetic field is being used to investigate the decay of a highly anisotropic pitch angle distribution. Dimensional analysis considerations appear quite promising, and the problem has been set up for a numerical solution. The numerical work will be undertaken this winter.

A related question is the origin and evolution of magnetic fields in extended extragalactic radio sources. These fields must be generated *in situ*, and some recent developments in the theory of fully developed, nonlinear MHD turbulence are being applied to the problem. What is sought is a quantitative description of the evolution of both large and small-scale magnetic field structures observed in these sources.

Other studies in progress include an evaluation of the role of Compton scattering of plasma waves in the emission from sources and an investigation of a model for the luminosity evolution of sources.

3. Cluster Sources and Clusters of Galaxies

Multiple frequency maps of the QSO 3C 196 are being made with the VLA to be combined with past observations made with the Green Bank interferometer. Preliminary results indicate that this source has a head-tail structure, which implies it is moving relative to a gaseous medium, presumably associated with a cluster of galaxies. If so, the redshift of $z \approx 0.8$ would make this the most distant, albeit indirect, detection of a cluster of galaxies, and the presence of dense intracluster gas at such early epoch provides interesting constraints upon models for the production of this gas.

The interpretation of interferometer and VLA data on several radio sources in clusters of galaxies will continue. Important developments to be followed up on include: the common existence of very thin streams of "jets" requiring high confinement pressures; the existence of a class of "aligned" head-tail sources, i.e., with ejection velocities apparently aligned with the galaxy motion; and the flattening of the spectral index along the tail of 3C 129, indicative of particle acceleration far from the nuclear source.

Other work on clusters of galaxies include analysis of an interferometer survey of distant objects in the Gunn-Oke catalog, in an attempt to find evolutionary effects in radio galaxies, and observations of objects from the Owen-Rudnick cluster survey, including radio maps with the VLA and optical redshifts from KPNO. VLA maps will be made of the four head-tail sources in the x-ray cluster Abell 2256. The single-dish survey of compact clusters of compact galaxies will be continued. The survey of nearby clusters at 600 MHz, in a search for diffuse, possibly steep-spectrum components, will be completed.

The very difficult high-frequency observations of x-ray clusters of galaxies will be continued in an attempt to find the "dip" caused by inverse Compton scattering in the intracluster medium. Only one group has yet measured this important effect; all other results are in disagreement with the published measurements.

C. MISCELLANEOUS

Multi-frequency observations of satellite Titan will be made with the VLA with the object of determining diameter, surface temperature and atmospheric structure. This has special relevance for planning of the Voyager flyby.

The VLA offers exciting possibilities for the measurement of accurate radio positions. Programs now under consideration include a study of approximately fifty pulsars, to compare the interferometric positions with the timing positions; the measurement of the parallax and proper motion of

selected radio stars; and the measurement of the positions of asteroids, with a view towards refining the fundamental coordinate system.

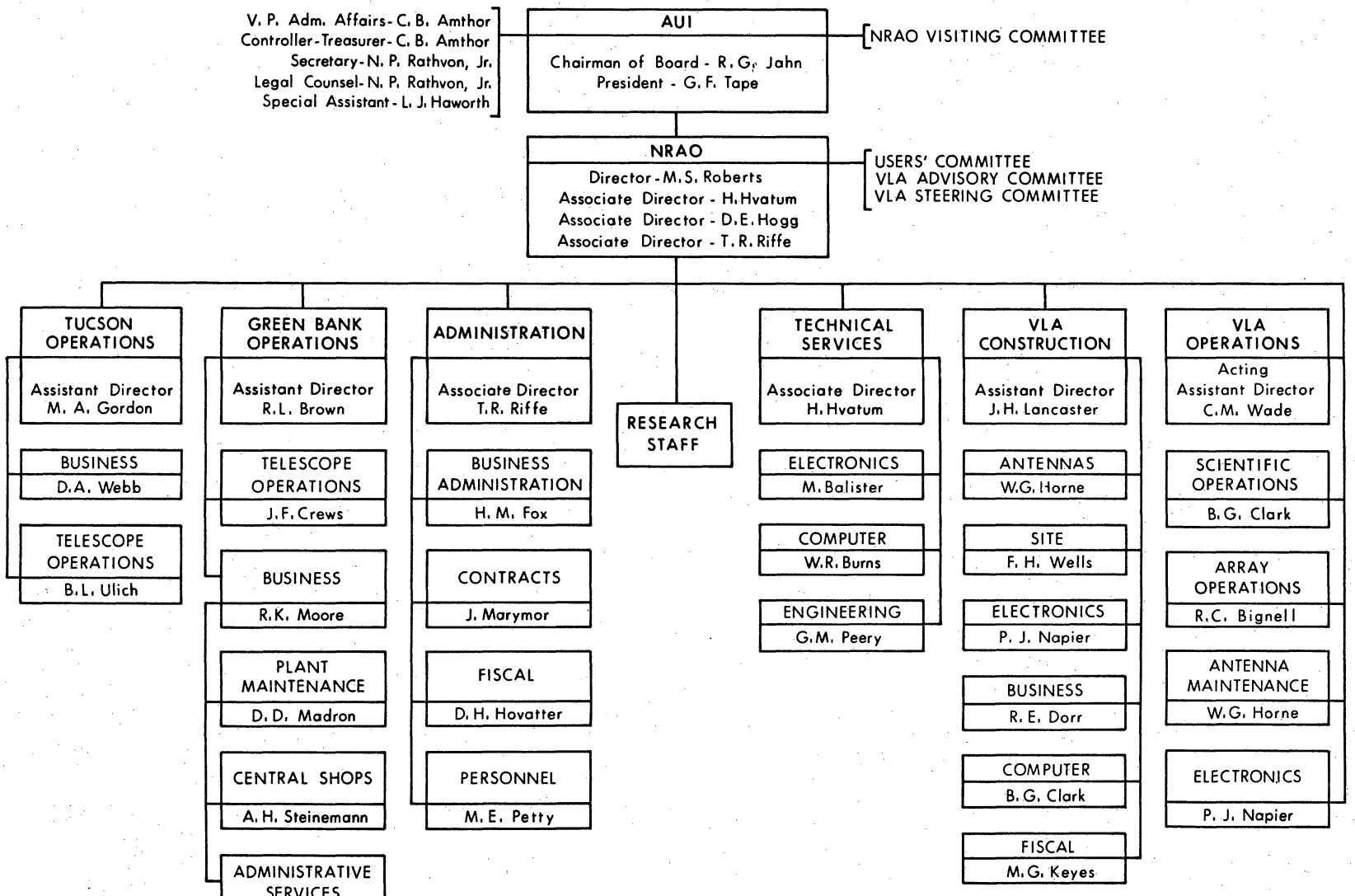
Members of the staff will study various problems associated with highly precise millimeter-wave antennas. The main thrust at this time deals with the ways in which surfaces can be made and measured. Additional effort will be directed toward an understanding of the deformation and panel errors of the 140-ft telescope in order to improve its performance, with a deformable subreflector, at frequencies up to 25 GHz.

APPENDIX B

NRAO PERMANENT SCIENTIFIC STAFF WITH MAJOR SCIENTIFIC INTERESTS
(November 1978)

Bignell, R. C.	Planetary Nebulae; Polarization of Radio Sources
Brown, R. L.	Theoretical Astrophysics; Interstellar Medium
Clark, B. G.	VLA Development; VLB; Interferometry
De Young, D. S.	Theories of Extragalactic Radio Sources; High Energy Astrophysics
Findlay, J. W.	Absolute Flux Density Measurements; Telescope Design
Fomalont, E. B.	Interferometry; Extragalactic Radio Sources; Relativity Tests
Gordon, M. A.	CO; Galactic Structure
Greisen, E. W.	Structure of Interstellar Clouds
Heeschen, D. S.	Variable Radio Sources; Normal Galaxies
Hjellming, R. M.	Radio Stars; VLA Development
Jaffe, W.	Radio Galaxies, Clusters of Galaxies
Liszt, H. S.	Molecular Lines; Galactic Structure
Owen, F. N.	Clusters of Galaxies; QSO's; Radio Stars
Reid, M. J.	Spectral Line VLA
Rickard, L. J	Galactic and Extragalactic Interstellar Molecules
Rudnick, L.	Extragalactic Radio Sources; Cosmology
Shaffer, D. B.	VLBI; Extragalactic Radio Sources
Sinha, R. P.	Planetary Nebulae; Galactic Structure
Spangler, S. R.	Variable Radio Sources; Radio Binary Stars
Sramek, R. A.	Normal Galaxies; Quasars; Astrometry
Turner, B. E.	Molecular Lines; OH
von Hoerner, S.	Cosmology; Star Clusters; Antenna Design
Wade, C. M.	Astrometry; Interferometry; VLA Development

National Radio Astronomy Observatory
Organization Chart
November 1, 1978



APPENDIX D

NRAO COMMITTEES

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.

The current membership of the Committee is:

F. J. Kerr	University of Maryland
W. A. Fowler	California Institute of Technology
P. P. Kronberg	University of Toronto, Canada
R. B. Leighton	California Institute of Technology
J. M. Moran	Smithsonian Astrophysical Observatory
J. P. Ostriker	Princeton University Observatory
V. C. Rubin	Department of Terrestrial Magnetism
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--developments 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 and meets twice a year.

The present membership of this Committee is:

D. C. Backer	University of California, Berkeley
B. Balick	University of Washington
A. H. Barrett	Massachusetts Institute of Technology
J. J. Broderick	Virginia Polytechnic Inst. and State University
B. F. Burke	Massachusetts Institute of Technology
W. B. Burton	University of Minnesota
E. J. Chaisson	Center for Astrophysics
F. O. Clark	University of Kentucky
T. A. Clark	Goddard Space Flight Center
J. J. Condon	Virginia Polytechnic Inst. and State University

J. R. Dickel	University of Illinois
D. M. Gibson	New Mexico Inst. of Mining and Technology
S. J. Goldstein	University of Virginia
S. T. Gottesman	University of Florida
C. Heiles	University of California, Berkeley
R. W. Hobbs	Goddard Space Flight Center
D. R. Johnson	National Bureau of Standards
K. J. Johnston	Naval Research Laboratory
F. J. Kerr	University of Maryland
G. R. Knapp	Owens Valley Radio Observatory
M. R. Kundu	University of Maryland
M. L. Kutner	Rensselaer Polytechnic Institute
R. A. Linke	Bell Telephone Laboratories
J. M. Moran	Smithsonian Astrophysical Observatory
P. Palmer	University of Chicago
P. P. Solomon	State University of New York, Stony Brook
L. E. Snyder	University of Illinois
J. H. Taylor	University of Massachusetts
P. Thaddeus	Institute for Space Studies
N. Thonnard	Department of Terrestrial Magnetism
P. A. Vanden Bout	University of Texas
J.F.C. Wardle	Brandeis University
B. Zuckerman	University of Maryland

VLA Advisory Committee

The VLA Advisory Committee periodically reviews the status and progress of the VLA. Its particular concern is with the broad elements of the Project, and especially those that directly influence the scientific capabilities and performance characteristics of the array. It advises on broad aspects of design, scientific emphasis, and priorities, as well as on general progress, to assist the Director and the Project staff in assuring that the scientific and technical specifications are met and that the VLA will be responsive to the needs of radio astronomy. 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 to maintain, in the membership, reasonable geographic distribution and representation of the major radio astronomy centers. The Committee generally meets two or three times a year, depending on the nature of current project activities and their rate of progress.

The current membership of the Committee is:

B. Balick	University of Washington
B. F. Burke	Massachusetts Institute of Technology

J. N. Douglas	University of Texas
F. D. Drake	Cornell University
R. D. Ekers	Kapteyn Laboratories
C. Heiles	University of California, Berkeley
P. P. Kronberg	University of Toronto, Canada
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 Project. Its principal function is to continuously review technical design, 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, etc.

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

The current membership of the Committee is:

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