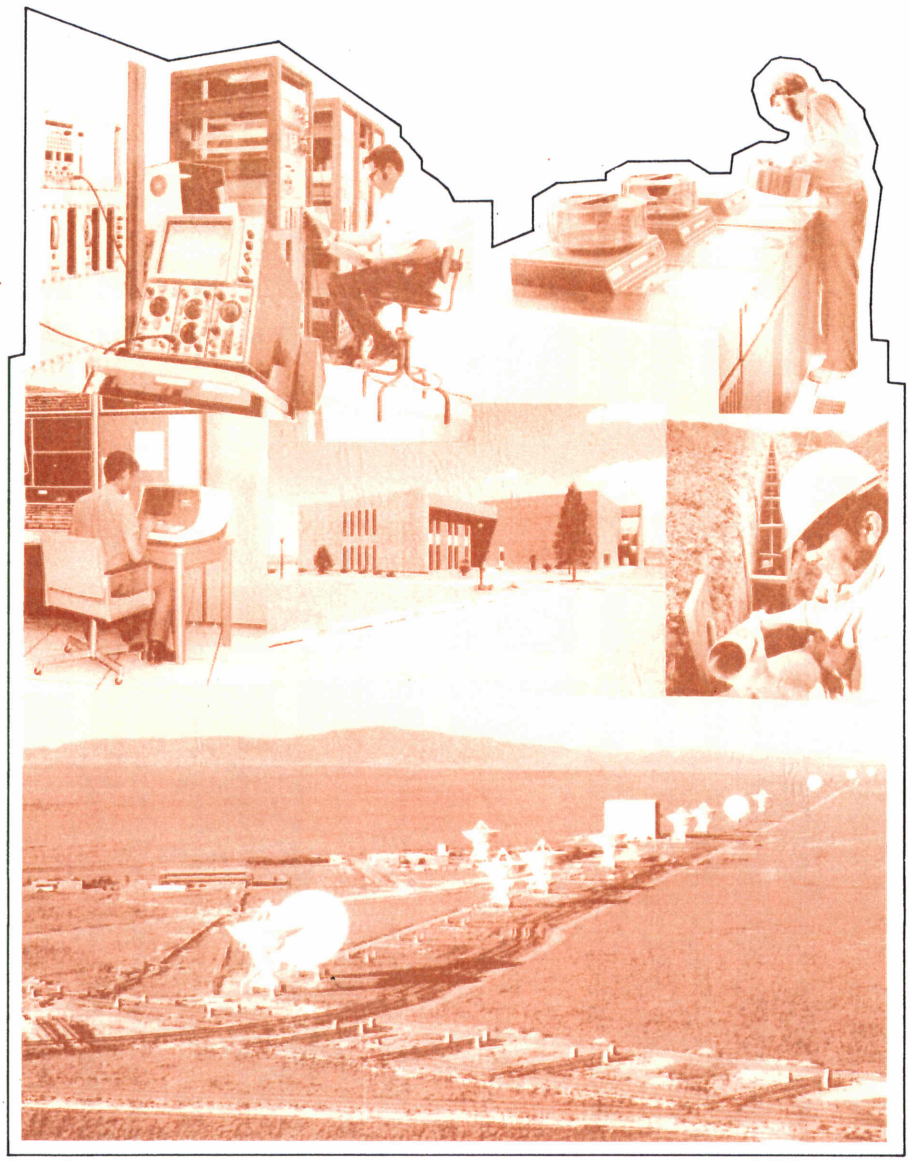
NATIONAL RADIO ASTRONOMY OBSERVATORY



PROGRAM PLAN 1978

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CALENDAR YEAR 1978 PROGRAM PLAN

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I. INTRODUCTION

The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract to the National Science Foundation, and serves as one of the Foundation's National Centers for research in radio astronomy. At least 60 percent of the observing time on the four major radio telescopes which the Observatory operates will be used by visiting scientists both from universities and institutions elsewhere in the United States and from abroad. The research planned for this period by the NRAO permanent staff and the visiting investigators is summarized in the following section.

The operations of the three single dishes--the 36-foot millimeter wavelength telescope, the 140-foot telescope, and the 300-foot meridian transit telescope--will continue, with the observing pressure on the 36-foot remaining exceptionally high. An increasing fraction of the programs requiring high resolution or aperture synthesis will be run on the completed portion of the VLA. The interferometer at Green Bank will be fully utilized until October, 1978, when, for budgetary reasons, operations with it will be stopped.

An important aspect of the Observatory's operation is the design and development of new research instrumentation for the telescope systems. Such instrumentation might for example enable observations in a new portion of the radio spectrum, or might yield much greater sensitivity in a part of the spectrum where some observations have already been made. Section III of this Program Plan summarizes the plans for expenditures in this activity.

Subequent 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 VIII, 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

Although the scientific program for 1978 cannot be described in complete detail, because of the need to have sufficient flexibility to respond quickly to new opportunities, the present plans include a wide variety of investigations.

An increasing number of programs will study various aspects of clusters of galaxies. For example, the properties of the intra-cluster medium may be deduced directly from the observations of the scattering of the microwave background and indirectly from the structure of radio sources in the cluster. Studies of individual galaxies, both in clusters and in the field, will continue, with a view towards obtaining further information on the galaxies themselves and on the presence of satellite hydrogen clouds. Measurement of absorption features in galaxy-quasar pairs will be of help in estimating the extent of the hydrogen envelope around galaxies.

Our understanding of the structure of radio galaxies and of the incidence of compact active components in radio sources will be advanced by the availability of high-resolution, high-sensitivity maps made with the completed portion of the VLA. The VLBI technique will be used to monitor sources showing apparent super-luminal velocities, in an investigation of the dynamics of individual components and of their relative motion. There is renewed interest in the statistical properties of sources at very low flux densities; such sources are probably sufficiently distant that they reflect conditions at an early stage of the universe.

Programs on the single dishes will be primarily concerned with problems of the Galaxy and of galactic sources. Galactic structure studies will concentrate on the physical characteristics and kinematic behavior of the inner region of the Galaxy, and will include a search for the fundamental plane of symmetry within 2 kpc of the center. A number of proposals have been received relating to dark dust clouds and Bok globules; briefly, it is hoped that observations of continuum, recombination lines, and lines of certain key molecules will enable a picture of the density and temperature structure in these objects to be developed. Other molecular line studies will continue the investigation of the manner in which molecules are formed and of the distribution within the Galaxy of certain isotopes such as deuterium. Continuum observations of x-ray stars, radio stars, and novae will be continued.

All proposals for telescope observing 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 these proposals. It is anticipated that approximately 280 observers will use the NRAO telescopes during 1978.

The program of the NRAO staff, which comprises approximately 30 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; (4) the Very Large Array; and (5) the four-element interferometer. At this time the bulk of the program of new instrumentation is in support of the first three telescopes. No further development of the interferometer is planned. 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 1978 program for new instrumentation has three categories, with budget allocations as follows (in thousands of dollars):

Item 1.	Other Observing Equipment.....	670
Item 2.	Research Equipment.....	200
Item 3.	Test Equipment.....	35
	Total.....	905

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	
Correctable subreflector	10			
Autocorrelator	20			
300-Foot Telescope				
300-foot low-noise system		80		
Traveling feed		20		
36-Foot Telescope				
130-170 GHz receiver	10			
200-230 receiver			65	
Varactor downconverter			60	
Other				
VLA post-processor			75	
VLBI			150	
Diode and Josephson dev.			60	
Subtotal	40	100	530	
TOTAL				670

A. Other Observing Equipment: Items to Complete

The items expected to be completed in 1978 include:

1. Correctable Subreflector - The 140-foot telescope will be improved in the 1 to 3-cm wavelength range by the development and installation of a subreflector which is programmed to correct astigmatism.

2. 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 the end of 1978.

3. 130-170 GHz Receiver - This receiver will be completed in 1978 and give a single channel capability in the 130-170 GHz frequency range.

B. Other Observing Equipment: New Development Items

The following new items are planned for 1978:

1. 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.

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.

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. 200-250 GHz Receiver - A dual-channel cooled mixer receiver for the 200-250 GHz frequency range will be started.

3. 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.

4. VLA Post Processor - Further work will be done on a VLA postprocessor to enable observers to process raw VLA data.

5. VLBI - The plans include the development of a Mark III VLBI recording terminal and the start of the development of a processor. The system will be compatible with the VLBI system being developed at Haystack.

6. 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 instrumentation program for 1978 envisions the development of a low-noise system for 3 millimeters, further work on the new 2 millimeter system which was first tested late in 1977, and the completion of a system for 1.3 millimeters. There will be continued investigation of such potentially interesting techniques as the Josephson junction.

Considerable progress in the design of the 25-meter millimeter wavelength telescope was made during 1977, culminating in the submittal to the NSF of a second volume describing the telescope, the astrodome, the proposed site, and the estimated project cost. During 1978 further studies will be made of surface plates for the telescope, and a modest level of design and engineering effort will be continued.

IV. EQUIPMENT

No major equipment acquisitions are planned for 1978. 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	14.0
	Total	54.0

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 things 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 check-out and calibration of instrumentation.

II. Technical Support and Development - This unit has the general responsibility for the observatory-wide technical and instrumentation 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 73k, 525k, 120k, and 115k, respectively, with an additional 193k 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 1978 MS&S budgets, are: Telescope Operations (108k); Electronics (155k); Shops (20k); Plant Maintenance (150k); and Administrative Services (105k). An additional 606k is required for personnel benefits, communications, and utilities, and miscellaneous revenue is estimated to amount to 100k.

IV. Tucson Operations - This smaller group maintains and operates the 36-foot millimeter wavelength telescope at Kitt Peak, and developes 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 budget for this group includes 175k for Operations and Maintenance, 110k for Electronics, and 85k for Personnel Benefits.

V. VLA Operations - This group will be expanded significantly as the number of antennas and the complexity of the data handling will both increase over 1977 levels. For example, the number of antennas which are operational will grow from 10 in January, 1978 to 15 by the end of the year. The pressure on available observing time will become heavy, both because of the intrinsic power of the completed portion of the VLA and because of the removal of the interferometer from service. The four divisions--Antenna Maintenance, Scientific Services, Array Operations, and Electronics--will require MS&S in the amount of 20k, 102k, 4k, and 18k, respectively. An additional 125k is required for personnel benefits, and the Operations' share of Common Cost is 339k.

VI. General and Administrative - Included in this unit are the Director's Office, the Fiscal Office, and the Business Office, with total MS&S budget of 135k. Rent and maintenance of the Charlottesville buildings, including utilities, will require 243k, and 100k is allocated to personnel benefits. The management fee will be 165k.

A summary of the CY 1978 budget for these Operation Units is provided in the following table.

CY 1978 Budget--Operation Units
(in thousands of dollars)

	Operation Unit	Salaries and Wages	Materials, Supplies & Services	Travel	Total
I.	Research Support	777	163	135	1075
II.	Technical Support & Development	912	1026	47	1985
III.	Green Bank Operations	1721	1044	30	2795
IV.	Tucson Operations	400	370	35	805
V.	VLA Operations	583	608	9	1200
VI.	General & Administration	475	643	60	1178
	Total Operations	4868	3854	316	9038

VI. CONSTRUCTION

The construction of the Very Large Array (VLA) will continue in 1978 with new funds in the amount of $12,500,000. A detailed description of this program will be found in the VLA Project Plan submitted separately.

VII. PERSONNEL

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

Category	1977 Level	1977 Salaries	1977 Benefits	1978 Level	1978 Salaries	1978 Benefits
Operations						
Scientific & Engineering	65	1,395,500	256,600	73	1,704,200	359,200
Technical	87	1,314,600	241,800	86	1,440,200	303,500
Administrative & Clerical	55	970,800	178,500	53	1,046,300	220,500
Operations & Maintenance	48	599,000	110,200	50	677,300	142,800
Total Operations	255	4,279,900	787,100	262	4,868,000	1,026,000
VLA Common Costs	28	345,000	74,000	30	358,000	77,000
VLA Construction	76	1,199,000	256,000	58	973,000	209,000
Total Personnel	359	5,823,900	1,117,100	350	6,199,000	1,312,000

VIII. PRELIMINARY FINANCIAL PLAN - 1978

(in thousands of dollars)

	(a) Actual Exp. 1977	(b) Comm. Carried to 1978	(c) Uncomm. Funds Carried to 1978	(d) New Funds 1978	(e) Available for Exp. & Comm. (b,c,d) 1978
I. SCIENTIFIC RESEARCH					
A. Operations					
Personnel Compensation	4,279.9			4,868.0	4,868.0
Personnel Benefits	787.1			1,026.0	1,026.0
Travel - Domestic	283.6			291.0	291.0
Travel - Foreign	20.0			25.0	25.0
Other Materials, Supplies, & Services	2,261.6	254.0	375.0	2,288.0	2,917.0
Management Fee	165.0			165.0	165.0
Subtotal	7,797.2	254.0	375.0	8,663.0	9,292.0
B. Equipment					
Research Equipment	893.4	330.0	347.0	558.0	1,235.0
Operating Equipment	55.8	20.0	4.0	50.0	74.0
Subtotal	949.2	350.0	351.0	608.0	1,309.0
Total - Scientific Research	8,746.4	604.0	726.0	9,271.0	10,601.0
II. CONSTRUCTION					
Very Large Array	11,786.5	10,700.0*	(6,000.0)*	12,500.0	17,200.0
Total - Construction	11,786.5	10,700.0	(6,000.0)	12,500.0	17,200.0
TOTAL	20,532.9	11,304.0	(5,274.0)	21,771.0	27,801.0

* $7.2M of the CY 1978 VLA funds were made available in CY 1977, and commitments were made against these funds.

Note: This is a preliminary plan based on estimated 1977 figures. The final Financial Plan, reflecting actual year-end figures, will be submitted early in 1978.

APPENDIX A

RESEARCH PROGRAMS OF THE NRAO SCIENTIFIC STAFF

The permanent staff at the NRAO has planned for 1978 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

Observations of cold, neutral hydrogen appearing in self-absorption will be compared with observations of CO in an investigation of the co-existence of atomic hydrogen and molecules. This work may yield several benefits. First, estimates of the HI/H_2 fraction in galactic dark clouds may be obtained. Second, when the molecular clouds are seen in HI self-absorption, they must be at the near kinematic distance. Thus for the first time, one has a means of resolving the distance ambiguity inside the solar circe, and so can study in an unambiguous fashion the distribution of cloud sizes, etc. Finally, CO emission has been detected in the direction of six (out of 14) extragalactic continuum sources toward which the HI spin temperature can be reliably determined. The CO intensity is proportional to the column density of HI in the strongest absorption component seen in HI. This probably indicates optically thin molecular emission from hot, diffuse clouds in which partial HI-H_2 conversion is occurring.

Further studies of the physical characteristics and kinematic behavior of the inner few kiloparseconds of the Galaxy will be made through comparisons of the data for CO, CS, and neutral hydrogen. The value of the hydroxyl radical as a tracer of galactic structure will be investigated. The CO data will also be used to study the distribution of size and separation of interstellar clouds. The line strengths from isotopically-substituted CS will be measured in sources covering a wide range of galactocentric distance in order to determine if the ratio $^{12}C/^{13}C$ varies.

An investigation of the relation between the distribution of galactic non-thermal continuum radiation and the distribution of dense gaseous matter in the Galaxy will be made. The extent to which these distributions are correlated provides a measure of the magnetic field strength in interstellar clouds.

Finally, various galactic extinction models will be tested with the extensive data, both 21-cm and optical, now available from the Green Bank surveys of normal galaxies.

2. The Galactic Center Region

A search for the fundamental plane of symmetry in the inner 2 kpc of the Galaxy will be made using observations of hydrogen, CO, and CS. The asymmetries in the HI kinematics (for which no satisfactory explanation has been advanced) can be removed by proper choice of a spatial symmetry axis. The same model successfully accounts for the HI and molecular kinematics. The molecular ring proposed earlier appears to be an artifact of earlier, incomplete sampling of the molecular gas distribution. The inner 1 kpc of galactocentric radius in the galaxy is a separate subsystem of the Galaxy with a different axis of rotation. The molecular distribution is much more extensive than was previously believed.

The analysis of the maps made in the three lines of CH at 9 cm of the Galactic center region will be continued. A survey of the distribution of H_2O maser emission in the Galactic center will be made, and this distribution will be compared to that of the OH masers to determine the lifetime and luminosity function of protostellar masers. Observations of HNCO and CH_3CN will be interpreted using an approximate radiative transfer scheme to study the structure and excitation of the high-density molecular core of Sgr B2.

The study of the compact continuum sources at the Galactic center will be pursued with both the interferometer and with VLBI. It is expected that the interferometer will provide data on the spectral and temporal variations in the source, while the VLBI data will enable an estimate of the effect of the interstellar medium on the observed size.

3. Radio Stars, Novae, and Supernovae

The combination of the VLA and the interferometer offers the unique possibility of determining spectra of rapidly varying objects at six wavelengths between 21 cm and 1.3 cm. This capability will be exploited in the study of both thermal and non-thermal radio stars. These instruments will also be used to monitor changes in well-known objects such as Cyg X-1, to search for radio counterparts of x-ray sources, and to monitor the decline in the radio emission of four novae.

The VLBI will be used to measure the dimensions of the radio-emitting regions associated with radio stars, and to search for compact sources in supernova remnants. The long-standing program of absolute measurement of the flux of Cas A will be continued.

4. HII Regions, Dust Clouds, and Infrared Objects

In order to deduce the temperature and temperature gradient in HII regions from recombination-line observations, it is necessary to know the

gas density in the region. An estimate of the gas density will be made from VLA and interferometer observations of the continuum brightness of a sample of 25 HII regions. Complementary radio recombination-line data will be obtained at many frequencies, enabling the temperature structure in these HII regions to be determined. The kinematics of the complex source W51 will be studied using spectra of hydrogen and a number of molecules.

A comprehensive study of the dynamical, thermal, and chemical evolution of Bok globules will be made. By comparing the theoretical results with available molecular observations, information on the physical conditions and the age of these objects can be obtained. Analysis of the detailed maps of N_2H^+, HCO^+, HCN, and HNC in the directions of CII recombination-line sources in dark dust clouds will be continued.

The distribution of OH in dense self-absorbed HI clouds (objects that appear to represent the transition stage between fully atomic and fully molecular hydrogen clouds) is being measured in order to derive the abundance of OH as a function of HI/H_2. Studies are in progress of OH excitation in Heiles' Cloud 2, the site of the recently discovered heavy molecules HC_5N and HC_7N, and of OH emission towards stars with optical or radio lines of OH, CH, or CO, using the high angular resolution of the Arecibo telescope to overcome beam dilution effects.

Observations will be made of evolved carbon stars and related objects in the lines of CO and HCN, to determine $^{13}C/^{12}C$ isotope ratios and to further define the picture of those stars as progenitors of planetary nebulae. A VLB study in the hydrogen line of the curious source CL4 may provide data which will determine if it is extragalactic. The VLA will be used to make high-resolution maps of a number of planetaries at northern declinations.

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.

The results of a previous 6-cm spectral-line VLBI experiment will be analyzed to measure the characteristics of the excited-state OH masers. These observations should provide fundamental information concerning the causes of polarization in OH masers and how OH masers form in interstellar molecular clouds. Further polarization data will be obtained at 6 cm with the 140-ft telescope, and a search for quasi-thermal features will be made at 7.8 GHz.

A survey, using thermal emission of SiO, will be made of large molecular clouds having compact HII regions and point sources of infrared radiation.

5. Molecular Line Studies

The analysis of observed $^{13}C/^{12}C$ ratios in molecular clouds will continue, using detailed radiation-trapping models, to assess how the observed ratios depend on temperature and density, and hence to determine whether there is or is not a "characteristic" interstellar value of $^{13}C/^{12}C$. Further work will have to be done on the deuterium problem in view of the surprisingly high ratio DNC/HNC $\sim$ $DCO^+/HCO^+ \sim 2$ found in some sources. The detection of other deuterated species may be of help in this matter.

The excitation mechanisms and isotropic abundances of H_2CO, HCN, and OCS will be analyzed by solving the multi-level radiative transfer problem and comparing the results with available observations. The effects which have to be considered include frequency overlapping of the hyperfine transitions and line interlocking.

An attempt will be made to confirm the possible detection of hydroxylamine (NH_2OH) and searches will be undertaken for SiH, using newly calculated frequencies, and NO. Model predictions of the NO abundance vary widely and have not been tested against observations to any significant degree. Detailed computer programs have been written to predict accurate millimeter-wave spectra for several hundred laboratory-measured molecular species which may be relevant astrophysically. Attempts to identify the approximately 32 unidentified lines observed in the past three years are continuing in collaboration with laboratory spectroscopists.

B. EXTRAGALACTIC STUDIES

1. Normal Galaxies

A study will be made of the shapes of velocity profiles of galaxies in some detail through computer modeling and by obtaining examples of very high signal-to-noise profiles. The gross features of such profiles may be understood in terms of a simple, rotating galaxy. But there are both systematic differences among observed profiles as well as anomalous features in many such profiles. As an example, most galaxies classified as "peculiar" in terms of their optical image also have peculiar-appearing velocity profiles.

A continuing project is being conducted to locate and describe intergalactic HI clouds. Such clouds are known to exist, but the currently available evidence indicates that they are found only in groups of galaxies and are most likely tidal in origin.

The results of some recent work on CO emission from nearby galaxies include the detection of NGC 891 and extensive maps of M51 and Maffei 2.

Future work will complete maps of NGC 253, M83, and NGC 891, and will extend the search to other galaxies in order to investigate suspected correlations of CO with nuclear infrared emission and with the nonthermal continuum emission from the galaxy disk. Searches will be made for ^{13}CO, OH, and H_2O in selected galaxies.

Continuum studies of normal galaxies will include searches for compact components in nearby galaxies and a search for emission in dwarf galaxies. The spectral indices of a large number of spirals will be measured to determine the relative contributions of thermal and nonthermal emission. Analysis of line and continuum observations of the dwarf galaxy II Zw 40 will be completed. A survey of distant clusters will be made which, when combined with optical data, may enable the determination of the radio luminosity function of galaxies.

2. Radio Galaxies and Quasars

A number of ongoing programs are aimed at the detailed understanding of individual sources in terms of morphology, spectral index, and polarization. Two areas of current interest, for example, are the necessity (or lack thereof) for a continuous resupply of energetic particles and the amount of mass and energy present in thermal material within the radio source. A separate program investigating very large ($\gtrsim$ Mpc) sources is planned, as they provide some of the most severe constraints on radio source models. Included in this latter category are 0136+397, 3C 319, and 3C 315, a giant radio source with a well-defined radio jet.

The reduction, analysis and publication of a study of radio sources associated with elliptical galaxies will be continued. Several papers are in progress concerning a new set of 70 radio sources with nuclear components, new identifications of radio sources, better statistics concerning the radio versus optical orientation of elliptical galaxies, and discussion of several bizarre sources.

Several VLBI experiments will address the problem of the active nuclei in active galaxies. If the spatial structure can be measured, it may be possible to determine if the compact nucleus is the source of energy for the large double radio lobes and to provide boundary conditions on the formation of these lobes. The VLBI will also be used to monitor sources with apparent super-luminal velocities. The higher resolution obtained by the use of transatlantic baselines will permit a study of the dynamics of individual components and of their relative motion. An important advance will be the use of a network experiment designed to obtain phase information, making possible the determination of the source structure without the normal assumptions required by the modeling technique.

A search will be made for lines indicating an intervening HII in front of one component of Cyg A but not the other, thus explaining the discrepant rotation measure between the two components. Other effects that might produce the anomalous rotation measure will be investigated theoretically. In a related program, one or two carefully chosen extended sources will be observed with the VLA at two frequencies to determine the distribution of thermal plasma and reacceleration regions within the source.

A number of surveys are planned. About 250 sources will be reobserved at 318 MHz to find the incidence of low-frequency variability in a complete sample of sources. The 300-ft telescope will be used at 6 cm to search for sources with highly inverted spectra, and to study the magnitude-flux density relation for sources with flat spectra and for sources at very low flux densities from a confusion-limited survey. Multi-frequency observations in coordination with optical and infrared telescopes will be made of BL Lac objects, and spectra of sources which are strong in the millimeter range will be measured between 318 MHz and 90 GHz. The VLA will be used in attempts to detect radio emission from high-redshift quasars and from bright, low-redshift quasars (both sets of objects found from optical surveys).

Optical photometry of a sample of QSOs from the Jodrell Bank survey will be undertaken in a search for low-level variability on time scales of months to years. The optical identification of flat-spectrum sources from the Parkes 2700-MHz surveys will be continued.

Work will proceed on the development of a finite size particle hydrodynamic simulation technique to determine the efficiency of turbulent reacceleration of particles within extended radio sources. The multiple scattering problem of Compton and inverse Compton scattering will be studied with emphasis on the effects of stimulated scattering. The results will be applicable to the physics of x-ray sources, quasars, and the cosmic microwave background.

3. Clusters of Galaxies and the Interstellar Medium

The mapping of radio sources in clusters of galaxies will continue, using the VLA and the interferometer. Included in this work are Abell 2256 and a number of Zwicky clusters, as well as several Abell clusters. This work may lead to a better understanding of the source of the energetic particles, and of the evolution of the radio sources through interaction with the intracluster medium.

In a related program, a number of sources from the 4C survey which lie outside clusters are being mapped to investigate the importance of cluster memberships on source morphology. The initial stages of the mapping program

are complete; preliminary indications are that the gross structural distortions seen in cluster radio sources are not common in this sample. For the lower luminosity sources studied, however, many diffuse structures are visible which are similar to the cluster sources.

The thermal intracluster material will also be studied through the predicted effects due to inverse Compton scattering of blackbody photons (the "cold spot" in x-ray clusters), and thermal bremsstrahlung radiation from possibly cooler intracluster gas. Current work has set limits in five clusters on the central electron density as a function of kinetic temperature. Calculations are planned to evaluate both the fundamental and technical limits on these studies, and the implications for studying small-scale background anisotropy at centimeter wavelengths.

An investigation will be made of the possibility that the "missing mass" problem in clusters is due to the clusters themselves being of considerably greater extent than previously appreciated.

C. MISCELLANEOUS

The VLA will be used in a study of the rings and satellites of Saturn, and to measure positions with astrometric accuracy of radio stars, pulsars and quasars. Observations of the compact sources A0 0235+164 and of selected pulsars will be made to study the interplanetary medium near the Sun.

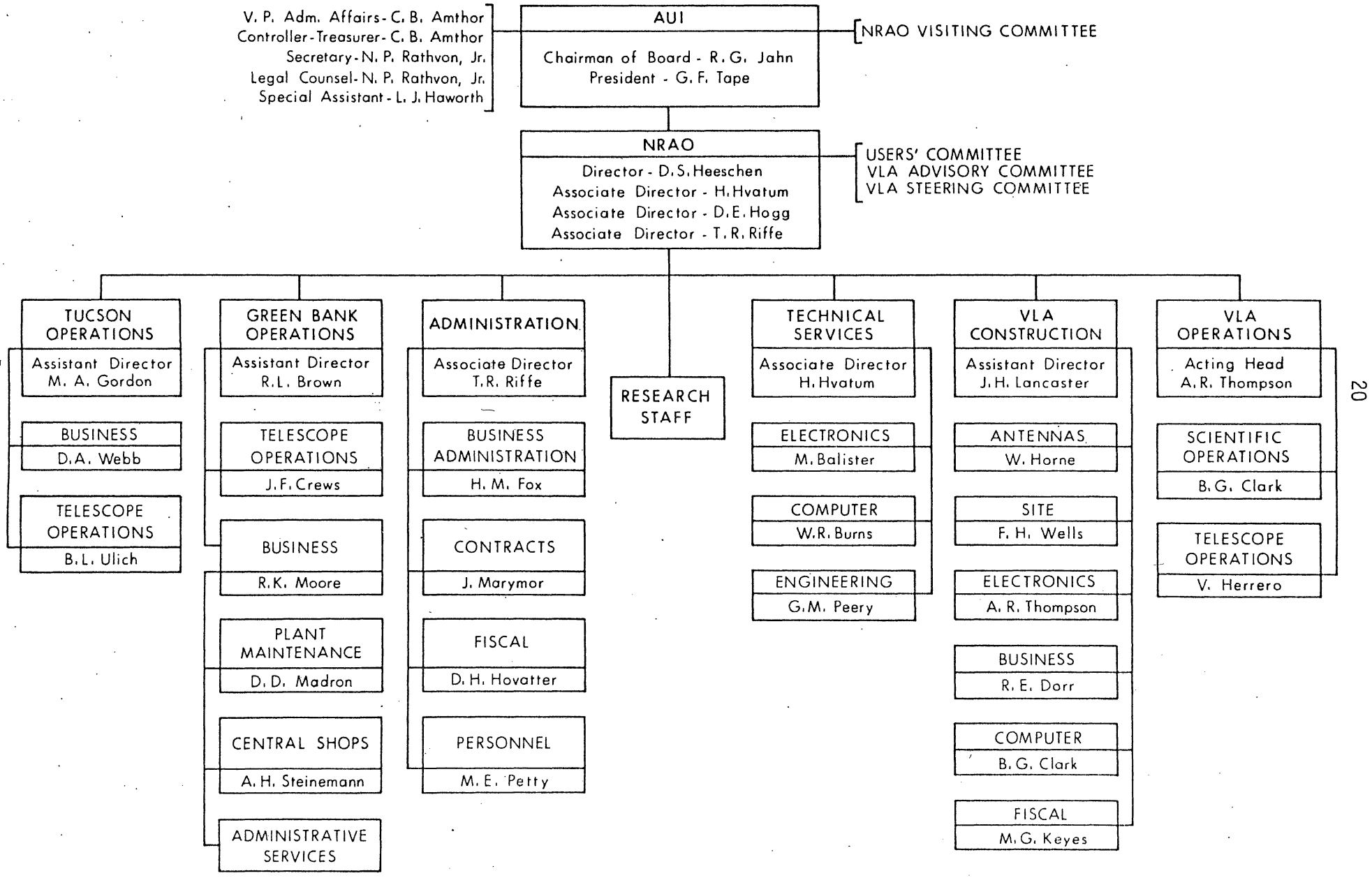
APPENDIX B

NRAO PERMANENT SCIENTIFIC STAFF WITH MAJOR SCIENTIFIC INTERESTS
(December 1, 1977)

Brown, R. L.	Theoretical Astrophysics; Interstellar Medium
Burton, W. B.	Neutral Hydrogen; CO; Galactic Structure
Clark, B. G.	VLA Development; VLB; Interferometry
Condon, J. J.	Extragalactic Radio Astronomy
DeYoung, 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
Hjellming, R. M.	Radio Stars; VLA Development
Jaffe, W.	Radio Sources in Clusters; Large Radio Sources; VLA Development
Kellermann, K. I.	Spectra and Structure of Extragalactic Sources; VLB
Leung, C. M.	Radiative Transfer in the Interstellar Medium
Liszt, H. C.	Molecular Lines; Galactic Structure
Owen, F. N.	Continuum Emission and Radio Spectra of Galaxies and Clusters
Reid, M. J.	Spectral Line VLBI; Molecular Masers
Rickard, L. J	Galactic and Extragalactic Interstellar Molecules
Roberts, M. S.	Extragalactic Research
Rudnick, L.	Extragalactic Radio Sources; Cosmology
Shaffer, D. B.	VLBI; Extragalactic Radio Sources
Turner, B. E.	Molecular Lines; OH
von Hoerner, S.	Cosmology; Star Clusters; Antenna Design
Wade, C. M.	Astrometry; Interferometry; VLA Development

APPENDIX C

NATIONAL RADIO ASTRONOMY OBSERVATORY
ORGANIZATION CHART
NOVEMBER 1, 1977



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:

R. D. Ekers	Kapteyn Laboratory, Groningen
W. A. Fowler	California Institute of Technology
C. Heiles	University of California, Berkeley
F. J. Kerr	University of Maryland
J. M. Moran	Smithsonian Astrophysical Observatory
J. P. Ostriker	Princeton University Observatory
V. C. Rubin	Department of Terrestrial Magnetism
R. W. Wilson	Bell 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:

B. Balick	University of Washington
A. H. Barrett	Massachusetts Institute of Technology
J. J. Broderick	Virginia Polytechnic Institute & State University
B. F. Burke	Massachusetts Institute of Technology
F. O. Clark	University of Kentucky
T. A. Clark	Goddard Space Flight Center
M. M. Davis	Arecibo Observatory
W. A. Dent	University of Massachusetts
J. R. Dickel	University of Illinois Observatory

J. N. Douglas	University of Texas, Austin
F. D. Drake	Cornell University
W. C. Erickson	University of Maryland
D. M. Gibson	New Mexico Institute of Mining & Technology
S. J. Goldstein	University of Virginia
C. 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 College Observatory
C. H. Mayer	U. S. Naval Research Laboratory
J. M. Moran	Smithsonian Astrophysical Observatory
P. Palmer	University of Chicago
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	NASA Institute for Space Studies
G. L. Verschuur	University of Colorado
J.F.C. Wardle	Brandeis University
J. W. Warwick	University of Colorado
G. Westerhout	U. S. Naval Observatory
D.R.W. Williams	University of California, Berkeley
R. W. Wilson	Bell Laboratories
W. J. Wilson	Aerospace Corporation
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 as responsive to the needs of radio astronomy as is possible. 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, Austin
F. D. Drake	Cornell University
R. D. Ekers	Kapteyn Laboratories, Groningen
C. Heiles	University of California, Berkeley
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 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, 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:

W. R. Burns	D. E. Hogg
R. L. Brown	H. Hvatum
B. G. Clark	J. H. Lancaster
L. R. D'Addario	F. N. Owen
E. B. Fomalont	P. J. Napier
E. W. Greisen	L. Rudnick
D. S. Heeschen	A. R. Thompson
V. Herrero	N. Vandenberg
R. M. Hjellming	C. M. Wade