NATIONAL RADIO ASTRONOMY OBSERVATORY

PROGRAM PLAN 1976

NATIONAL RADIO ASTRONOMY OBSERVATORY

CALENDAR YEAR 1976 PROGRAM PLAN

NATIONAL RADIO ASTRONOMY OBSERVATORY

CALENDAR YEAR 1976 PROGRAM PLAN

Table of Contents

NATIONAL RADIO ASTRONOMY OBSERVATORY

CALENDAR YEAR 1976 PROGRAM PLAN

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 telescope systems--the 36-foot millimeter wavelength telescope, the 140-foot telescope, the 300-foot meridian transit telescope, and the four-element variable baseline interferometer--are all heavily subscribed and an important aspect of the Observatory's operation is the design and development of new research instrumentation for these 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.

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 VII, 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 1976 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.

Studies of the Galaxy will be highlighted by further observations of the distribution of CO, and, by inference, of the molecular hydrogen which is the dominant constituent of the cold gas in the Milky Way. Other investigations utilizing line radiation at millimeter wavelengths will bear on problems of star formation and the physical conditions in circumstellar shells associated with newly-formed stars, highly-evolved giant stars, and planetary nebulae. The continuum emission from radio stars and X-ray sources will be monitored, as will the predicted rise of the emission from the recent bright nova, Nova Cygni 1975. Observations of supernova remnants will concentrate on the interaction of the expanding remnant shell with the interstellar medium, and will utilize both line and continuum radiation. Studies of pulsars will include an attempt to measure the proper motion of selected objects.

The principal effort in the investigation of the structure and motions of normal galaxies will continue to be based on the 21-cm line of neutral hydrogen, although the recent discovery of CO emission from a number of galaxies will be followed up. Amongst the programs planned are surveys of the hydrogen content in bright spirals, dwarf spirals and irregular galaxies, studies of the dynamics of pairs of galaxies, and the determination of the rotation curves of nearby spiral galaxies. Searches will be made for absorption features in the emission from quasar-galaxy pairs.

Interferometers--both the four-element system at Green Bank and multi-element VLB systems--will be used to map the radio structure of quasars and radio galaxies. The "head-tail" radio galaxies found in clusters are of great interest at this time, since their structure apparently reflects both the energy processes in the radio galaxy and the influence of the intergalactic medium through which the radio galaxy moves. Further studies will be made of the compact structure in radio galaxies and quasars, and of how this structure changes with time. Surveys of radio sources will be made to determine the frequency with which compact components occur.

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 250 observers will use the NRAO telescopes during 1976.

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 primary research instruments at the National Radio Astronomy Observatory consist of: (1) a 140-foot telescope; (2) a 300-foot telescope; (3) an interferometer, consisting of three 85-foot telescopes and a 45-foot transportable telescope; and (4) a 36-foot telescope. With the exception of the 36-foot telescope, all NRAO research instruments are located at Green Bank, West Virginia. The 36-foot telescope is located on Kitt Peak, near Tucson, Arizona. The following two tables summarize the funds needed to equip NRAO research instruments (in thousands of dollars).

Item 1.	Other Observing Equipment.....	592.0
Item 2.	Research Equipment.....	260.0
Item 3.	Test Equipment.....	30.0
	Total.....	882.0

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

[See attached table, page 4]

A. Other Observing Equipment: Items to Complete.

The items expected to be completed in 1976 include:

1. Other Observing Equipment (in thousands)

	Estimate To Complete (k$)	Estimate New Development (k$)	Estimate Continued Development (k$)	General Development (k$)	
140-ft Telescope					
Low-noise front-end	50				
Correcting subreflector		40			
New correlator		40			
Second maser system		100			
36-ft Telescope					
9 mm receiver	10				
120-160 GHz receiver	30				
1-1.5 mm receiver		25			
Other					
VLBI Mark II		125			
Diode development			30		
Josephson junctions			30		
360 graphics		50			
General				62	
Subtotal	90	380	60	62	
TOTAL					592

1. Completion of 9-mm Cassegrain Receiver - A dual-beam, dual-polarization (four receivers) 700° K, 500 MHz bandwidth continuum receiver will be provided.

2. 120-160 GHz Receiver - Cooled mixers for a 120-160 GHz receiver will be designed in a similar manner to the presently available 80-120 GHz receiver. These mixers will be incorporated in a receiver in CY 1976.

3. 140 Foot Very Low-Noise Front-End - The improved short wavelength performance provided by a correcting subreflector plus the additional flexibility of the Cassegrain mode must be matched by a high performance 1.2-2 cm receiver. A maser system for wavelengths near 1.2 cm is on order.

B. Other Observing Equipment: New Development Items.

The following new items are planned for 1976:

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

2. VLBI Mark III - The development of a Mark III VLBI recording terminal and the start of the development of a processor. The design goal is a 100 Mbit/s system compatible with the Mark II system and with the VLBI system being developed at Haystack.

3. 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 3-level quantization), 2.5 times more channels, and a larger bandwidth.

4. 1-1.5 mm Receiver - Development of mixers and local oscillators for the 1-1.5 mm wavelength range.

5. Very Low-Noise Receiver for the 140-foot Telescope[1] - Start expansion of the 1.2 cm maser system into a dual-channel radiometer which also will incorporate parametric upconverters to cover the 8.2-10.8 GHz and 13.4-16.4 GHz frequency ranges.

6. Development of NRAO Image Processing System[2] - We wish to extend the image recording system, presently based on the Dicomed image recorder to support interactive manipulation of radio astronomical maps.

---

[1]Defined as second maser system in the table.

[2]Defined as 360 graphics in the table.

C. Other Observing Equipment: Continuing Development Items.

1. Josephson Junction - This sum will be used to continue development of a 3-mm mixer receiver.

2. Diode Development - This amount will be contracted for development of Schottky diodes for improvement of millimeter-wave mixers.

Item

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 telescope.

Millimeter-Wavelength Instrumentation

All the items listed under the 36-foot telescope are part of the Observatory's continuing effort to develop instrumentation in the millimeter-wave region. Millimeter-wave electronics has developed rapidly during the last years. The cooled Cassegrain system for the 36-foot telescope has provided considerable improvement and also presents the opportunity for future low-noise radiometers.

The successful operation of the 36-foot telescope has led to a rapid advance in millimeter-wave astronomy. This field now clearly requires a larger telescope with a more accurate surface. In response to this need, the National Radio Astronomy Observatory started in 1974 the design of a millimeter-wave telescope of diameter 25 meters with an r.m.s. surface accuracy of 75 μm. A proposal, "A 25 Meter Telescope for Millimeter Wavelengths", has been submitted to the National Science Foundation.

IV. EQUIPMENT

No major equipment acquisitions are planned for 1976. The distribution of funds (in thousands of dollars) in the various equipment accounts is as follows:

Item 1.	Maintenance, Shop and Repair Equipment	25.0
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	10.0
	Total	60.0

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, chairs, tables, lamps, draperies, carpets, etc., used in the residence hall and furnished houses in Green Bank.

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

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

Category	1975 Level	1975 Salaries	1975 Benefits	1976 Level	1976 Salaries	1976 Benefits
Scientific & Engineering	61	1,183,000	231,900	63	1,352,400	270,500
Technical	75	932,100	182,700	77	1,039,500	207,900
Administrative & Clerical	58	932,000	182,700	59	1,026,500	205,300
Operations & Maint.	53	537,700	105,300	53	581,600	116,300
Total - Operations & Maintenance	247	3,584,800	702,600	252	4,000,000	800,000
VLA Construction	83	1,196,000	252,000	92	1,323,000	278,000
Total - Personnel	330	4,780,800	954,600	344	5,323,000	1,078,000

V. OPERATIONS AND MAINTENANCE

A. Personnel Levels at December 31, 1976

Category	Green Bank	Charlottesville	Tucson	New Mexico	Total
Operations					
Scientific & Engineering	24	35	4	-	63
Technical	46	17	14	-	77
Administration & Clerical	31	24	4	-	59
Operations & Maintenance	51	2	-	-	53
Total - Operations	152	78	22	-	252
VLA Construction					
Scientific & Engineering	-	4	-	30	34
Technical	-	9	-	20	29
Administration & Clerical	-	1	-	18	19
Operations & Maintenance	-	-	-	10	10
Total - Construction	-	14	-	78	92
TOTAL PERSONNEL	152	92	22	78	344

B. All Other Materials, Supplies and Services (in thousands of dollars)

1. Directors Office..... 4.0
2. Research Group..... 2.0
3. Scientific Services..... 85.0
   Includes planned expenditures for library books, periodicals and other supplies for the Green Bank and Charlottesville libraries and also includes cost of preprints and reprints, darkroom and scientific drafting materials and supplies.
4. Electronics Division..... 285.0
   Includes expenditures for general electronics and laboratory supplies at Green Bank, Charlottesville and Tucson, including receivers and electronics equipment maintenance, materials and supplies, e.g., helium, wire, tubes, resistors, small tools, special parts, etc., and radio noise control and suppression costs.
5. Computer Division..... 60.0
   Includes cost of tapes, cards, paper, maintenance agreement; outside programming assistance for the computer division.
6. Engineering Division..... 90.0
   Includes cost of engineering and drafting supplies, small A/E studies and telescope improvement studies.
7. Tucson Operations Division..... 168.0
   Includes reimbursement to KPNO for services, general maintenance of telescopes, building rental and office upkeep, vehicle rental and supplies, postage, telephone, etc.
8. Fiscal Division..... 26.0
   Includes cost of audit service, tax assistance, general office supplies, e.g., blank checks, records, cards, tapes, paper, etc.
9. Business Management Division (CV)..... 105.0
   All Charlottesville general office supplies, freight (in and out), Xerox rental, office machine service agreements, GSA auto rental, legal services, outside printing, personnel recruitment, etc.
10. Telescope Operations Division (GB)..... 70.0
    Includes costs of maintaining the telescopes, e.g., painting, cryogenics, oil, grease, spare parts, special cabling and wiring, etc.
11. Plant Maintenance (GB)..... 150.0
    Includes cost of maintaining the Green Bank physical plant, e.g., electrical, water and sewer systems,

materials, and supplies for the auto shop, paint shop and carpentry shop and general equipment maintenance. Costs of maintaining the buildings, houses, control buildings, grounds, roads and airstrip. Also includes cost of materials and supplies for safety and security and cost upkeep of the ambulance and fire-fighting equipment.

12. Central Shops..... 30.0
Includes costs of general machine shop supplies, metals, welding materials, etc.

13. Administrative Services (GB)..... 120.0
Includes cost of operating the cafeteria and residence hall, e.g., food for resale and other cafeteria supplies, linen and laundry service, freight and express (in and out), office machine service agreements, Xerox rental, GSA vehicle rental, purchasing office supplies, warehouse supplies (not stock items), darkroom and printing supplies, office supplies, etc., all for Green Bank.

C. Very Large Array Operations

Operations with the completed portion of the Very Large Array will begin in 1977. However, there are items such as spare parts and motors for the antennas and replacement components for electronics that should be acquired in advance of the actual start of operations. Funds in the amount of $100,000 are planned for this activity.

VI. CONSTRUCTION

The construction of the Very Large Array (VLA) will continue in 1976, with new funds in the amount of $12,400,000. A detailed description of this program will be found in the VLA Project Plan submitted separately.

VII. PRELIMINARY FINANCIAL PLAN - 1976
(in thousands of dollars)

	(a) Actual Exp. 1975	(b) Comm. Carried to 1976	(c) Uncomm. Funds Carried to 1976	(d) New Funds 1976	(e) Exp. & Comm. (b,c,d) 1976
I. SCIENTIFIC RESEARCH					
A. Existing Operations					
Personnel Comp.	3585.0			4000.0	4000.0
Personnel Benefits	703.0			800.0	800.0
Travel--Domestic	214.0			210.0	210.0
Travel--Foreign	13.0			20.0	20.0
Comm. & Utilities	246.0			270.0	270.0
Computer Rental	458.0			475.0	475.0
Bldg. Rent & Maint.	124.0			130.0	130.0
Mgmt. Fee	125.0			125.0	125.0
Other Mat., Supp. & Serv.	1080.0	190.0		1195.0	1385.0
Misc. Revenue	(90.0)			(95.0)	(95.0)
Subtotal	6458.0	190.0	-0-	7130.0	7320.0
B. New Operations					
VLA Operations	-0-	-0-	-0-	100.0	100.0
Subtotal	-0-	-0-	-0-	100.0	100.0
C. Equipment					
Research Equipment	651.6	317.0	372.0	510.0	1199.0
Operating Equipment	114.0	10.5	-0-	60.0	70.5
Subtotal	765.6	327.5	372.0	570.0	1269.5
TOTAL - SCIENTIFIC RESEARCH	7223.6	517.5	372.0	7800.0	8689.5
II. CONSTRUCTION					
Very Large Array	12070.0	6400.0*	<2896.4>*	12400.0	15903.6
Other	2.3	87.7	-0-	-0-	87.7
TOTAL - CONSTRUCTION	12072.3	6487.7	<2896.4>	12400.0	15991.3
TOTAL	19295.9	7005.2	<2524.4>	20200.0	24680.8

* $6.0M of the CY 1976 VLA funds were made available in CY 1975, and commitments were made against these funds.

Note: This is a preliminary plan based on estimated 1975 figures. The final Financial Plan, reflecting actual year-end figures, will be submitted early in 1976.

APPENDIX A

NRAO SCIENTIFIC STAFF PROGRAMS

Research on the following scientific programs has been planned for 1976 by the permanent staff of the NRAO. Some of the work will be done in collaboration with visiting scientists.

A. Galactic Studies

1. Hydrogen Line

The NRAO spectral-line interferometer has been used to detect bright concentrations within high velocity clouds. These concentrations have diameters ~5 minutes of arc and may not be optically thin. Since the nature of these concentrations has considerable bearing on theories of the origin of the high velocity clouds, they will be further studied in a full aperture synthesis program.

The neutral hydrogen absorption profiles of a number of HII regions are being used in studies of the spatial structure and thermal and chemical states of the interstellar medium, of the distances to the HII regions, of galactic structure, and of the nature of the hydrogen associated with, and affecting the development of, the HII regions. Further observations in these fields will include (1) high resolution aperture synthesis of four strong HII regions, (ii) short-spacing observations of four unusual HII regions, and (iii) a limited aperture synthesis at several locations within a large HII complex. This complex has short-spacing absorption profiles which, if taken at face value, suggest that the complex is extragalactic.

Experiments are being designed to search for an HI envelope surrounding our Galaxy that might be similar to the extensive envelope that has been found to surround the Andromeda galaxy. Observations with high sensitivity will investigate the nature of the transition region between the nuclear bulge and the galactic disk.

2. Radio Stars, Novae, and Supernovae

Observations of radio stars, radio counterparts of X-ray sources, and of novae will be continued. Emphasis will be placed on the determination of the time dependence of the radio emission from the bright nova Nova Cygni 1975, as well as on the close binary systems of the type RS Canes Venatici.

Many of the NRAO telescopes will participate in the widely coordinated study of UV Ceti flare stars. Observations of radio stars at millimeter wavelengths will be made with the 36-foot telescope. Measurements of the flux of Cas A at frequencies near 1400 MHz will be continued.

Calculations will be made of the effects on the secondary member of a binary system when the primary undergoes a supernova explosion. This is of importance in understanding the subsequent evolution of galactic X-ray sources in which X-rays are produced by accretion onto a neutron star of material supplied by the secondary, since it is not known if the secondary can supply this material after being exposed to the supernova explosion.

3. HII Regions, Dust Clouds, and Infrared Objects

Measurements will be made of the radio continuum radiation from dark clouds both as emitted by discrete sources within the clouds and by the entire cloud as a whole. Discrete radio sources associated with dark clouds are signposts of early-type stars embedded in the clouds that ionize the gas in the near vicinity and appear as compact HII regions. These sources are detectable on the interferometer and an identification of their existence and position is crucial to a meaningful analysis of molecular spectral-line data from these clouds. On the other hand, synchrotron radio emission from dark clouds is expected from the entire extent of dark clouds if the magnetic field of the general interstellar medium is compressed isotropically as the cloud condenses. After the magnitude of this type of emission has been estimated theoretically, an observational search will be made for it.

Another facet of the problem of early stars embedded in dark clouds will be studied by observations of OH and formaldehyde (H_2CO) at and near the position of such stars. Such data may enable the determination of both the excitation conditions and the chemical abundances in the clouds near the exciting stars.

An extensive survey of the high-frequency recombination lines of hydrogen and helium in a large number of HII regions will be made, in order to pursue the cosmologically important question of the ratio of helium to hydrogen in the galaxy. Such recombination lines appear to offer the best possibility for an accurate determination of this ratio.

Recently, molecular emission has been detected from CRL 2688, an object thought to be either an early form of planetary nebula or a much younger (pre-main sequence) object. The results indicate that it is a planetary nebula and, when taken in conjunction with earlier work on similar objects (IRC 10216, CRL 618), suggest an evolutionary sequence for the

formation of planetary nebulae from evolved carbon stars. This concept will be further explored by studying several similar objects in the lines of CO, HCN, CS and HC_3N.

A theoretical study of radiation transfer in dusty HII regions will be made in hopes of better understanding the role of dust in determining the structure and emission of such regions. Results will also be applied to planetary nebula and galactic nuclei. Another analysis of infrared emission from shells around late-type giant stars will be extended to include an examination of radiation pressure-driven mass loss in such stars. Such an analysis could lead to a better understanding of the role of these stars in the replenishment of the interstellar medium.

Studies will be continued of the general correlation of IR, compact continuum, and molecular line emitters, in an effort to understand the early phases of star formation.

4. Molecular Line Studies

The investigation of galactic structure using the carbon monoxide lines near 2.6 mm will be continued. These lines provide, by implication, the galactic distribution of molecular hydrogen, the predominant constituent of the interstellar gas. Amongst the goals are the measurement of the degree of confinement of carbon monoxide to the geometrical plane of the galaxy, the examination of the rotation curve and the relative motions of hydrogen and carbon monoxide, and the investigation of the fine-scale velocity and spatial distribution of CO in the region of the galactic center. Complementary theoretical studies involve modelling of theoretical CO profiles in an attempt to simulate the apparently unsaturated profiles produced by optically thick gas.

The large-scale survey of galactic OH has been completed and will also be used in an analysis of the distribution of gas in the galaxy.

Observations of the kinematic and spatial distribution of carbon monosulphide will be used to study the regions of high gas density in the galactic nucleus.

An attempt will be made to confirm the tentative detections made during the past year of several new species--ketene (H_2CCO), methyl mercaptan (CH_3SH), and deuterated ammonia (NH_2D). The vibrational-rotational interactions in the newly discovered cyanamide (NH_2CN) will be studied both by further observations with the 36 foot and by laboratory work at the National Bureau of Standards.

A new picture of interstellar molecule formation is being developed which combines the salient features of ion-molecule reactions with some new aspects of catalytic reactions on the surfaces of dust grains, not previously applied to the interstellar problem. This picture promises to explain several hitherto puzzling aspects of interstellar molecules such as the absence of N-O bonds, and how the more complex molecules can form and avoid freezing out on cold surfaces in the absence of UV radiation. It may also explain the absence of the simplest Mg, Fe, P, and Cℓ-containing molecules which have been sought unsuccessfully for some time.

B. Studies of Extragalactic Sources

1. Flux Densities of Radio Galaxies and Quasars

The program of monitoring 250-1000 MHz variable sources on the 300-foot telescope will be continued. At least five and possibly eight sources have been observed to be variable in this frequency range, one of which has not been previously reported. There is evidence (contrary to other studies) that the variability is coherent over one or more frequency octaves, and the prime objective in the coming year will be to confirm or deny this possibility.

Source surveys are planned of selected groups of quasistellar sources, including a number of bright new objects found in an optical survey at Caltech, and of rich clusters of galaxies. A major sky survey will be started with the 300 foot at 9 cm wavelength, using a new radiometer.

2. Angular Structure of Radio Galaxies and Quasars

Three interesting cluster sources (1159+583, 1200+519, and 1638+538) found during the interferometer survey of rich clusters are being mapped at 2695 and 8085 MHz. Complementary work is also being carried out at Westerbork on these sources and three others (1339+266, 1636+379, and 1709+397). Optical spectra of the associated clusters are being obtained at Kitt Peak and McDonald observatories.

Detailed studies are being made of a number of individual sources, including the head-tail galaxy NGC 1265 and four clusters of galaxies containing sources (Abell 576, 665, 1904 and 2256).

The Very Long Baseline Interferometer technique will continue to be used to monitor the temporal variations in flux density and structure of compact components in radio galaxies and quasars. However, an increasing fraction of the VLB observations will be made with five or more antennas, obtaining both visibility amplitudes and phases, in order to reconstruct images of radio sources. Such maps will have, for example, an angular

resolution of 0.01 arcsec at 18 cm wavelength. These observations will be used to investigate the frequency with which compact sources occur in extended radio galaxies, and to determine the shape of the spectra in the compact components, especially for frequencies at which these sources are optically thick.

Interferometric observations will be made to investigate the structure of a complete sample of quasistellar sources, and to compare the radio and optical orientations of sources in elliptical galaxies. Studies of the structure of sources in rich clusters of galaxies will be completed.

3. Theories of Radio Galaxies

A number of theoretical analyses will be made of the mechanism by which relativistic particles are produced and accelerated in radio sources, and of the energy loss mechanisms which might obtain in a typical radio source. For example, an investigation will be made of in-situ particle acceleration which results from turbulence of the thermal plasma in extended sources. The turbulence is generated by the passage of the source through the surrounding medium.

The results of recent calculations predicting the theoretical polarization behavior of compact extragalactic nonthermal sources will be compared with recent observational information in hopes of evaluating the predictions and learning more about the physical parameters of these sources. Other sources comprised of a mixture of condensed objects and thermal plasma will also be studied.

4. Normal Galaxies and the Intergalactic Medium

In early 1975, CO was detected in several external galaxies. The CO emission was remarkable for its strength and velocity range, although several of the galaxies were unusual in other respects (strong IR emission, evidence of explosions or very active nuclei). Maps of the CO gave preliminary rotation curves, which are essential in understanding the dynamics and masses of these systems. This work will be continued by (i) obtaining better rotation curves further out from the galaxy centers; (ii) obtaining a better sample of galaxies to determine what aspects are most correlated with the presence of copious amounts of molecules; and (iii) trying to detect other molecules (HCN, CS), and the ^{13}CO isotope in the most promising cases (M82, NGC 253).

The integral properties of a sample of apparently bright spiral galaxies are being derived from 21 cm hydrogen-line studies. This study,

based on a catalogue of galaxies brighter than 13^{th} magnitude is being augmented by observations of a uniformly distributed sample of late-type, high-luminosity spirals (ScI-II) to better define the intrinsic dispersion of these properties. This latter sample will also yield information on galactic extinction and the motion of the local group.

The survey, using the 140-foot and 300-foot telescopes, of hydrogen in 1400 galaxies is essentially complete and will form the basis of a completely new picture of the distribution of galaxies in the local universe. The survey has uncovered several possible new candidates for inclusion in the "Local Group" of galaxies, and optical observations will be undertaken of these objects in an attempt to estimate their distances by resolving them into stars.

An extensive program to detect or to set stringent upper limits to any intergalactic neutral hydrogen is planned (part of this program is underway now). This will involve 21-cm absorption measurements against radio sources located in the general field and in the direction of galaxy clusters, the latter to search for intracluster neutral hydrogen. These data will be combined with the extensive set of blank field measurements which are incidental to total power observations and which yield information on intergalactic hydrogen concentrations in emission. Such concentrations have been described near two late-type spirals, NGC 55 and NGC 300. These spiral regions as well as other fields near galaxies will be searched for both confirmation and possible additional concentrations. Because the reported concentrations may be part of the Magallenic stream, selected regions of this stream will be observed in some detail to better understand its small-scale spatial and velocity structure.

The intergalactic medium is also the subject of a theoretical investigation which attempts to determine the rate at which gas is removed from galaxies in clusters as they move through the intercluster medium, and the rate at which this motion heats the medium.

A method to derive the dynamical age of clusters of galaxies from observed density distribution is being developed, using numerical N-body integrations. The analysis of equal-mass systems is finished, and that for systems with realistic mass spectra is in preparation.

5. Accurate Positions and Astrometry

Absolute positions will be measured, as accurately as possible, for approximately 40 unresolved sources, using the 35 km interferometer. These objects are well distributed over the sky north of -20° declination. It is expected that this work will provide basic astrometric data on, for example, polar motion, the determination of time, and the constants of precession and nutation, as well as providing a direct tie-in to the FK 4 and FK 5 astrometric systems.

APPENDIX B

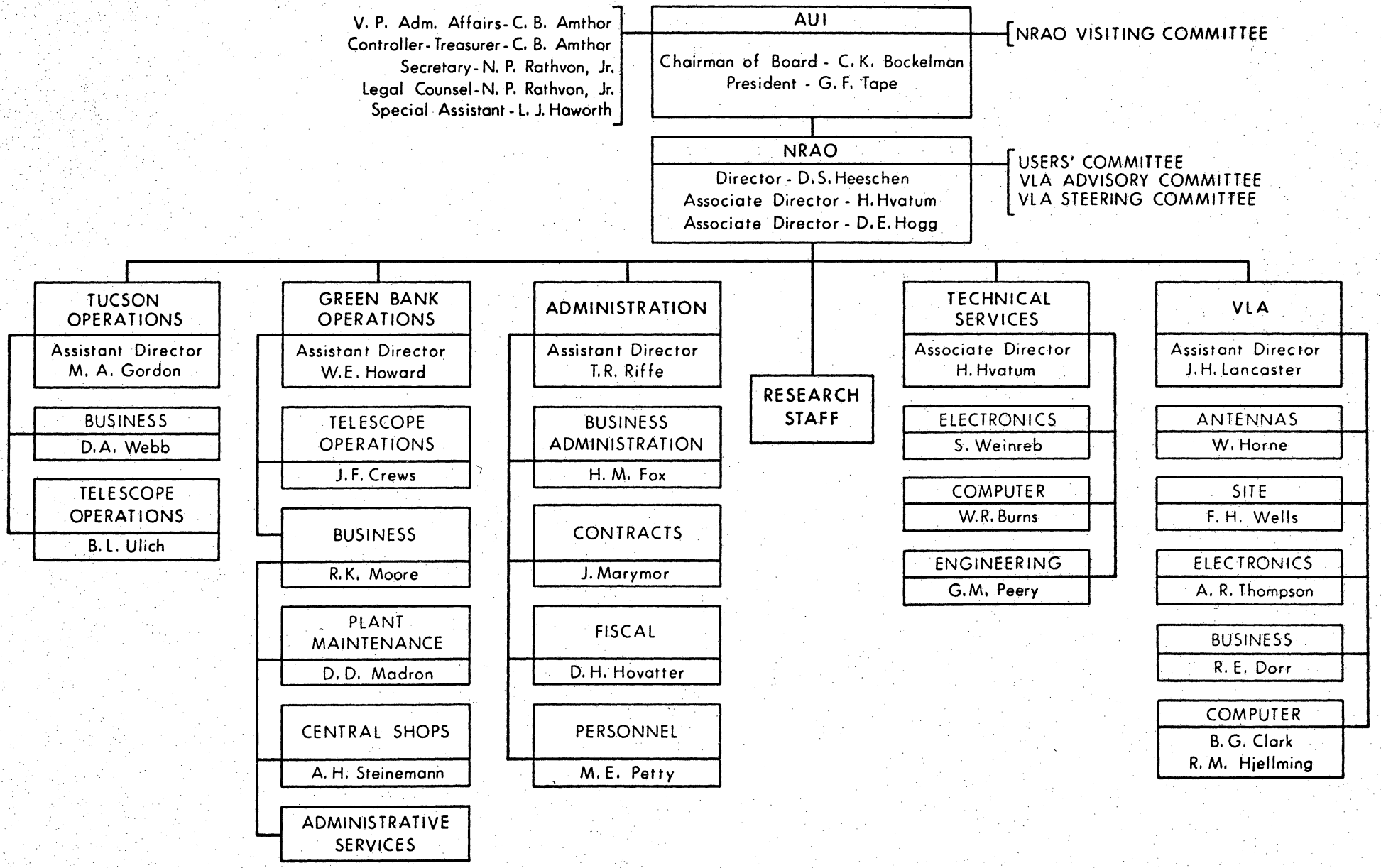
NRAO PERMANENT SCIENTIFIC STAFF WITH MAJOR SCIENTIFIC INTERESTS

(December 1, 1975)

Brown, R. L.	Theoretical Astrophysics; Interstellar Medium
Burton, W. B.	Neutral Hydrogen; CO; Galactic Structure
Clark, B. G.	VLB; Interferometry; VLA Development
De Young, D. S.	Theories of Extragalactic Radio Sources; High Energy Astrophysics
Findlay, J. W.	Absolute Flux Density Measurements; Telescope Design
Fisher, J. R.	Hydrogen in Dwarf Galaxies; Low Frequency Radio Astronomy
Fomalont, E. B.	Interferometry; Extragalactic Radio Sources; Relativity Tests
Gordon, M. A.	CO; Galactic Structure
Greisen, E. W.	Line Interferometry; Interstellar Hydrogen
Hjellming, R. M.	Radio Stars; VLA Development
Jones, T. W.	Theoretical Astrophysics; Nonthermal Sources; Galactic Nuclei
Kellermann, K. I.	Spectra and Structure of Extragalactic Sources; VLB
Owen, F. N.	Continuum Emission and Radio Spectra of Galaxies and Clusters
Roberts, M. S.	Extragalactic Research
Shaffer, D. B.	VLB; 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 15, 1975



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:

E. J. Blum	Meudon Observatory
R. D. Ekers	Kapteyn Laboratory, Groningen
C. E. Heiles	University of California, Berkeley
F. J. Kerr	University of Maryland
V. C. Rubin	Dept. of Terrestrial Magnetism
E. E. Salpeter	Cornell University
P. Thaddeus	Institute for Space Studies
D. T. Wilkinson	Princeton University

NRAO Users' Committee

This Committee consists of users, and potential users, of NRAO facilities from throughout the scientific community. It advises the Director and Observatory staff on all aspects of Observatory activities that affect the users of the telescopes--development of radiometers and auxiliary instrumentation, operation of the telescopes, the computer and other support facilities, and major new instruments. This Committee is appointed by the NRAO Director and meets twice a year.

The present membership of this Committee is:

B. Balick	University of California, Santa Cruz
A. H. Barrett	Massachusetts Institute of Technology
J. J. Broderick	Virginia Polytechnic Institute and State University
B. F. Burke	Massachusetts Institute of Technology
T. A. Clark	Goddard Space Flight Center
J. J. Condon	Virginia Polytechnic Institute and State University

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
S. J. Goldstein	University of Virginia
C. E. Heiles	University of California, Berkeley
M. Kaftan-Kassim	State University of New York, Albany
F. J. Kerr	University of Maryland
H. C. Ko	Ohio State University
M. R. Kundu	University of Maryland
A. E. Lilley	Harvard College Observatory
H. S. Liszt	University of Pittsburgh
C. H. Mayer	Naval Research Laboratory
P. Palmer	University of Chicago
K. W. Riegel	University of California, Los Angeles
A. G. Smith	University of Florida
L. E. Snyder	University of Illinois Observatory
P. Solomon	State University of New York, Stony Brook
G. W. Swenson	University of Illinois
J. H. Taylor	University of Massachusetts
P. Thaddeus	Institute for Space Studies
G. L. Verschuur	University of Colorado
J. F. C. Wardle	Brandeis University
J. W. Warwick	University of Colorado
G. Westerhout	University of Maryland
D.R.W. Williams	University of California, Berkeley
R. W. Wilson	Bell Telephone Laboratory
W. J. Wilson	Aerospace Corporation
B. Zuckerman	University of Maryland

VLA Advisory Committee

The VLA Advisory Committee will periodically review 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 will advise 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.

When scientific observing commences, this group may also advise on the observing programs to be carried out.

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

The current membership of the Committee is:

B. G. Clark
J. W. Findlay
E. B. Fomalont
E. W. Greisen
R. M. Hjellming
D. E. Hogg
K. I. Kellermann
F. N. Owen
C. M. Wade