NATIONAL RADIO ASTRONOMY OBSERVATORY

LONG RANGE PLANS CY 1979-CY 1983

April 15, 1977

INTRODUCTION

The National Radio Astronomy Observatory, as one of the national centers sponsored by the National Science Foundation, is charged with the responsibility of providing forefront radio telescopes for the use by the radio astronomy community. In furtherance of this role, the NRAO currently operates four major telescope systems: the 300-foot transit telescope, the 140-foot telescope, the four-element interferometer, and the 36-foot millimeter wavelength telescope. Each of these instruments has unique properties, so that the demand for telescope time continues to be high. However, after reviewing the nature of the research that is currently being conducted with these instruments, we can anticipate that major changes in them will have to be made to meet the demands of the research of the early years of the next decade. These instrumental developments may conveniently be grouped into four categories.

1. Completion and Operation of the Very Large Array. The characteristics of this instrument and its potential for research at centimeter and decimeter wavelengths on objects requiring high sensitivity and angular resolution have been described extensively elsewhere. We assign the highest priority to successfully completing it, on schedule, in 1981. This will require money for construction in CY 1979 and CY 1980. It is also of importance to support the operations with this instrument at a high level. A crucial element in the operations support, beginning CY 1981, is money for further development of the electronics, in order that, with time, the frequency range and sensitivity of the instrument can be further improved; the amount of this support is $1M per year.

The four-element interferometer, having been superceded by the VLA in all aspects, will be closed.

2. Improved Capabilities for the Green Bank Paraboloids. Even with the advent of the VLA there will be a continuing need for filled apertures to address problems of extended sources with low surface brightness, and to provide high sensitivity over a wide range of frequencies in a manner not now possible with a multi-element array. The radiometers now used on the 300 foot and 140 foot are competitive with any used elsewhere in radio astronomy. However, maser technology has advanced to the point where in the near future it will be possible to provide low temperature systems at many different frequencies. A program has been started to provide such systems for the 300 foot, over the range 500 MHz to 5 GHz, and for the 140 foot, over the range 5 GHz to 30 GHz. This program will require funding, in the Non-Expendable Equipment Account, at least into CY 1980.

The speed of digital logic has increased dramatically over the last decade, to the point where a new generation of autocorrelation receivers for use in spectral line studies can be introduced. This project is in progress, but will require Equipment funds through CY 1979. In later years an effort will be made to develop a receiver of this type for millimeter wavelengths, where the need for a large bandwidth is also critical.

3. Development of Millimeter Wavelength Instrumentation. The 36-foot telescope has been a heavy contributor to the progress of millimeter wavelength astronomy, especially in the frequency range 80-120 GHz where the radiometer development is furthest advanced. It is anticipated that within the next year new systems for the windows at 33-50 GHz and 125-160 GHz will be introduced, providing increased sensitivity for research at these frequencies. The next priority will be the development of a radiometer for 230 GHz, enabling observations of the important transitions of CO to be undertaken. Further funding in the Equipment account for the period CY 1979-1983 will be used in the development of very low noise systems based on a down-converter and maser or, possibly, on a Josephson junction.

In spite of these developments, which will keep the 36 foot at the forefront of the field, an increasing number of research problems will not

be addressed because of the limitations in resolution, collecting area and frequency coverage of the 36 foot. In recognition of these limitations the NRAO has proposed the construction of a 25-meter telescope capable of observing with good aperture efficiency in the window at 230 GHz, and which will also be usable in the window at 350 GHz (800 μm). This telescope has been described in more detail elsewhere. The estimated time required for detailed design and construction is three years. If the detailed design can be started in CY 1979, the telescope could become operational in CY 1982. The estimated cost of the project is $12.5M, in 1976 dollars, corresponding to a cost of $16.3M in CY 1980, at an assumed annual escalation of 7 percent.

4. Development of Very Long Baseline Interferometry (VLBI). The VLBI technique has developed over the last ten years and has, for example, demonstrated the existence of very small sources in the nuclei of certain spiral and radio galaxies, and has found compact components in some quasars which are expanding with apparent speeds greater than that of light. Much of the current work, in both line and continuum, requires the capability of mapping the brightness distributions in sources. To facilitate these observations, a number of U.S. institutions, including the NRAO, have joined together to form a Network Users Group, which acts to coordinate the use of the various antennas in the U.S. as elements in a VLBI network. As many as seven antennas have been used in VLB experiments.

One of the principal limitations of present observations is sensitivity. The NRAO has begun the development of a new broadband recording system (the Mark III) which will provide an increase by a factor of 28 in the bandwidth of the current Mark II system. This corresponds to an increase of a factor of 5.3 in sensitivity. Completion of the recording systems and the development and completion of a five station processor will require funding in the Equipment accounts through CY 1981.

Another limitation is the incompleteness of the sampling of the spatial spectrum of the source, arising because of the peculiarities of the location of existing radio telescopes. A major improvement could be

achieved by placing a 25-meter telescope at a midwestern site. The NRAO urges the NSF to undertake this project, and to this end we have included the construction of such a telescope in this long range plan. Obviously only one such telescope is required, and were the telescope to be funded through some other institution, the NRAO would withdraw its request.

THE LONG RANGE PLAN CY 1979-1983

For each year of this period two different funding levels are described. The Low Level provides for only minimal expansion of the NRAO. The Need Level provides for both the 25-meter millimeter wavelength antenna and the midwest VLBI antenna, as well as a moderate increase in the scientific and technical staffs.

CY 1979. The amount of $11.7M shown for radio astronomy research operations envisions a scientific, engineering, and support staff of 322, of whom 90 (including those from Common Cost) will be working with the completed portion of the VLA. By the end of the year there will be 22 operational antennas and about 34 km of track with associated stations.

This year's VLA construction will provide for the completion of the final six antennas started the previous year ($0.5M), five sets of antenna electronics and completion of procurement of the spectral-line processor ($2.4M), continuation of the programming of the continuum computer and procurement of the remaining components of the spectral-processor computer ($0.8M), the start of construction of the remaining 27 km of wye ($8.7M), and project management and common costs ($0.6M).

The detailed design of the telescope and astrodome for the 25-meter millimeter-wave antenna will be started and completed during the year. Construction of the telescope could start early in 1980.

CY 1980. An increase of $2.5M is planned in the operations budget, with the principal areas of growth being in general technical support, in millimeter-wavelength support, and in operations of the VLA. An additional $0.4M is included for the rental of a large central computer facility.

This year's VLA construction will provide for outfitting of the final antennas ($0.15M), three sets of antenna electronics ($1.6M), completion of the programming of the continuum computer ($0.15M), completion of the waveguide system ($0.6M), and project management ($0.1M). The construction phase of the project will be completed by the end of the year.

At the Opportunity Level, a new 25-meter telescope for centimeter wavelengths will be acquired, at a cost of $2M. It will be used as an element in the network of telescopes used in very long baseline interferometry, and will be situated in the midwest.

The construction of the telescope for millimeter wavelengths will be started, at a cost of $14.9M.

CY 1981. The VLA will be fully operational, with 28 antennas, 61 km of wye, and a staff of 108 people. A large increase in funds ($1.0M) in the category of non-expendable equipment, to be used for research instrumentation, is required to ensure that the electronics on the array are kept at the state of the art.

The other principal area of growth is in millimeter wavelength support, where funds have been assigned to build research instruments for the 25-meter telescope and to start to add the operating staff. An amount of $0.3M is allocated to VLB operations with the new antenna.

CY 1982. The 25-meter antenna will be completed and become operational during this period. Other operations will continue at slightly higher levels, with the principal increase resulting from escalation.

CY 1983. The staff level in this year will be approximately 412 persons. The increase in costs results primarily from escalation.

LONG-RANGE PLAN: CY 1979-CY 1983
($ in Millions)

PROGRAM: NATIONAL RADIO ASTRONOMY OBSERVATORY (NRAO)

	CY 1977	CY 1978	CY 1979 SCIENTIFIC NEED LEVEL	CY 1979 LOW LEVEL	CY 1980 SCIENTIFIC NEED LEVEL	CY 1980 LOW LEVEL	CY 1981 SCIENTIFIC NEED LEVEL	CY 1981 LOW LEVEL	CY 1982 SCIENTIFIC NEED LEVEL	CY 1982 LOW LEVEL	CY 1983 SCIENTIFIC NEED LEVEL	CY 1983 LOW LEVEL		
RADIO ASTRONOMY														
Green Bank-Charlottesville Operations	7.09	6.56	7.38	7.38	8.61	8.61	9.58	9.26	10.43	10.05	11.34	10.85		
Very Large Array Operations	0.70	1.20	2.50	2.50	3.36	3.36	3.77	3.77	4.00	4.00	4.24	4.24		
Millimeter Wave Operations	0.71	0.75	0.79	0.79	0.94	0.86	1.63	0.95	2.75	1.01	2.91	1.07		
Non-Expendable Equipment	0.80	0.79	1.03	0.63	1.30	1.00	2,50	2.00	2.50	2.00	2.50	2.20		
Subtotal	9.30	9.30	11.70	11.30	14.21	13.83	17.48	15.98	19.68	17.06	20.99	18.36		
SITE DEVELOPMENT/ CONSTRUCTION														
Very Large Array	12.50	13.00	13.00	13.00	2.60	2.60	-	-	-	-	-	-		
Millimeter-Wave Telescope	-	-	1.40	-	14,90	-	-	-	-	-	-	-		
Mid-West VLB Antenna	-	-	-	-	2.00	-	-	-	-	-	-	-		
Subtotal	12.50	13.00	14.40	13.00	19.50	2.60	-	-	-	-	-	-		
TOTAL	21.80	22.30	26.10	24.30	33.71	16.43	17.48	15.98	19.68	17.06	20.99	18.36		

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	CY 78*	CY 79	NEED CY 80	LOW CY 80	NEED CY 81	LOW CY 81	NEED CY 82	LOW CY 82	NEED CY 83	LOW CY 83	NEED CY 84	LOW CY 84	
OPERATIONS - GREEN BANK; CHARLOTTESVILLE; TUCSON													
Salaries and Wages	4270	4425	5035	4990	5815	5395	6540	5855	7110	6340	7685	6840	
Benefits	875	905	1035	1025	1195	1105	1345	1205	1455	1295	1575	1405	
Divisional Materials, Supplies, & Services	1170	1460	1660	1640	1990	1780	2955	1945	3165	2080	3410	2245	
General Materials, Supplies, & Services	1015	1080	1450	1450	1550	1540	1650	1630	1785	1750	1895	1850	
Travel	285	300	370	365	425	390	610	425	655	455	705	495	
Subtotal	7615	8170	9550	9470	10975	10210	13100	11060	14170	11920	15270	12835	
EQUIPMENT	785	1030	1300	1000	1500	1000	1500	1000	1500	1200	1500	1200	
TOTAL OPERATIONS - GREEN BANK: CHARLOTTESVILLE; TUCSON	8400	9200	10850	10470	12475	11210	14600	12060	15670	13120	16770	14035	
* Assumes $300k from CY 1977													
VLA OPERATIONS (incl. eqpt.)	1200	2500	3360	3360	5000	5000	5240	5240	5490	5490	5765	5765	
TOTAL OPERATIONS - NRAO	9600	11700	14210	13830	17475	16210	19840	17300	21160	18610	22535	19800	
CONSTRUCTION													
VLA	13000	13000	2600	2600	-	-	-	-	-	-	-	-	
25-meter Millimeter Wave Telescope	-	1400	14900	-	-	-	-	-	-	-	-	-	
VLB Array									38.75M				