

PROGRAM OBJECTIVES

LONG RANGE PROGRAM ESTIMATES CY 1978 - 1982

PROGRAM/PROJECT: NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory operates major radio telescopes for use both by visiting scientists and the NRAO staff in the course of their research in radio astronomy. The objectives during the period CY 1978-1982 are to:

- Undertake studies of the nature of radio emission from objects in our solar system and in our Milky Way, and from quasistellar sources, galaxies, and clusters of galaxies lying beyond the Milky Way. The investigations of the distribution of gas in the Milky Way using line radiation from various interstellar molecules show the potential that this technique holds for the fields of galactic structure and star formation. The recently discovered "head-tail" radio galaxies offer the possibility of studying the rate at which energetic particles are released during the lifetime of the parent object.
- Continued operation, maintenance, and upgrading of observing facilities. The VLA will come into full operation during this period, providing a major new instrument for the study of the brightness distributions in radio sources, and for the study of very faint sources. New receivers will be developed to permit observations of much greater sensitivity. At centimeter wavelengths maser radiometers show the most promise; further research will be required to determine the best radiometers for millimeter wavelengths. Modifications to existing telescopes will improve their surface accuracy, thereby increasing the efficiency with which they receive radio waves.
- Design and construct new research facilities. The construction of the VLA will be completed during this period. Construction of a 25-meter telescope for use at millimeter wavelengths is proposed for 1977. Acquisition in 1981 of an antenna to provide critically needed baselines is envisioned as the first step towards an intercontinental array.

PROGRAM ESTIMATES CY 1978-1982

PROGRAM/PROJECT: NATIONAL RADIO ASTRONOMY OBSERVATORY (excluding VLA Construction Project)

Calendar Years	1975	1976	1977*	1978	1979	1980	1981	1982
Planning Level	7.5	8.0	9.1	10.7	12.5	14.4	16.3	17.4
Opportunity Level			20.3	10.9	13.6	15.8	19.9	19.3

\*Includes \$2.3M for transition budget.

- Planning Level
- Operation of all major telescopes will continue. The 300-foot and 140-foot telescopes will be maintained, and upgraded where possible. Initial operations with the completed portion of the VLA will begin in CY 1977. Millimeter-wave research will continue with the 36-foot telescope. Continued operation of the interferometer in Green Bank will be reviewed when the impact of the VLA has been assessed.
  - New electronics systems will be introduced, including maser radiometers for Green Bank and the next generation of recording/processing equipment for long-baseline interferometry.
- Opportunity Level
- Capabilities for millimeter-wave research will be expanded when the 25-m millimeter-wave telescope becomes operational in CY 1980.
  - The first step in the construction of an intercontinental array will be made by acquiring a 25-m centimeter-wavelength antenna, to be located geographically so that it fills in the baselines not sampled by the network of existing antennas.
  - Buildings for the Green Bank site include a front-end box facility (CY 1978) and a tour center (CY 1979).

PROGRAM ESTIMATES CY 1978-1982

PROGRAM/PROJECT: VERY LARGE ARRAY (VLA) CONSTRUCTION PROJECT

Calendar Years	1975	1976	1977*	1978	1979	1980	1981	1982
Planning Level	13.0	13.0	13.0	13.0	13.0	5.0	0	0
Opportunity Level				13.0	13.0	5.0	0	0

\* Includes the transition budget of \$3.5 million.

Planning Level - The funding schedule shown will enable completion of the construction phase of the VLA in CY 1980.

Opportunity Level - The Opportunity Level is the same as the Planning Level.

## BRIEF DESCRIPTION OF THE PROGRAM CY 1978-CY 1982

The broad field of galactic studies will continue to be an area of productive research, with new instrumentation playing an important role. Studies of collapsing interstellar clouds, of protostars, and of newly-formed stars embedded in the gas from which they condensed will be made using high-resolution continuum maps, observations of recombination lines of various elements, and measurements of line strengths of emission from various molecules. Many of the same techniques can be used in the study of stars at the other end of the stellar evolutionary sequence--stars such as novae, X-ray stars, and planetary nebulae. Of particular value in the further investigation of variable radio stars will be coordinated observations at radio, optical, ultraviolet and X-ray wavelengths. On a larger scale, continued studies of molecular line radiation offer the possibility of measuring the detailed distribution of the cold gas in the Milky Way, and of determining the relative abundance of common atoms and their isotopes as a function of position within the Milky Way.

Recent observations of compact variable sources in extended radio galaxies and quasars and of "head-tail" radio galaxies have given a new stimulus to the quest for an understanding of the energy processes involved in these objects. The compact variable sources, best studied by long-baseline interferometry, are found in many extended radio galaxies and apparently are the site of a relatively recent release of a large amount of energy. The head-tail galaxies often show a central compact object, but as well have a long and well-ordered train of radio emission extending behind them, giving in effect a historical record of the outbursts which the parent object has undergone. The relationship between these two types of radio galaxies, as well as the role that clusters of galaxies play in the formation of extended components, are promising avenues of future research which can be explored with detailed maps from the VLA and high-resolution studies by long-baseline interferometers.

Investigations of normal galaxies, particularly of types spiral and irregular, will be continued. Such objects are valuable for testing theories of spiral structure, since differences in the distribution of the cold interstellar gas, dust, and young, hot stars can now be measured accurately. Other measurements will be used to infer the total mass of typical objects, either from the observed rotation curves or from the observed effects of companion galaxies.

The scientific programs summarized briefly in the preceding paragraph will require the NRAO to maintain state-of-the-art instrumentation on the 300-foot and 140-foot telescopes, and to bring the Very Large Array and the 25-meter millimeter telescope into operation as rapidly as possible. The details of the long-range plan to accomplish this objective are as follows:

CY 1978 - The amount of \$10.7M shown for radio astronomy research operations includes \$6.7M for salaries, wages and fringe benefits of the scientific, engineering and support staff of 309 persons. The completed portion of the VLA will be brought into operation, and will comprise 15 antennas and about 49 km of wye by the end of the year. Construction of the 25-m millimeter antenna which was requested at the Opportunity Level in CY 1977 will begin. A new facility for handling and storing front-end boxes will be constructed in Green Bank adjacent to the Indoor-Outdoor Test Facility, at a cost of \$0.1M.

The amount of \$13.0M for ongoing VLA construction will be used to order five antennas (\$3.8M), complete five sets of antenna electronics and the initiation of the spectral processor (\$2.4M), continuation of programming of the continuum computer and procurement of the spectral-line computer components (\$0.7M), construction of 15 km of wye (\$5.7M) and provision of project management (\$0.4M).

CY 1979 - An increase of \$1.9M is planned in the operations budget, with the principal areas of growth being in millimeter wavelength support and in operations of the VLA. By the end of the year the completed portion of the VLA will include 20 antennas and about 61 km of track.

This year's VLA construction will provide five antennas (\$3.9M), five sets of antenna electronics and completion of procurement for the spectral-line processor (\$2.2M), continuing programming of the continuum computer and procurement of the balance of the spectral-line computer components (\$1.1M), construction of 14 km of wye (\$5.5M) and project management (\$0.3M).

A tour center will be built at Green Bank (\$0.4M).

CY 1980 - The completion of the 25-m millimeter wavelength antenna will be accompanied by a further increase in the level of support of millimeter studies. Operation of the VLA, which will have 25 antennas and 63 km of wye by mid-year, will also require an increase in the level of support. Additional funds are required for a larger central computer at the Charlottesville laboratory. Completion of the VLA construction entails the final three antennas (\$2.3M), three sets of antenna electronics (\$1.2M), final programming of the continuum computer (\$0.2M), construction of 3 km of wye (\$1.2M) and project management (\$0.1M).

CY 1981 - The VLA will be completely operational, with 27 antennas and 61 km of wye. A large increase in funds for research instrumentation will be required to ensure that the electronics on the array is kept at the state-of-the art.

At the Opportunity Level, a new 25-m telescope for centimeter wavelengths, to be used as an element of an intercontinental array, will be acquired, for a cost, including electronics, of \$2M.

CY 1982 - The staff level in this year will be approximately 395 persons, unchanged from the preceding year. The increase in operating costs results primarily from escalation, although there is a small increment at the Opportunity Level for the operation of the 25-m centimeter telescope.

#### IMPACT OF LOWER PROGRAM LEVEL

The principal impact of the lower funding level will be on research at millimeter wavelengths, a field which is now at a very fruitful stage in its development. If the 25-m millimeter-wave antenna is deferred and if the support levels are not therefore increased, many of the research programs now envisioned for this period will not be completed, since they require greater sensitivity and resolution at shorter wavelengths than the 36-foot telescope is capable of providing.

The lower program level will require deferral of a long-baseline interferometer element critically needed to complement the baselines available with the network of existing telescopes.

Low-level funding will require indefinite deferral of the front-end box facility and the tour center for Green Bank.

LONG-RANGE PLAN: CY 1976 - CY 1982

(\$ in Millions)

PROGRAM: NATIONAL RADIO ASTRONOMY  
OBSERVATORY (NRAO)

	CY 1976	3 Months Period	CY 1977	CY 1978 Opportunity Level	CY 1978 Planning Level	CY 1979 Opportunity Level	CY 1979 Planning Level	CY 1980 Opportunity Level	CY 1980 Planning Level	CY 1981 Opportunity Level	CY 1980 Planning Level	CY 1982 Opportunity Level	CY 1982 Planning Level
Radio Astronomy													
Green Bank-Charlottesville Operations	6.53	1.74	6.92	7.63	7.60	8.26	8.13	9.28	9.09	9.93	9.70	10.80	10.35
Very Large Array Operations	0.10	0.18	0.70	1.50	1.50	2.49	2.49	3.36	3.36	3.68	3.68	3.93	3.93
Millimeter-Wave Operations	0.63	0.18	0.66	0.73	0.70	1.33	0.75	2.06	0.80	2.23	0.86	2.37	0.92
Non-expendable Equipment	0.74	0.20	0.82	0.90	0.90	1.10	1.10	1.10	1.10	2.10	2.10	2.20	2.20
Subtotal	8.00	2.30	9.10	10.76	10.70	13.18	12.47	15.80	14.35	17.94	16.34	19.30	17.40
Site Development/Construction													
Very Large Array	13.00	3.5	13.00	13.00	13.00	13.00	13.00	5.00	5.00				
Millimeter-Wave Telescope			11.20										
Intercontinental Array				0.10						2.00			
Other (Facilities)						0.40							
Subtotal	13.00	3.5	24.20	13.10	13.00	13.40	13.00	5.00	5.00	2.00			
TOTAL	21.00	5.80	33.30	23.86	23.70	26.58	25.47	20.80	19.35	19.94	16.34	19.30	17.40



NOTES TO TABLE

The following notes explain the assumptions upon which the long-range forecast on the previous page is based. It is noted that the funds for the transition quarter are assumed to be for the first quarter of CY 1977, and are also included in the totals shown for the whole year.

Green Bank-Charlottesville Operations - The Planning Level projections assume constant manpower levels of 238 permanent, full-time employees from CY 1978 through CY 1982. Dollar levels are based on an operating cost per man of \$29.8K in CY 1977, and assume an annual compounded cost escalation of 7% thereafter. An additional \$400K is included each year beginning in CY 1980 for rental of a larger computer facility. The Opportunity Level permits an increase in the staff, to 244 in 1982, and includes \$200K of additional support for long baseline interferometer operations, in CY 1982.

Very Large Array Operations - Operations with the completed portion of the VLA will begin in CY 1977 with a staff of 16, and will require a staff of 94 in CY 1981 when the array is fully operational.

Millimeter-Wave Operations - Planning Level projections assume a constant manpower throughout the period. Opportunity Level projections envision a major increase in support of the 25-m millimeter-wave telescope which would begin operation in CY 1980.

Non-Expendable Equipment - Planning Levels and Opportunity Levels are the same, and represent the expenditures required to keep the telescopes equipped with state-of-the-art radiometers. Both levels include \$100K for the VLA in CY 1979 and CY 1980, and \$1.0M for other Observing Equipment on the VLA in CY 1981 and CY 1982.

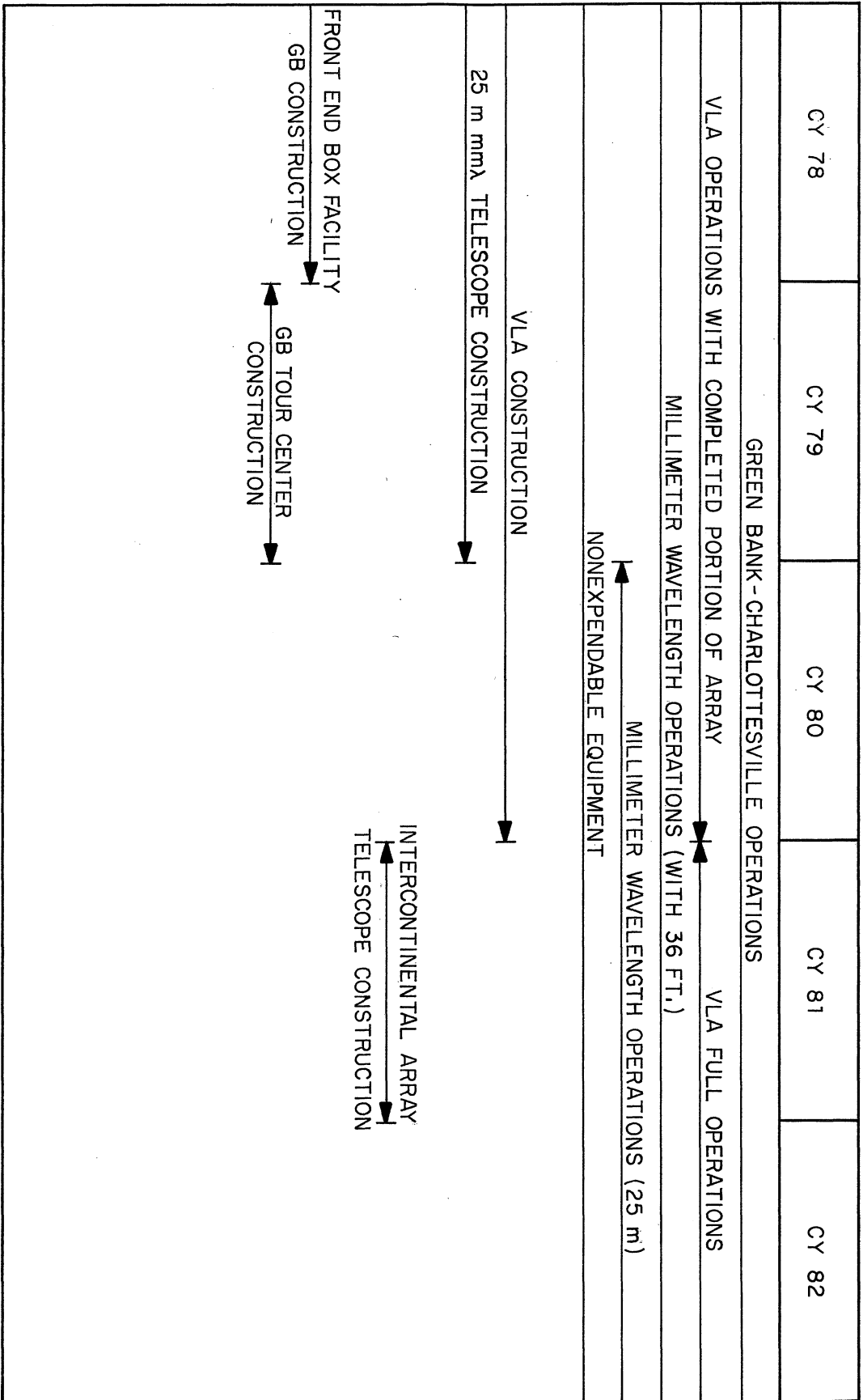
Very Large Array Construction - The Planning Level and Opportunity Level budgets are the same. The total estimated cost is \$78M, based on the re-estimate of the project made in August 1975. The construction plan is detailed in the VLA Project Plan for 1975.

Millimeter-Wave Telescope - Construction costs totaling \$11.2M are requested at the Opportunity Level in CY 1977 for a 25-m telescope capable of operating at 1.2 millimeter wavelengths. The telescope would become operational in CY 1980.

Intercontinental Array - As the first step towards an array of telescopes using long baseline interferometer techniques, the Opportunity Level in CY 1981 includes the acquisition of a 25-m antenna of the type used on the VLA.

Other (Facilities) - Included in this category at the Opportunity Level are a front-end box facility (\$100K) and a tour center (\$400K), both for Green Bank.

(SCIENTIFIC NEED LEVEL)



GANTT CHART

(LOWER LEVEL)

CY 78	CY 79	CY 80	CY 81	CY 82
GREEN BANK - CHARLOTTEVILLE OPERATIONS				
VLA OPERATIONS WITH COMPLETED PORTION OF ARRAY				
MILLIMETER WAVELENGTH OPERATIONS (WITH 36 FT.)				
VLA FULL OPERATIONS				
NONEXPENDABLE EQUIPMENT				
VLA CONSTRUCTION				

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