National Radio Astronomy Observatory
Green Bank, West Virginia

Quarterly Report

October 1 - December 31, 1964

RESEARCH PROGRAMS

85-foot Telescopes

During this quarter the 85-foot telescopes were used for two telescope observations (as an interferometer) with the exception of seven hours of lunar occultation observing with the 85-2 by S. von Hoerner at 234, 256, and 405 MHz.

The tabulation below reflects the use of the two telescopes as an interferometer.

		Hours
Scheduled		1724.25
Equipment installation and scheduled maintenance		153.25
Time lost due to:	equipment failure	330.5
	weather	.75
	interference	13.25
	power failure	1.50

The 85-2 telescope was moved from station 1 to station 2 on October 9, giving an interferometer baseline of 1500 meters, and has been used at this baseline length for two basic programs. The first program had as its objective the determination of highly accurate positions of small discrete radio sources. The second program constituted the first series of observations in a preliminary synthesis program which will provide data relating to the detailed brightness distribution of several of the most intense complex sources. The source position program included observations of about 30 discrete sources, each having a flux density greater than 2 flux units at 2695 MHz. Seven other sources were observed in the synthesis program.

In addition to the above, some observing time was devoted to measurements of system stability and baseline parameters necessary both for the calibration of the interferometer and for the design of the very large antenna array.

300-foot Telescope

		Hours
Scheduled		1892
Equipment installation and scheduled maintenance		195.5
Time lost due to:	equipment failure	113.25
	weather	10.25
	interference	13.00

During this quarter J. Baars observed specially chosen sources to appraise the telescope parameters at a frequency of 2695 MHz. At the same frequency H. Wendker continued galactic survey observations. Combined DTM and NRAO equipment was used by B. Burke and K. Turner (Department of Terrestrial Magnetism, Carnegie Institution of Washington, D.C.) for a sky survey at 234 MHz.

Observations with the autocorrelation receiver were made for the following programs: T. K. Menon observed absorption profiles of neutral hydrogen at positions of strong discrete sources. G. Westerhout (University of Maryland) continued observations of the galactic plane, and with W. E. Howard observed open clusters. C. Heiles (Princeton University) observed high latitude interstellar clouds. M. Roberts observed extragalactic systems to test the validity of data taken on the same sources with the NRAO multichannel receiver and collaborated with C. Wade in a study of M 82. G. Rougoor (Leiden Observatory) was engaged in a short program to supplement Leiden's program on galactic high velocity hydrogen clouds.

Millimeter Wave Program

The following programs are being carried out at 1.2 mm:

a) Solar observations with special emphasis on the affects caused by atmospheric water content on signal attenuation in the 1.2 mm region.

b) Observations of three selected areas of the moon during the lunar cycle in order to perform absolute temperature measurements as well as to determine cooling and heating rates during the lunation.

c) Continuing temperature measurements of the planets Venus, Jupiter, Saturn, and Mars when atmospheric conditions permit.

d) A receiver development program to reduce further the noise temperature of the detector as well as to increase the efficiency of the microwave feed system.

The total lunar eclipse of December 18-19 was observed at 1.2 mm, and preliminary data reduction indicates very good results were obtained relative to lunar cooling and heating during the eclipse.

A field trip to Mount Palomar is planned for the period January 11-22, 1965 to use the 200 inch optical telescope, at both 1.2 mm and 10 microns, for measurements of some faint thermal sources as well as all available planets.

The intermediate infrared program is being continued at the University of Arizona, and with the availability of some new filters, it is now being extended to the 5, 11, 12.8, and 20 micron wavelengths.

The 82 inch McDonald telescope was used during the period December 9-18 for a confirming measurement of 3C 273 and for some additional stellar measurements not possible with the 28 inch telescope at the University of Arizona.

ELECTRONICS DIVISION-EQUIPMENT DEVELOPMENT

Two 1400 MHz continuum radiometers for observation of polarization on the 300-foot telescope have been built. Tests of the system are being made on the 40-foot telescope. Work on radiometer systems for the 140-foot is continuing.

Cables for the interferometer have been completed to the 2400 m baseline (station 5).

Experience gained during routine observations with the interferometer suggests several possible improvements of the system, especially in the areas of data recording and monitoring of the instrument performance. Modifications of the present equipment are under construction.

The design of a permanent central control building for the interferometer has been started.

The following Electronics Division internal reports were issued during the report period:

No.	Title	Author	Date
36	The Characteristics of the NRAO 85-ft Telescope at 2.07 cm Wavelength	J. Baars and P. Mezger	Oct. 1964
37	Strip or Sky and Low Frequency Systems on 300-foot Telescope	D. Ross and Y. Terzian	Oct. 1964
38	A Ferrite Switch Driver	J. Dolan	Oct. 1964
39	Radiometer Systems for Observations of Lunar Occultations	B. Pasternak	Nov. 1964
40	NRAO Interferometer: Design, Operation and Early Results	N. Keen	Nov. 1964

No.	Title	Author	Date
41	NRAO Interferometer: The Delay Switching Computer	N. Keen	Nov. 1964
42	A Digital Cross-Correlation Interferometer	N. Keen	Dec. 1964
43	Design Studies for 127-channel Filter Hydrogen Line Radiometer	B. Hoglund	Dec. 1964

CONSTRUCTION

Charlottesville Laboratory Building

Bids from four contractors for the construction of the laboratory facility on the campus of the University of Virginia were opened on October 27. The contract was awarded to R. E. Lee & Son, Inc., of Charlottesville, Va., for $585,404 for the basic building on a 365 calendar day completion basis. Excavation for this facility was started on December 2.

THE 140-FOOT TELESCOPE PROJECT (October-December, 1964)

During October the NRAO Engineering Division completed the design of stiffener trusses for the quadrupod legs and an instrument stand for panel adjustments. The trusses were welded in place on the legs, along with cable supports.

In November designs were completed for an adjustable feed support. The work was ordered and is now scheduled to arrive in January 1965. Welding was completed on the lifting devices on the aluminum superstructure and, after one unsuccessful attempt at erection of the superstructure, the structure was raised on November 10, secured, and locked into position to prevent its rotation on the bearings. The quadrupod assembly was then lifted into place, the stools were welded and the assembly removed temporarily to permit the installation of the surface panels. By December 21 all panels were in place and the derricks were removed from the construction area. Meanwhile, work continued on such items as the hydraulic and electrical systems for the telescope, the acquisition of an emergency power generator and the installation of the polar drives and brakes. The antenna was rotated to the zenith position toward the end of December, where work is proceeding on the declination gear and drive unit and the placing of the declination counterweight.

In the next quarter work will continue on the declination gear, the telescope will be optically aligned, the panels tested and set, and pointing and tracking tests initiated.

THE NRAO MILLIMETER WAVE ANTENNA

Progress in engineering design of the telescope and dome at Rohr has been very satisfactory. By early December 1964 all the design drawings had been completed. Work had started on the foundations for the specially-built machine on which the 36-foot dish will be machined.

Consideration of the most desirable site continued until early December. The area around Los Alamos was surveyed as a possible alternate to Kitt Peak. At the AUI Trustees meeting of December 14, the Kitt Peak site was agreed upon; approval in principle had already been given by the AURA Trustees. The approval of the National Science Foundation is now being sought.

A site map has been prepared, a foundation survey by seismic methods and by rock drilling is underway, and the first draft of an administrative agreement between NRAO and KPNO is being considered.

ANTENNA DESIGN STUDIES

Since Dr. G. W. Swenson arrived at the NRAO, it has been possible to share responsibilities for work on the design of future antenna systems. The work on a large, high-resolution antenna, closely following the proposal of the Whitford Committee report, is being led by Dr. Swenson. The work for a study of the possibilities of building a large steerable filled-aperture antenna, also proposed by the Whitford Committee, is being led by Dr. Findlay.

The High Resolution Antenna (Very Large Antenna Array)

The problem of the Very Large Antenna Array is being considered in general. An ad hoc panel of astronomers from various institutions was convened on December 11-12 to discuss the mission and the astronomical parameters of the proposed antenna. This is to be the beginning of a continuing program of liaison with the astronomical and engineering communities.

The characteristics and performance of the long-baseline interferometer at NRAO are being observed very carefully in the light of their implications for the very large array, particularly as regards phase stability in the electronic system, atmospheric effects, and mechanical stability. Theoretical and experimental studies have been undertaken concerning the effects on baseline parameters of small errors in construction, illumination, and pointing of the constituent paraboloidal antennas of an array.

The Largest Feasible Steerable Paraboloid (LFSP)

The report of a meeting held at Green Bank, under the Chairmanship of Dr. Gart Westerhout, is reproduced below.

"AD HOC MEETING OF RADIO ASTRONOMERS:

Largest feasible steerable filled-aperture telescope

Green Bank, October 30, 1964

"Present:

R. N. Bracewell
B. F. Burke
F. D. Drake
J. W. Findlay
D. S. Heeschen
G. Keller
J. D. Kraus
A. E. Lilley
E. F. McClain
R. B. Read
M. S. Roberts
G. W. Swenson
H. F. Weaver
G. Westerhout

"The main aim of the meeting was to discuss the question of whether this is the time to start thinking about a design study for a very large steerable telescope. The meeting was unanimous in its positive answer. A very much larger steerable telescope than those now in existence or in the design stage is certainly needed. Since the time between initial studies and the completed instrument is long (8 years?), the next step in large telescope design should be started now. The N.R.A.O. is willing, and the meeting considered the staff able, to undertake a feasibility study. It was emphasized that the studies for a very large array should not in any way suffer from this new undertaking.

"After some discussion, it was decided that in order to make the telescope as universal as possible a more or less circular beam would be preferable. Thoughts will have to be concentrated mainly on some form of single-focus antenna, so that equipment from different observers can be easily interchanged. The steerability question was discussed at length and it was decided that a very considerable declination coverage would be most necessary. In particular, it was felt that both the Galactic Center and the Andromeda Nebula should be reachable, if at all possible. This requires a declination coverage of at least 70°, which in essence means a full declination coverage. The minimum coverage in right ascension should be at least one hour, in order to reach reasonable integration times. It was felt that a complete azimuth coverage was not necessary. One of the few fields in which complete sky coverage would be necessary is that of occultations. It has been shown that these can be more profitably observed at wavelengths longer than those for which the large telescope will be mainly used, and therefore would be better observed with an inexpensive special-purpose telescope.

"The telescope under discussion here should still be reasonably efficient down to 10 cm and in any case it should be fully operable at 18 cm.

"The main discussion centered around the question of size. The Whitford Committee Report states that a design study should be made of the largest feasible, movable telescope; the present meeting was called to implement this point. Within the next 10 years, several telescopes with diameters

of the order of 300 feet will be available. It is clear that with the present-day techniques, telescopes up to 450 feet are feasible. In fact, the initial studies of designs for this kind of diameter have been made. We are dealing with a feasibility study; therefore, our limits should be considerably higher. Although every increase in size is a step forward, the astronomers at the meeting were agreed that a step of at least a factor of 2 is a minimum for the largest instrument. Possible research projects for this telescope range through the entire field of radio astronomy and might even include a limited amount of planetary radar. In every single field, the highest possible resolution is required. It was therefore decided that the feasibility study should be of a telescope with a minimum diameter of 600 feet. This may well lead to completely new concepts in the construction.

"As was said before, this study is secondary to the study of a very large array, which was the highest priority item in the Whitford Committee Report. Also, it has been assumed throughout the meeting that at least two steerable telescopes of the order of 300 feet would be available within the next five years, built either by groups of Universities on the East coast and the West coast, and/or by the N.R.A.O.

"Summarizing, the meeting gave the N.R.A.O. a mandate to undertake a feasibility study of a steerable instrument with a circular beam, a diameter of at least 600 ft., useful down to 18 cm. and hopefully down to 10 cm."

As a result of this report, an outline program of work has been prepared by NRAO and will shortly be circulated widely to those who may be interested.

PERSONNEL

Mr. Y. Leonard Chow, a candidate for the Ph.D. degree in electrical engineering from the University of Toronto in early 1965, accepted a one year appointment as a research associate on October 5. His principal activity will be with Dr. George Swenson in the design study of a very large array of antennas.

Dr. Barry G. Clark, who recently received his doctorate in astronomy from the California Institute of Technology, joined the research group as an assistant scientist on November 30.

Mr. Nigel J. Keen, who received his B.Sc. degree in physics from the University of Nottingham, England in 1957, ended a two year appointment as research associate on December 11. Mr. Keen was chiefly concerned with the NRAO interferometer.

Appendix A

An Updating of NRAO Reprints Series A and B

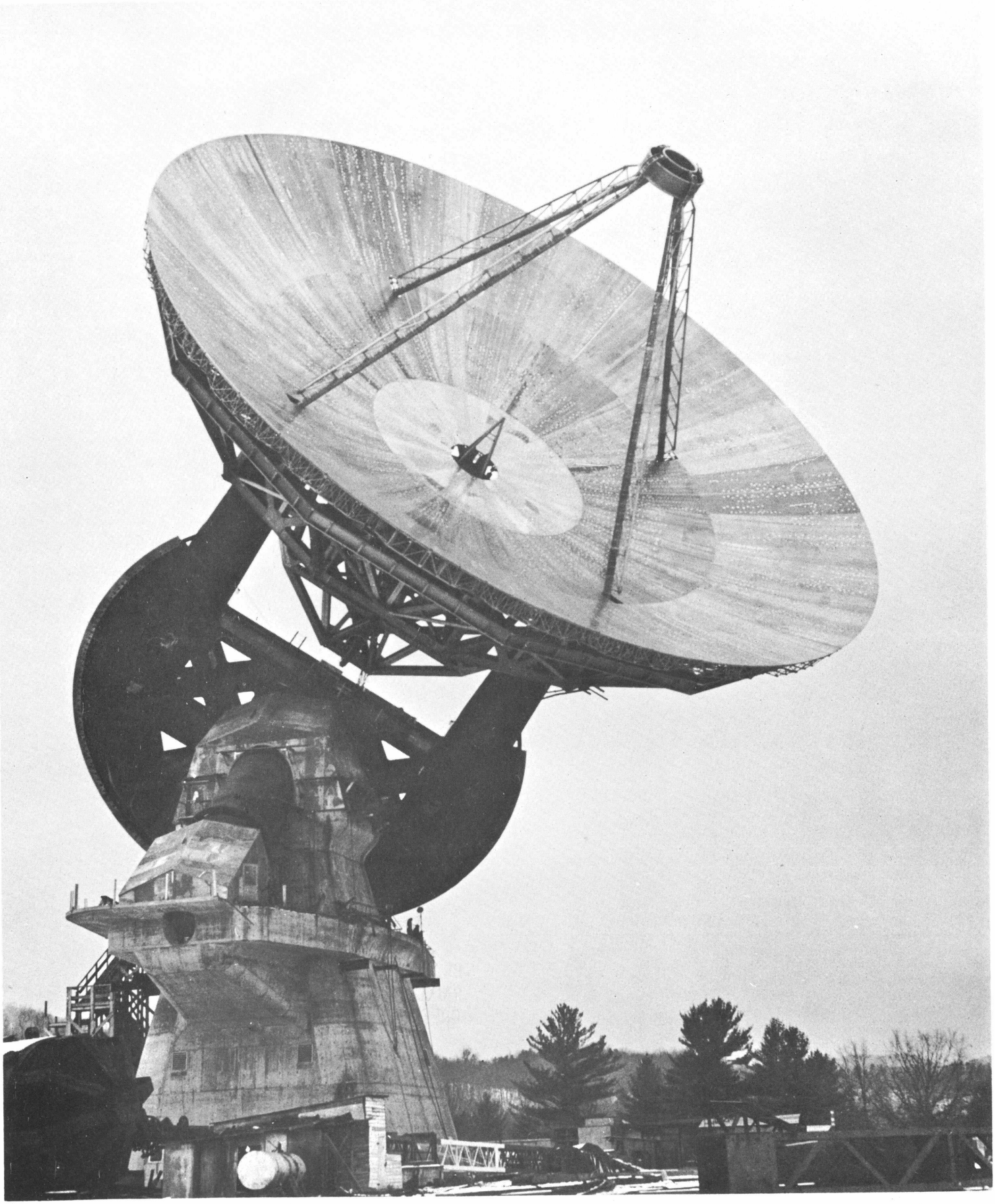
Series A

No.	Title	Author	Journal
29	Radio Telescopes	John W. Findlay	IEEE Trans. on Mil.Elec. Vol. MIL-8, Nos. 3-4, July-October 1964
30	Requirements for Cosmological Studies in Radio Astronomy	Sebastian von Hoerner	IEEE Trans. on Mil.Elec. Vol. MIL-8, Nos. 3-4, July-October 1964
31	Thermal Galactic Sources	T. K. Menon	IEEE Trans. on Mil. Elec. Vol. MIL-8, Nos. 3-4, July-October 1964

Series B

39	Radio Astronomy	John W. Findlay	Annals of the N.Y. Acad. of Sci., Vol. 116, Art. 1, pp. 5-9
40	Operating Experience at the National Radio Astronomy Observatory	John W. Findlay	Annals of the N.Y. Acad. of Sci., Vol. 116, Art. 1, pp. 25-37
41	Radio Observations of the Galaxy and Extragalactic Sources	David E. Hogg	R.A.S.C. Jour., Vol. 58, No. 5
42	The Radio Structure of IC 443	David E. Hogg	Astrophys. J., Vol. 140, No. 3, Oct. 1964

	Antennas and Receivers for Radio Astronomy	John W. Findlay	Advances in Radio Physics, Vol. II, 1964. Academic Press



140-ft Telescope, December 21, 1964, during the first rotation to the zenith after lifting the superstructure.