NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

Quarterly Report

July 1 - September 30, 1964

RESEARCH PROGRAMS

85-foot Telescopes

During this quarter the 85-foot telescopes were used for both single telescope observations and for two telescope observations (as an interferometer) as reflected in the following information.

85-foot Telescope No. 1

		Hours
Scheduled		444.75
Equipment installation and scheduled maintenance		29.00
Time lost due to:	equipment failure	23.25
	weather	1.75
	interference	2.00

All observations were made at 2695 MHz. S. von Hoerner observed lunar occultations and P. Mezger continued observations on a survey of galactic continuum radiation and extended sources. N. Keen and D. Hogg made focussing and pointing calibrations and measured fluxes of sources to be used in the interferometer research program.

85-foot Telescope No. 2

		Hours
Scheduled		40.90
Equipment installation and scheduled maintenance		55.00
Time lost due to:	equipment failure	0.00
	weather	0.00
	interference	10.00

D. Hogg and N. Keen completed focussing and pointing calibrations for the interferometer program at 2695 MHz. S. von Hoerner made observations of lunar occultations at 234, 256, and 405 MHz, simultaneously. Equipment installation and scheduled maintenance time is quite high due to the fact that about 8 hours of installation and check-out time is required for a 1.5 to 2.0 hour occultation measurement. Almost all the interference was incurred during occultations and was in part due to local man-made interference and in part due to radio broadcast transmissions originating from distant locations.

300-foot Telescope

		Hours
Scheduled		2057.25
Equipment installation and scheduled maintenance		150.75
Time lost due to:	equipment failure	55.50
	weather	4.75
	interference	5.00
	power failure	1.00

During this quarter M. Roberts measured H I radiation from discrete sources with the NRAO 20-channel multifilter receiver. H. Wendker made flux measurements of 3C 123 at 750 MHz. P. Mezger continued a 2695 and 1410 MHz survey of galactic continuum radiation and extended sources. E. McClain, J. Bologna and R. Sloanaker, of the Naval Research Laboratory, using NRL equipment, observed polarization of external galaxies at 1413.5 MHz.

Interferometer

		Hours
Scheduled		869.75
Equipment installation and scheduled maintenance		139.00
Time lost due to:	equipment failure	248.00
	weather	0.00
	interference (at observing frequency)	11.75
	low frequency interference elimination (see below)	208.75

The interferometer was found to be susceptible to interference from low frequency broadcast stations, requiring an extensive investigation before the effect was finally eliminated.

The use of the interferometer at a baseline length of 1200 meters has been directed toward observations which measure the instrumental parameters. The amplitude and phase stability of the system were measured in two series of observations:

1) transit observations of about twelve sources,
2) extended delay tracking of nine sources, including five quasi-stellar calibrators, and Cygnus A.

The baseline parameters have now been determined both by standard surveying techniques and by a series of observations of sources at the cross-over point.

Millimeter Wave Program

A number of measurements of Venus have yielded an internally consistent value for the brightness temperature at 1.2 mm, which is below the infrared value of 225°K and is difficult to understand on any simple model of the planet. There are very considerable uncertainties in the calibration procedure, but they do not explain this result. The most recent measurement of Jupiter yields

a temperature close to the expected temperature. Lunar temperatures are consistent with a solar temperature of 6000°K. The maria are somewhat colder than the highlands. These efforts are continuing.

Over 40 stars have been observed at an effective wavelength of 9.25 micron with the 28-inch telescope of the University of Arizona.

In June an elliptical galaxy, NGC 5846, was found to have a measurable brightness at 10 microns. The flux density of 3C 273, quasi-stellar source, was measured at 10 microns. Further measurements of these two objects will be made in late December

ELECTRONICS DIVISION - EQUIPMENT DEVELOPMENT

A series of modifications of the autocorrelation hydrogen line receiver suggested by various observers after its first observing period on the 300-foot telescope have recently been made. The receiver is now installed on the 300-foot telescope and will be used until the end of the year. The 20-channel hydrogen line receiver has been modified and prepared for an observing program on the 85-foot No. 1 telescope.

Preliminary observations with the 2695 MHz interferometer were regularly disturbed by interference from short-wave broadcast stations leaking into the IF amplifiers. A considerable amount of shielding and filtering was necessary to overcome this difficulty. The delay tracking facility for the interferometer has been completed, and the low noise parametric amplifiers have been delivered and tested. The cable system for extension of the baseline to 1500 m (station 2) has been completed, and the work is underway on further extension to 2700 m. The digital readout system made for the occultation experiment is temporarily being used for digital data acquisition from the interferometer. A permanent data output system will be built after experience has been gained with the temporary system. The 85-foot telescope No. 2 is now remotely controlled from the 85-foot No. 1 telescope during interferometer observations.

The 3.2 mm receiver has been delivered. Preliminary laboratory tests show stable performance, although with a somewhat higher noise temperature than expected. In addition, the basic design of a 128-channel hydrogen line filter receiver has been completed, and a front end for 1400 MHz and 2695 MHz using parametric amplifiers was built and installed on the 300-foot telescope.

Work has begun on the receiving systems for the 140-foot telescope, and the conversion of all data output systems to magnetic tape is continuing.

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

No.	Title	Author	Date
33	An Automatic Temperature Control System for Telescope Pillboxes	G. Behrens	July 1964
34	Digital Sidereal Clock System	C. Bare	July 1964

No.	Title	Author	Date
35	The Flux Density Values of Standard Sources Used for Antenna Calibrations	J. Baars, P. Mezger, and H. Wendker	August 1964

CONSTRUCTION

Charlottesville Laboratory Building

Advertisements for bids for the construction of the Observatory facility on the campus of the University of Virginia at Charlottesville appeared in public print in Virginia newspapers on Sunday, September 27, 1964. Bids are receivable for a period of thirty days. Initiation of construction is planned for about December 1, 1964, with occupation of the building scheduled during the winter 1965-66.

THE 140-FOOT TELESCOPE PROJECT (April-September, 1964)

The main hemispherical bearing, the hydropads and the fifth pad and jack were transported from the manufacturers to the site in April and welding operations on the aluminum superstructure continued. Toward the end of April the sphere was attached to the shaft, pipe and tubing was installed for the hydraulic system and the tail bearing was set in position.

In May the first four surface panels arrived from Kennedy, work commenced on the counterweight and the assembled shaft and sphere were lifted into place. This lift totaled 385 tons. Sightings through the shaft were made on Polaris in order to align the shaft. The hydropads were positioned and the load was transferred from the fifth pad to the main bearing hydropads. Work continued on the electrical and control systems.

In June welding of the gear girder of the aluminum superstructure was completed, the shaft and sphere were stabilized and the tail bearing seal plates were installed. The 479 ton assembly was lifted on June 5 and set in place on the north face of the sphere. The load tank, a 17-foot diameter temporary counterweight containing 70,000 gallons of water, was mounted on the two yoke arms in preparation for rotation tests of the shaft.

By July, twenty surface panels had been received and all outer panels had been either delivered to the NRAO or were in the fabrication stage at the manufacturers. A prototype intermediate panel had been partially assembled. A total of 567 tons of aggregate and 282 tons of grout had been placed in the counterweight section by the end of July. The load tank was filled with water.

By the end of August, all twenty-four outer surface panels had been received and the intermediate prototype panel was ready for testing on September 1. The railway tracks upon which the superstructure has been constructed were extended toward the pedestal and the superstructure was moved 114 feet toward the pedestal within reach of the derricks in preparation for erection in October. The torque unit was checked by rotating the structure to $\pm$ 10 degrees from the meridian. As a result of this test about 45 tons of additional

counterweight was added inside the yoke. After this, controlled rotation of the structure was accomplished to 108 degrees east and west. During the rotations the shaft was aligned to within 15 seconds of arc, parallel to the earth's axis.

Intermediate surface panels began to arrive in September and assembly of the inner panels at Kennedy were under way. All radiography of the yoke and counterweight had been completed and the work was approved. By the end of the month 15 of the 28 gear segments were set and the brake hydraulic system was being installed. Aluminum housing over the spherical bearing had been completed and the polar inductosyn mount was rough set at the tail bearing.

The superstructure is scheduled for erection toward the end of October and the surface panels will be installed in November. Preliminary tests of the behavior of the telescope as a whole are anticipated for the first months of 1965, with full operation to begin in the spring.

THE NRAO MILLIMETER WAVE ANTENNA PROJECT

Since the last report progress has been made in selecting the site for the telescope and in the choice of a fabrication and erection contractor. Design work has started.

1. Site Selection

Observations at millimeter wavelengths are mainly affected by the total amount and variability of the water vapor content of the atmosphere. A convenient measure of total water vapor content is the total precipitable water contained in an atmospheric column of unit cross-section. This is usually given in millimeters of water for a vertical column through the atmosphere. Some average values for this quantity (from General Meteorology by H. R. Byers, 3rd ed. McGraw-Hill 1959) for the lowest 8 km of the atmosphere range between 7.5 mm and 50 mm. The contribution to precipitable water is much greater for stations near sea level from the first 2 km of atmosphere, and is usually small from levels above 8 km.

It is clear that a high and dry site is desirable for a millimeter wave telescope. Estimates of the total precipitable water content of the atmosphere were made for various regions in the USA, and these led to a closer consideration of possible sites in California, Colorado and Arizona. A simple type of instrument (based on a Weather Bureau design) was built and several sites were tested during the early months of 1964. The sites were tested in turn and the day-to-day fluctuations in water content at any site are considerable. The following table summarizes the results obtained.

Site Test Results (January 13 -April 26, 1964)

Site	Altitude Meters	Precipitable water for unit air mass		
		Mean of (n) days observing	Maximum observed	Minimum observed
Mt. Pinos, Calif.	2600	2.2 mm (5)	3.5 mm	0.9 mm
Table Mt., Calif.	2300	1.8 mm (4)	2.6 mm	1.1 mm
Catalina Mts.,Ariz.	2600	1.8 mm (21)	3.2 mm	0.8 mm
Climax, Colo.	3350	1.2 mm (24)	2.0 mm	0.3 mm
Green Bank*, W.Va.	850	2.5 mm (18)	5.5 mm	1.3 mm

*Observations made December 12, 1963 to January 16, 1964.

A study of the table shows first that the higher sites are all superior to Green Bank, particularly when it is noted that the Green Bank tests took place during the time of year giving dryest conditions. For other times of the year Green Bank figures rise to 10-20 mm. However, the table does not show strong evidence for a choice between the high sites measures, except that Climax may be slightly superior to the rest.

The final site choice was influenced by the water content measurements but took account of several other factors. The Climax site at the High Altitude Observatory is subject to more extreme climate than the others. The area near Tucson was acceptable for dryness and climate and also for its existing observatories and the University of Arizona. In addition to the Catalina Mountain site near Tucson, the location on Kitt Peak offered many obvious advantages. A site at about 1900 meters might be available near the summit. Access and control of the use of the neighborhood were both good. Water content measures have been started on this site, but will only become of value when the short wet season ends. In comparison to Kitt Peak, the Catalinas suffer the disadvantages of difficulty of controlling development of the land near an observing site, and also by the existence of television, radar and aircraft control installations on the peaks.

After a final survey by Drs. Heeschen and Findlay, the location of the instrument on the southwest ridge of Kitt Peak was preferred. The use of this site has been requested from AURA through the Director of Kitt Peak National Observatory, and if it can be granted the concurrence of the National Science Foundation will be requested.

2. Selection of a Contractor

Responses to the letter of March 19 were received from six companies, of which three proposals were for the complete instrument. Two were for the supply of the dish alone, and one for the mount alone. A preliminary evaluation of these proposals was made at a meeting at the NRAO on May 26, and this

resulted in reducing the proposals for final consideration to three, from North American Aviation (Columbus, Ohio), Philco Western Development Laboratories (Palo Alto, California) and the Rohr Corporation (Chula Vista, California).

All three proposals were fairly close together in price, and all three companies had either built or were in the process of building an accurate millimeter wave dish. Visits were made in June by J. W. Findlay, F. J. Low, P. G. Mezger and W. W. Powell to the proposers and to various existing millimeter wave dishes. At a final meeting on July 10, 1964, the group decided that Rohr was the most acceptable proposer.

3. Progress in Design

Since mid-July Rohr has been proceeding with engineering design of the telescope and the astrodome. The astrodome will resemble a large optical telescope dome, except that it will have a 40-foot wide door opening for observing. At present it is planned to be 95 feet in diameter and 60 feet high. It requires a foundation extending only slightly above the ground. The telescope mounts on a separately founded pedestal inside the dome, and a small fixed observing building will be placed within the dome on the north side of the telescope.

4. Fabrication and Erection Schedule

The following approximate schedule is based on one proposed by Rohr for fabrication and erection of the telescope and astrodome. It has been modified slightly, since the original scheduled called for foundation work to start in the fall of 1964. This is probably not possible.

Date	Action
July 20, 1964	Engineering design starts on telescope and astrodome
October 1, 1964	Negotiate contract for telescope and astrodome
November 10, 1964	Commence dish fabrication at Rohr
December 8, 1964	Commence dome fabrication at Rohr
April 1, 1965	Start foundation work at site for telescope and dome
May 1, 1965	Complete foundation
June 1, 1965	Commence telescope erection
June 15, 1965	Commence dome erection
July 15, 1965	Complete erection

NRAO COMPUTATION FACILITIES

During early 1964 it became evident that the conversion of telescope outputs to magnetic tape and the advent of complex outputs of the 21-cm autocorrelation receiver and the interferometer would necessitate the acquisition of a larger computer than the IBM 1620, one that would have a tape-handling capability. By the summer of 1964 the IBM 1620 was already scheduled a week in advance with reduction programs running through a full

24-hour day. At the end of August a new IBM 7040 computer was installed in a new facility at the north end of the warehouse building. After some additional modifications to the system, the new computer will have a 16K memory with five IBM 7330 tape drives, a card read punch and a printer. Three small offices and a conference room are located at one end of the computer area. The computer group now consists of an administrative head, four programmers, a machine operator, a clerk, and two key punch operators. A systems engineer is available from the IBM offices in Charleston, W. Va.

NRAO TOURIST FACILITY

During the summer 1964 tourist season over 10,100 tourists visited the Observatory. Seventy per cent of the visitors came from West Virginia, while the next most-represented state, Virginia, contributed seven per cent of those who registered for the tours. Forty-one states and four foreign countries were represented. Tours were given on Wednesday through Sunday from June 17 through September 7, 1964, and the program consisted of a lecture and a guided bus tour of the Observatory. Lectures in previous years were held in the basement conference room of the Jansky Laboratory. This year, however, the lectures were held in the Green Bank High School auditorium. The number of Observatory visitors this year exceeded the number last year by over 10 per cent. It is approximately double the number of visitors in the 1961 and 1962 summer seasons, and four times the number of visitors in 1960. Existing facilities at or near the NRAO are not adequate to handle the projected number of tourists next year and design studies of a tourist building are now under way. It will probably be located at or near the parking lot across from the high school and will be built before the tourist season peaks next summer.

UNDERGRADUATE AND GRADUATE STUDENT PROGRAMS

1. The Management of the Program

The programs followed the pattern adopted in earlier years. The director of the programs organized the selection of the students and their program of work, including the lectures given to them. The close scientific supervision of the students was done by the members of the Observatory staff to which the students were assigned. The total scientific staff is quite small, so it was a simple matter for the program director to keep in touch with the students' supervisors and their work.

2. Selection of Students

Notices of the programs were mailed out in January to the physics, engineering and astronomy departments of 69 undergraduate and 43 graduate schools. Applications from 58 undergraduate and 42 graduate schools were received. These applications were studied by the program director and the scientific staff chiefly interested, and the best students were selected. The choices were made by considering:

a) academic record,
b) the report of a referee in the student's university to whom the applicant was well known,
c) the suitability of the student's interests for helping in radio astronomical research, and
d) the academic class of the student.

3. Table of Participating Students

Participant	Academic Year	Descriptive Title of Assigned Project	Research Supervisor
Philip Atanmo (U. of Conn.)	Junior	Standards, calibrations, measurements and low-noise amplifier work	Dr. H. Hvatum, Scientist, Basic Research Group and Head of the Electronics Div.
Greg Burrowes (U. of Md.)	Sophomore	Data reduction at 6 cm and 11 cm wavelengths as part of a study of background radiation at short wavelengths	Dr. Peter Mezger, Associate Scientist, Basic Research Group
Edward Conklin (Yale U.)	Senior	The determination of an absolute value for the incident flux from Cassiopeia A which involved modifying existing installation, maintenance, observation and data reduction	Dr. H. Hvatum
Martin S. Ewing (Swarthmore)	Sophomore	Computer integrations for theoretical evaluation of non thermal radio spectra, and locating positions of radio sources on optical sky survey photographs	Dr. T.K. Menon, Associate Scientist, Basic Research Group
Mary K. Meacham (Notre Dame C.)	Junior	Theoretical calculations on the Orion nebula. Two Fortran II programs were written and used on the IBM 1620. Preliminary work for the optical identification of radio sources of the 3C catalogue.	Dr. T. K. Menon
June B. Myles (Hollins C.)	Senior	Reduction of data used for testing the interferometer	Dr. D. E. Hogg, Associate Scientist, Basic Research Group
Melvyn R. Viner (U. of Toronto)	Senior	Data reduction of radio astronomical observations for the 3C program	Dr. I. Pauliny-Toth, Assistant Scientist, Basic Research Group
Frances M. Wells (Vanderbilt U.)	Senior	Construction of modular type TWT amplifiers and design modifications; interferometer trouble-shooting	Mr. John Bringe, Electronics Engineer, Electronics Division

Participant	Academic Year	Descriptive Title of Assigned Project	Research Supervisor
Mark Fagerlin (U. of Fla.)	3rd yr. graduate student	Working with the interferometer group; positioning and focussing of the 11 cm systems in the two telescopes, and an accurate survey of the interferometer baseline	Mr. N.J. Keen, Research Associate, Basic Research Group
Lloyd Walker (U. of Chicago)	Senior	Preparing data for computer reduction, and writing of programs for IBM 1620 computer in connection with lunar occultation program	Dr. S. von Hoerner, Scientist, Basic Research Group
Hugh D. Aller (U. of Mich.)	Senior	Analyzing raw material on radio source spectra	Dr. W. E. Howard, Associate Scientist, Basic Research Group
Virginia Fagerlin (U. of N.C.)	Junior	Computer work -- writing programs, punched parameter cards, etc.	Dr. B. Hoglund, Visiting Associate Scientist, Basic Research Group
Byron Wicks (Manchester U., England)	Freshman	Reduction of data from the interferometer	Mr. N. J. Keen
William Ogden (U. of Ky.)	Junior	Assisted in the conversion of the NRAO programs from the IBM 1620 to the IBM 7040 computer	Dr. W. E. Howard
Robert Havlen (U. of Rochester)	Junior	Reduction of 21-cm hydrogen line observations of extragalactic radio sources	Dr. M.S. Roberts, Scientist, Basic Research Group
Margo Friedel (U. of Mich.)	2nd yr. graduate student	Compiled a card catalogue for all galaxies of magnitude 11.2 or brighter accessible with the 300-foot telescope	Dr. C. M. Wade, Associate Scientist, Basic Research Group
William Gebel (U. of Wisc.)	1st yr. graduate student	A search for nebulosities containing Wolf-Rayet stars on Palomar Sky Survey and other photographic materials in the literature. Contour maps prepared at 750 and 1400 MHz for HB 21, HB 9 and the Cygnus Loop	Dr. D. E. Hogg

Participant	Academic Year	Descriptive Title of Assigned Project	Research Supervisor
Dennis Baker (U. of Calif.)	Senior	Reduction of neutral hydrogen data for three galaxies observed with the 20-channel receiver on the 300-foot telescope	Dr. M. S. Roberts
Norman Savin (M.I.T.)	Senior	A project to determine the dielectric constant of the moon as seen by 2-cm observations	Dr. Peter Mezger

4. Students' Publications

Several students assisted in research projects which will eventually be published.

5. Evaluation by the Program Director

The student program is now of value to both the students and to the Observatory. There are now sufficient staff and visiting scientists at Green Bank to allow of a wide choice of tasks being developed for the students. The students work hard and give very useful help to the programs they assist.

6. A List of Lectures and Courses of Instruction

Subject	Number of Lectures	Given by
Introductory lecture on NRAO and the student program	1	Dr. J. W. Findlay
Computer instruction	1	Mr. R. L. Uphoff
History of radio astronomy	1	Dr. W. E. Howard III
Radiometers	2	Dr. H. Hvatum
Antennas	2	Dr. P. G. Mezger
NRAO telescopes	1	Mr. J. F. Crews
Generation of radio waves in space	2	Dr. T. K. Menon
The radio Milky Way	1	Dr. G. Westerhout
Galactic radio sources	2	Dr. D. E. Hogg
Extragalactic radio sources	2	Dr. C. M. Wade

Subject	Number of Lectures	Given by
Galactic hydrogen line studies	1	Dr. G. Westerhout
Extragalactic hydrogen line studies	1	Dr. M. S. Roberts
Planetary radio emission	1	Mr. F. Bash
Lunar occultations	1	Dr. S. von Hoerner
Millimeter wave astronomy	1	Dr. F. J. Low
Radio interferometry	1	Mr. N. J. Keen
Cosmology	1	Dr. S. von Hoerner

On August 11, a full day's symposium of 23 papers by staff and visiting scientists was given, which covered research results from all areas of the Observatory work. This was attended by the students.

PERSONNEL

Dr. Warren C. Tyler, formerly director of research at the Ewen-Knight Corporation, and Dr. May A. Kaftan-Kassim, from the University of Bagdad, have been employed in the research group as research associates.

Dr. G. W. Swenson, Jr., on leave from the University of Illinois, is working for a year in the research group as a visiting scientist.

Mr. Carl Heiles, a Princeton University graduate student, is doing his thesis work at the Observatory on the structure of interstellar hydrogen clouds.

Mr. M. L. Kaiser, a recent graduate of the State University of Iowa, has been employed as a computer programmer.

Mr. F. N. Bash, astronomer associate, and Mr. R. L. Uphoff, programmer analyst, have left the Observatory. Mr. Bash has entered the University of Virginia to further his education, and Mr. Uphoff has joined the computer group at the Brookhaven National Laboratory.

Appendix A

An updating of NRAO Reprint Series A and B.

Series A

No.	Title	Author	Reference
26	Lunar Observations at $\lambda 10\mu$ and 1.2 mm	Frank J. Low	Astron. J., 69, No. 2, March 1964
27	West Ford and the Scientists	J. W. Findlay	Proc. IEEE, Vol. 52, No. 5, May 1964, pp. 455-460
28	A Radio Survey of Galaxies	D.S. Heeschen and C.M. Wade	Astron. J., 69, No. 4, 1964

Series B

36	10-cm Observations of Jupiter, 1961-1963	F.N. Bash, F.D. Drake, E. Gundermann, C.E. Heiles	Ap.J., Vol. 139, No. 3, April 1964, pp.975-985
37	Radio Observations of M 33	V.R.Venugopal	Astron. Soc. of the Pacific, Vol. 75, No. 446, Oct. 1963
38	Lunar Occultations of Radio Sources	S. von Hoerner	Ap.J., 140, No. 1, July 1964, pp. 65-79