NATIONAL RADIO ASTRONOMY OBSERVATORY
Charlottesville, Virginia

Quarterly Report

April 1 - June 30, 1966

RESEARCH PROGRAMS

Interferometer		Hours
Scheduled		1731.25
Equipment changes and scheduled maintenance		263.75
Time lost due to:	equipment failure	61.75
	interference	0.0
	weather	12.50
	power	2.25

During this quarter the interferometer has been operated at two different frequencies, 2695 MHz and 234 MHz. All available antenna spacings have been used. The table below shows the amount of time spent at each spacing for each of the two frequencies.

Dates	Frequency (MHz)	Spacing (Meters)
9 Feb. - 14 April	2695	1800
14 April - 11 May	2695	1500
11 May - 24 May	234	1200
24 May - 31 May	234	1500
31 May - 7 June	234	1800
7 June - 14 June	234	2100
14 June - 23 June	234	2400
23 June - (5 July)*	234	2700

*Planned Moving Date

The observing programs carried out during this quarter are briefly described below.

2695 MHz

1. Aperture Synthesis Program. This is a continuation of our program to map 12 extended complex sources. The program during this period concentrated on improving observations which were taken during the early operation of the interferometer when a less sensitive and less stable receiving system was being used.

2. Quasars. Thirty small, optically identified objects were observed, some of which exhibited structure. For these sources a small field of view synthesis will be attempted. For the unresolved sources, accurate position determinations have been made.

3. Source Positions. Six new sources were included in the program to determine accurate positions of unidentified, unresolved sources.

4. Long Integration. Twelve hour tracks of TON 730 were made to determine the faintness limit of the present interferometer.

5. Source Angular Size Survey. F. Bash (University of Virginia) completed the observations for his thesis during this quarter. The program will give angular size estimates for a large number of extragalactic radio sources.

6. Polarization Calibration. Six strongly polarized sources were observed to determine the polarization characteristics of the interferometer and for calibration of earlier data.

234 MHz

1. Low Frequency Aperture Synthesis. S. Zisk (M.I.T.) has carried out an aperture synthesis program for approximately 24 of the strongest radio sources at this frequency. The program will almost be completed during this quarter. Eighteen to 20 of the sources will be completely mapped with a resolution of 40 arc-sec. The remaining sources lie in regions of high confusion and the results are of limited value at this time.

Two very promising results, from the standpoint of the operation of the interferometer, have come from this program. First, the conversion from 2695 MHz to 234 MHz was accomplished in only three days, with Zisk supplying the antenna feeds, R. F. amplifiers and mixer-preamps from M.I.T. Secondly, the station moves have been made once a week with very short telescope downtime. A typical number is eight hours which includes calibration of the new spacing.

2. W. Cronyn (U. of Maryland) attached non-interfering equipment during the low frequency observations to measure the scintillation of small diameter sources using the total power output of each of the two telescopes and cross correlating data in the computer.

NRAO staff members involved in the above programs were B. G. Clark, D. E. Hogg, W. C. Tyler, and C. M. Wade.

300-foot Telescope

	Hours
Scheduled	62.25
Equipment changes and scheduled maintenance	2114.75

Observations at 1420 MHz and 750 MHz were continued for the short time the telescope was operational. M. DeJong and C. Wade mapped normal galaxies. P. Mezger mapped selected regions in the galactic plane. M. Davis (Leiden Observatory) continued verification of his Dwingeloo finding list of radio sources. M. Kaftan-Kassim observed planetary nebulae. K. Kellermann and I. Pauliny-Toth repeated some earlier observations of 3C sources. H. C. Ko (Ohio State) mapped the Coma Cluster.

On April 4, the telescope was shut down to undergo a rather extensive modification program through contract with the Rohr Corporation. There are three major areas of modification: 1) Replacement and strengthening of certain key members in the dish back-up structure; 2) Replacement of the existing feed support legs with much heavier ones and the addition of a larger room at the focal-point; 3) Replacement of steel cables that support the elevation wheel and counterweight with steel I-beams. With these modifications, the antenna is expected to be less subject to structural problems and equipment installation and maintenance at the focal point will be more easily accomplished.

140-foot Telescope

		Hours
Scheduled		1894.24
Equipment changes and scheduled maintenance		231.25
Time lost due to:	equipment failure	84.50
	weather	102.50
	interference	.50
	power	2.50

The time lost due to weather is mainly attributed to detrimental atmospheric observing conditions at short wavelengths.

Using a 15.375 GHz receiver, P. Mezger and others collected data to better evaluate telescope performance. Z. Turlo made scintillation measurements and M. Kaftan-Kassim continued planetary nebulae observations.

A Naval Research Laboratory 19.35 GHz receiver was installed on the telescope and used by C. Mayer (N.R.L.) for polarization measurements.

Observations of the OH line and an attempt to detect the CH line were undertaken by A. Barrett (M.I.T.) and A. Rogers (M.I.T.). P. Palmer (Harvard University) and B. Zuckerman (Harvard University) also made OH line measurements. M. Roberts collected OH line measurements in extragalactic systems.

S. Goldstein (University of Virginia) undertook both measurements of the Zeeman effect in interstellar clouds and a short program to check the correlation between Ca-II lines and H-II lines in interstellar clouds. Goldstein also made polarization measurements of Cygnus A. Polarization measurements were also made by I. Pauliny-Toth.

S. von Hoerner, M. DeJong and J. Taylor (Harvard University) observed lunar occultations of sources at 234 MHz, 256 MHz, and 405 MHz.

T. K. Menon measured H-and OH-lines in the direction of discrete sources. W. Burton (Columbia University) measured H-line emission near the discrete source W-51. P. Mezger undertook to measure recombination line 166α in the strongest galactic H-II regions.

I. Pauliny-Toth and K. Kellermann measured flux densities of sources at 15.375 GHz and at 2695 MHz.

ELECTRONICS DIVISION--EQUIPMENT DEVELOPMENT

Approximately 20 percent of the Electronics Division's effort was expended on routine repair, system installation, and minor modification of existing equipment. Receivers operating at wavelengths of 2 cm, 18 cm, and 21 cm were installed on the 140-foot telescope during this period.

A prototype of a new solid-state standard receiver back end has been completed during this quarter, and construction of 12 additional units is underway. The new standard receiver accommodates IF frequencies between 1 MHz and 300 MHz and can utilize switch frequencies of 1, 10, 50, and 400 Hz. Many other improvements are incorporated in the new receiver.

Equipment for use in a very long baseline (VLB) interferometer (in conjunction with the Arecibo antenna of Cornell University) has begun to arrive; most of the major components are expected by the end of July. The high speed tape drives and associated digital equipment are now being tested.

The improvements of the present interferometer system are well underway. A new front-end box temperature controller has been built, new receiver back-ends are under construction, and a prototype LO phase-lock system is being tested. Many major components (computer, paramps, cables) are on order and will be delivered in the early fall.

A project has been initiated to design and construct a universal local oscillator system. The system will provide stable signals for use in many radiometer systems, but it will be especially useful in spectral line work. The low frequency synthesizer and a few small parts have been received. The remaining components are on order.

A project to construct a 139 MHz receiver for polarization measurements has also been initiated.

The following Electronics Division internal reports were issued during this period:

No.	Title	Author	Date
54	Advanced Technology Calibration Loads for the 2 cm, 9.5 mm and 3.5 mm Wavelength Range	R. Menon and N. Albaugh	April 1966

No.	Title	Author	Date
55	Single Sideband, Double Sideband, or Mixed Interferometer Receivers	K. Wesseling	June 1966
56	A Possible Local Oscillator Distribution System for the NRAO Interferometer and Analysis of Its Phase Instabilities	K. Wesseling	June 1966

THE NRAO MILLIMETER WAVE ANTENNA

The installation of the improved dome cover was completed during the report period. All mechanical parts of the dome structure, with the exception of the opening and closing of the observing door, were working well. The observing door required minor design modifications in order to operate properly.

The reflector was moved from its temporary location at the base of the mountain to the site and installed on the telescope pedestal. Preliminary alignment of the telescope is presently taking place.

Work on the computer control program was delayed a few weeks because of problems with the computer hardware.

The construction of the power line is progressing. Meanwhile, the diesel generator is supplying adequate power to the site.

Some minor concrete work to prevent washout of the fill around the dome foundation is being done.

Trouble developed in one of the digital encoders for readout of the antenna position. It has been returned to the manufacturer for repair.

ANTENNA DESIGN STUDIES

The Largest Feasible Steerable Telescope

The LFST study group has continued its work on various possible concepts for a telescope, of 600 feet or greater in size, suitable for use at wavelengths perhaps as short as 10 cm.

A floating sphere design has been worked on by members of the group, and by sub-contractors both with Lear Siegler, Inc. and with North American Aviation.

Two designs of azimuth rotating telescope with limited elevation motion have been developed, and a third is also under study.

The use of the principles of homology, by which a structure may be designed in such a way as to minimize the effects of changing deflections with

changing elevation angle, has been brought to a stage where it can be applied and tested.

The group is planning to report back to interested astronomers in the near future; perhaps at the next meeting of the NRAO Users Committee.

The Very Large Antenna Array Project

During the past quarter studies have continued on possible configurations for the Very Large Array, with particular emphasis on obtaining optimum compromises between numbers of antennas and performance. The approach has been to calculate for a hypothetical source which coefficients of its two-dimensional Fourier series representation can be measured by a given array in a given interval of sidereal time. The latitude of the telescope, and the declination of the source are parameters. In this way a large store of information concerning the performance of various arrays has been accumulated, and it is now possible to choose an array configuration with the assurance that its performance is well understood.

A number of possible sites for the array has been chosen for detailed engineering investigation, and Limbaugh Engineers, Inc., of Albuquerque, New Mexico, has been commissioned to conduct the study. The work is under way and is to include detailed estimates of the costs of establishing the Observatory at each site.

A contract has been awarded to I.T.&T. Laboratories, Inc., for an investigation of certain electronic problems of the VLA, including local oscillator phase-reference distribution, correlator design, and delay-line design.

A contract has been awarded to the Radio Corporation of America for the study of structural and mechanical aspects of the design of the individual antennas of the array. Hopefully, this study will permit selection of a general antenna design.

RCA has submitted the final report on the preliminary study of the computer requirements of the VLA. The principal result of this study is an upper bound to the cost of the computer for real-time data processing and for antenna and electronics monitoring and control.

In-house work is in progress on certain electronics problems, including some of the problems also being studied by I.T.&T., and also on the computing problem of converting the data output of the array into maps of sky brightness distribution.

Atmospheric influences on the probable performance of the VLA are being studied by using records from the interferometer at Green Bank. While this instrument's baseline is not long enough to yield results valid for the longer baselines of the VLA, indications are that there may well be some significant atmospheric effects. To study these further, a 20-mile baseline is being established, using as one element the portable 42-foot antenna which has just been completed by Pacific Steel Products, Inc., of San Jose, California.

The other end of the 20-mile baseline will be one of the existing 85-foot antennas. A phase-locked local oscillator system for this interferometer, using a microwave link, is under procurement. Present opinion is that atmospheric effects will not prevent achievement of the goals of the VLA, but that they should be taken into account in choosing the site. As water vapor is one of the principal factors influencing atmospheric refractivity, a program of daily measurements of the total atmospheric water vapor has been established at each of the sites under investigation.

NRAO SUMMER STUDENT PROGRAM

In December 1965 announcements concerning the Observatory's summer student program were sent to the departments of astronomy, physics, mathematics, and electrical engineering of more than 85 universities. Approximately 85 students responded, from whom 11 graduate and 16 undergraduate students were chosen to participate in our program by a committee of three scientific staff members. The National Science Foundation is supporting 12 of our undergraduate summer students as a part of its Undergraduate Research Participation Program. The Observatory staff are delivering a series of 24 lectures to the students on various topics in radio astronomy, and the lectures are given in both Charlottesville and Green Bank.

The students are assigned to various staff members for the summer and participate in the research efforts of their advisors as junior research colleagues. Thirteen of the students are resident in Charlottesville and 14 are resident in Green Bank. The accompanying table shows a roster of our students, including their university affiliations and hometowns. Each student is selected on merit based upon his academic record, recommendations from at least two college instructors and advisors and his letter of application containing his background and scientific interests. The Observatory has found that the summer student program is valuable from many points of view: 1) It encourages students already interested in radio astronomy by exposing them to many direct techniques and areas of research; 2) It introduces bright students without prior academic background in the subject to a new field of research where their talents can be effectively applied; 3) It provides the scientific staff with rather intensive student contact for one quarter of the academic year. The program will be continued next summer.

Student	School	Yr.	Hometown
(Graduate)			
Judith Devaney	Univ. of Maryland	1	New York, N. Y.
James Fisher	Univ. of Maryland	1	Pittsburgh, Pa.
Kai Lee	Cornell University	3	Hong Kong, China
Kurtiss Gordon	Univ. of Michigan	4	Ann Arbor, Mich.
Rebecca Gordon	Univ. of Michigan	4	Ann Arbor, Mich.
Edward Churchwell	Indiana University	1	Bloomington, Ind.
James Cook	Ohio State	2	Jefferson, Ohio
Anselm Henderson	Univ. of Maryland	4	Washington, D. C.
Philip Honsberger	Ohio State	2	Sycamore, Ohio
Wen-pin Ou	Vanderbilt	2	Nashville, Tenn.
George Patton	West Virginia Univ.	1	Westover, W. Va.

Student	School	Yr.	Hometown
(Undergraduate)			
Thomas Barnes	Univ. of Rochester	4	Marion, Ohio
Shirley Ellis	Univ. of London	3	Warwickshire, England
Margaret Kepner	Vassar	3	Eugene, Oregon
George Purcell	M.I.T.	4	Dayton, Ohio
Philip Schwartz	M.I.T.	4	Feasterville, Pa.
Alfred Braun	V.P.I.	5	Downers Grove, Ill.
Jean Warren	Swarthmore	2	Ithaca, N. Y.
Gail McDaniel	Stanford	4	Ithaca, N. Y.
Curtiss Knight	M.I.T.	3	South Berwick, Maine
Bruce Lites	Univ. New Mexico	3	Albuquerque, N. M.
John Perry	Pomona	4	Cambridge, Mass.
John Rehr	Univ. Michigan	3	Carlisle, Pa.
Theodore Reiter	Ohio State	2	Columbus, Ohio
David Shaffer	Carnegie	2	Huntingdon, Pa.
James Shuman	Carleton	3	DesMoines, Iowa

OBSERVATORY COLLOQUIA

The NRAO colloquium program during the past fiscal year is outlined below. Speakers are usually invited by the scientific staff and generally talk on topics of current interest in radio astronomy or closely allied fields. The Department of Astronomy at the University of Virginia also invites speakers to participate in their own colloquium series. Both these series are announced jointly and are well attended by our staff, university physicists and astronomers and by students. The 25 outside speakers who visited the NRAO in our colloquium series are listed below.

Speaker	Institution	Date
Dr. Hong-Yee Chiu	Institute for Space Studies	July 9, 1965
Dr. A. R. Thompson	Stanford University	July 22, 1965
Dr. G. L. Verschuur	Jodrell Bank	July 23, 1965
Dr. Alar Toomre	Massachusetts Institute of Technology	August 26, 1965
Dr. Halton C. Arp	Mount Wilson and Palomar Observatories	September 7, 1965
Dr. Engelbert L. Schucking	University of Texas	September 9, 1965
Dr. Charles R. Cowley	Yerkes Observatory	September 21, 1965
Dr. H. C. Ko	Ohio State University	September 23, 1965
Dr. Glenn L. Berge	Cal Tech Owens Valley Observatory	October 5, 1965
Dr. Donald S. Mathewson	C.S.I.R.O.	October 19, 1965
Dr. Carlos Varsavsky	Argentina Radio Astronomy Observatory	October 20, 1965
Dr. Marshall Cohen	Cornell University	October 27, 1965

Speaker	Institution	Date
Dr. Armin J. Deutsch	Mount Wilson and Palomar Observatories	November 2, 1965
Dr. Eugene Epstein	Aerospace Corporation	November 11, 1965
Dr. H. P. Palmer	Jodrell Bank	December 13, 1965
Dr. Ludwig Oster	Yale Observatory	February 10, 1965
Dr. G. R. Huguenin	Harvard College Observatory	April 14, 1966
Dr. Donald E. Osterbrock	University of Wisconsin	April 28, 1966
Mr. Ronald J. Allen	Massachusetts Institute of Technology	May 4, 1966
Dr. Edward A. Spiegel	New York University	June 2, 1966
Dr. Francis Perkins	Cornell University	June 3, 1966
Dr. Carl Heiles	Princeton University and University of California, Berkeley	June 8, 1966
Dr. L. Woltjer	Columbia University	June 16, 1966
Dr. Carl Sagan	Smithsonian Astrophysical Observatory	June 23, 1966
Dr. Robert J. Davis	Smithsonian Astrophysical Observatory	June 30, 1966

MISCELLANEOUS

Interferometer Control Building. The successful contractor, Wilson Construction Company, on the project for the construction of the interferometer control building is on the site and construction is underway.

NRAO Airstrip. The bid package and construction procedure, along with request for funds (supplemental), was sent to the NSF on May 11, 1966. Construction procedure has been approved by NSF and $100,000 supplemental funds have been received. Should costs for this project exceed $100,000, the balance will be made up from regular NRAO funds.

On June 13, 1966, the Preliminary FY 1967 Financial Plan was submitted to the NSF. The total estimated amount available for commitment in FY 67 is $6.4M, of which $5.2M is from new funds (appropriation) and the remainder from reallocated or uncommitted funds carried over from prior years.

The distribution of available funds ($6.4M) between Operating and Capital is: Operating $3.6 M -- Capital $2.8M.

The NSF has released to the NRAO, by contract admendment, $40,000 which had previously been withheld from the FY 1966 financial plans. These funds are earmarked as follows: $15K for the acquisition of land west of the NRAO site and $25K for the millimeter wave project. These funds had been withheld pending a decision as to who (NSF or Forest Service) should acquire the land, and the latter amount was withheld as a contingency against the allocation for installing power on Kitt Peak.

PERSONNEL

	On Board June 30, 65	On Board March 30, 66	On Board June 30, 66	Change June 65/66
Scientific & Engr.	28	34	40	+ 12
Technical	58	63	66	+ 8
Administration	15	13	14	- 1
Clerical	30	34	35	+ 5
Maintenance	39	38	39	0
Other (Guards-Food Services)	11	11	11	0
Students	32	7	33	+ 1
Part-Time	19	11	19	0
TOTAL	232	211	257	+ 25

Scientific and Engineering Appointments During Last Quarter

V. Boriakoff	Electronic Engineer	May 2, 1966
M. Balister	Electronic Engineer	May 9, 1966
H. van der Laan	Vist. Associate Scientist	May 9, 1966
R. Conway	Vist. Scientist	May 16, 1966
P. Stumpff	Associate Scientist	June 13, 1966
W. Altenhoff	Research Associate	June 16, 1966

Administrative Appointments During Last Quarter

J. Marymor	Constracts/Business Manager	May 9, 1966

A list of Observatory reprints issued since September 30, 1965. See NRAO Quarterly Reports for April-June 1964 and April-June 1965 for reprints issued prior to this date.

Series A

No.	Title	Author	Reference
42	Variation of Galactic Rotation Parameters with Distance Scale	W. E. Howard III and John G. Kirk	A.J. 70, No. 6, 1965
43	Hydrogen Emission Line $n_{110} \rightarrow n_{109}$: Detection at 5009 Megahertz in Galactic HII Regions	B. Höglund and P. Mezger	Science 150, No. 3694, 1965
44	The New 140-Ft Radio Telescope	M. M. Small	Sky and Telescope XXX, No. 5, 1965
45	Flux Density Measurements of Planetary Nebulae at 1415 and 750 Mc/sec (abstract)	May A. Kaftan-Kassim	A.J. 70, No. 9, 1965
46	The Radial Velocity Field and Neutral Hydrogen Distribution in M 31 (abstract)	Morton S. Roberts	A.J. 70, No. 9, 1965
47	The Detection of the Hydrogen Emission Line $n_{110} \rightarrow n_{109}$ at the Frequency 5009 Mc/s in Galactic HII Regions (abstract)	B. Höglund and P. G. Mezger	A.J. 70, No. 9, 1965
48	Preliminary Results of 21 cm Line Observations of Open Clusters (abstract)	William E. Howard, III, and Gart Westerhout	A.J. 70, No. 9, 1965
49	First Observations at Short Wavelengths with the 140-ft Radio Telescope	J.W.M. Baars and P. G. Mezger	Sky and Telescope, XXXI, No. 1, 1966
50	National Radio Astronomy Observatory Annual Report	D. S. Heeschen	A.J. 70, No. 10, 1965
51	Power Law Detector	C.C. Bare, A. Steppe, and D. Thacker	Proc. IEEE, 53, No. 12, 1965
52	On the Error Involved in Poisson's Sum Formulation of Nonuniformly Spaced Antenna Arrays	Y. Leonard Chow	IEEE Trans. Ant. & Prop. 14, No. 1, 1966

Series B

No.	Title	Author	Reference
50	Structure of Quasi-stellar Radio Sources	T. K. Menon	Nature 206, No. 4986, 1965
51	Accurate Radio-Source Position Measurements with the NRAO Interferometer	C. M. Wade, B. G. Clark and D. E. Hogg	Ap.J. 142, No. 1, 1965
52	21-cm Hydrogen Measurements of NGC 5668, a Relatively Distant Galaxy	Morton S. Roberts	Ap.J. 142, No. 1, 1965
53	The Spectra of the Strongest Nonthermal Radio Sources in the Centimeter-Wavelength Range	F. J. Low	Ap.J. 142, No. 2, 1965
54	Radio Emission from HII Regions	Yervant Terzian	Ap.J. 142, No. 1, 1965
55	Lunar Nighttime Temperatures Measured at 20 Microns	F. J. Low	Ap.J. 142, No. 2, 1965
56	NGC 2359, NGC 6888, and Wolf-Rayet Stars	Hugh M. Johnson and David E. Hogg	Ap.J. 142, No. 3, 1965
57	Lunar Observations at a Wavelength of 1 Millimeter	F. J. Low and A. W. Davidson	Ap.J. 142, No. 3, 1965
58	The Diameter and Its Mean Error of a Radio Source	S. von Hoerner	Ap.J. 142, No. 3, 1965
59	Observations of 3C 273 and 3C 279 at 1 mm.	F. J. Low	Ap.J. 142, No. 3, 1965
60	Properties of Galaxies: The Neutral Hydrogen Distribution and Radial Velocity Field of NGC 925	B. Höglund and M. S. Roberts	Ap.J. 142, No. 4, 1965
61	Radio Observations of Several Normal Galaxies	M. L. DeJong	Ap.J. 142, No. 4, 1965
62	Observations of Six Spiral Galaxies at 1415 MHz	Marvin DeJong	Ap.J. 144, No. 2, 1966