National Astronomy and Ionosphere Center
Arecibo Observatory

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Cornell University, Ithaca, New York 14853

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The following report covers the period July 1996 through July 1997.

1. FACILITIES

The Arecibo Observatory is the primary research facility of the National Astronomy and Ionosphere Center (NAIC). The NAIC is operated as a visitor-oriented national research center by Cornell University under a cooperative agreement with the National Science Foundation (NSF). Partial support for the planetary radar program is provided by the National Aeronautics and Space Administration (NASA). Typically about 80% of the available observing time has gone to astronomical research programs, the remaining 20% going to research programs in atmospheric sciences (aeronomy).

The Arecibo Observatory is located about 12 km south of Arecibo, a city on the north coast of Puerto Rico about 80 km west of San Juan. The principle instrument of the observatory is a 305-m-diameter spherical radio reflector antenna. Radio sources can be tracked within 20 degrees of the zenith using moveable feeds suspended above the stationary reflector. The observatory latitude of 18°21′N gives a declination coverage of about $-1°39'$ to $+38°21'$. Depending upon their declinations, celestial objects may be within view at Arecibo for up to 2h40m each day.

Other facilities operated by the observatory include an optical facility and a high-power HF transmitting array. The optical and HF facilities are normally used for airglow observations and ionospheric heating experiments, respectively.

Operational support at Arecibo includes a scientific staff, an electronic maintenance and development shop, mechanical engineering and maintenance services, a computing center, technical library, drafting services, living accomodations for visiting scientists, and a cafeteria. Additional support is provided by the NAIC staff at Cornell University in Ithaca, New York, where a small electronics development group, some business functions, and a small scientific group are located.

2. TELESCOPE UPGRADE STATUS

The Observatory has just completed a major upgrade to the telescope, funded jointly by the NSF and NASA. The main component of the upgrade was the installation of a Gregorian subreflector feed system to replace most of the line feeds. Other parts of the upgrade included installation of a new, more powerful S-band transmitter and construction of a ground screen to eliminate spillover noise. Installation of the S-band transmitter in the Gregorian dome was completed in early summer of 1997 and the new radar tested out successfully. The new antenna drive systems were commissioned in September 1997 and full telescope tracking capability with both the Gregorian and 430 MHz (carriage house) feeds was achieved the following month. The first test observations (''first light'') with the completed Gregorian system were made in the third week of October, shortly before this report was submitted. The preliminary test observations of standard calibrator radio sources showed that the performance of the upgraded telescope was close to that expected. At that time the telescope commissioning phase began, to include pointing, calibration, and polarization tests for use in making final adjustments to the optical focus and alignment. Extensive azimuth rail alignment work remained that was expected to carry into the spring of 1998, although this was not expected to interfere with nighttime and weekend observations and commissioning work. A limited schedule of 430-MHz tracking-mode observations with the carriage-house feed was planned to begin in November 1997, and a special call went out for proposals to use the Gregorian feed during the interim commissioning phase. It is anticipated that the telescope will be in normal operational mode (with a full schedule of scientific observations on a fully calibrated instrument) by the summer of 1998.

3. INSTRUMENTATION

In the past, most observations with the Arecibo telescope used spherical aberration correcting line feeds mounted on one of two ''carriage houses'' on the azimuth arm. The telescope upgrade has replaced most of the line feeds with a single Gregorian subreflector system. Multiple feed horns at the Gregorian focus will eventually provide continuous frequency coverage between 300 MHz and 10 GHz. Replacing the 40-ft line feeds increases the maximum sensitivity at 1415 and 1665 MHz from 8 K/Jy to 12 K/Jy and lowers the minimum system temperature to 20 K. A new 1-MW S-band radar system has also been installed on the Gregorian; this new radar is more sensitive than the old S-band system by a zenith angle dependent factor of between 10 and 40. Carriage House #1 and its associated systems (including the 318 and 430 MHz feeds and the 430 MHz radar) have been retained, and a 430 MHz transmitting capability is planned for the Gregorian. The 430 MHz line feed has a sensitivity of 18 K/Jy and a beamwidth of 10 arcmin. This feed can be connected to a 2.5 MW peak-power (150 kW average power) radar transmitter; this 430 MHz radar is normally used for incoherent backscatter observations of the ionosphere. Radar observations of planets and other deep-space objects are normally made with the S-band (2380 MHz) radar, although the 430 MHz radar can also be used in cases where a lower radar frequency is desired.

Receiving systems to become available during the Gregorian commissioning phase (or shortly thereafter) include 430 MHz, 600-700 MHz, L-band (1.1–1.7 GHz), S-band (2.38 GHz), and C-band (3.95–5.85 GHz). An X-band (8.0–10.0 GHz) receiver is also planned for the near future.

Telescope pointing and realtime data acquisition are controlled using a network of VMEbus single-board computers

running the VxWorks operating system kernel. Custom-built data acquisition devices (''backends'') include (1) a general-purpose A/D system capable of sampling four analog channels at up to 10-MHz rates with programmable resolutions of 1 to 12 bits per sample per channel, (2) an (interim) 50-MHz, 4096-lag Spectral Line Correlator with programmable bandwidth from 195 kHz to 50 MHz, (3) a 50-MHz Radar Decoder, (4) a 100-MHz Spectral Line Correlator being developed, (5) a 10-MHz bandwidth Pulsar Search/Timing Machine with up to 256 channels, and (6) a wideband continuum/polarimetry instrument being developed. An S2 VLBI system is also available. Additional realtime signal processing capability is provided by four Skybolt i860-based VMEbus single-board computers with 240 MFLOPS peak combined capacity.

Data are recorded on 8mm tape using helical scan (Exabyte) recorders; short runs may be recorded on disk and accessed over the local area network. The analysis network consists of about forty Sun Microsystems workstations, about 30 GBytes of disk, and several 8mm (one 4mm) helical scan tape drives. Software available includes several interactive data reduction and display packages like ANALYZ, AIPS, IRAF, CLASS, IDL and MATLAB, the IMSL and PORTLIB mathematical subroutine libraries, specialized libraries for ephemeris calculation and data format conversions, and the FrameMaker desktop publishing system. Hardcopy devices include two 600dpi and two 300dpi black-and-white laser printers and one 300dpi dye-sublimation color printer. The Observatory network also includes about fifty IBM-AT compatibles and two Apple Macintosh computers, and is connected to the Internet via a dedicated 56Kbps link.

4. OBSERVING PROPOSALS

The Arecibo Observatory welcomes and encourages research projects by qualified scientists from other institutions. A complete explanation of proposal submission and evaluation procedures can be found on the observatory's Web site (**http://www.naic.edu**). Proposals are evaluated on a trimester basis, with submission deadlines of February 1, June 1, and October 1 of any given year. The normal scheduling window for a proposal begins four months after the corresponding deadline. All proposals are evaluated by anonymous referees outside of NAIC. Electronic proposal submission is preferred. This involves e-mailing the standard observatory Cover Sheet along with an attached Postscript file containing the body of the proposal. The Cover Sheet can be obtained by sending an empty e-mail to **cover@naic.edu**. Those proposers who cannot submit electronically, or who cannot provide a Postscript version of the body, may send their proposals to: Director, Arecibo Observatory, P.O. Box 995, Arecibo, PR 00614.

5. STAFF

The NAIC scientific staff is located in both Arecibo, Puerto Rico and on the Cornell campus in Ithaca, New York. Dr. Paul F. Goldsmith, Director of NAIC, is based in Ithaca.

The observatory's Director of Operations, Dr. Daniel R. Altschuler, is based in Arecibo. NAIC-affiliated scientists and their areas of specialization are listed below.

5.1 Arecibo Staff

D. R. Altschuler - *Active Radio Sources*
W. A. Baan - *Molecular Lines, Interstellar Medium*
M. M. Davis - *Pulsars, Extragalactic Line and Continuum*
Jo Ann Eder - *Extragalactic Astronomy, 21-cm Spectral Line Observations*
J. Friedman - *Optical Observations of Ionosphere*
T. Ghosh - *Low Frequency Variability, Active Galactic Nuclei, Interstellar Scintillation, VLBI*
S. A. Gonzalez - *Ionospheric Observations*
J. K. Harmon - *Planetary Radar, Solar Wind*
P. Hofner - *Molecular Lines*
B. Isham - *Ionospheric Radar and Modification*
B. M. Lewis - *Normal Galaxies, Interstellar Medium, OH/IR Stars, Circumstellar Shells*
B. MacPherson - *Ionospheric Modeling*
M. Nolan - *Planetary Radar, Asteroid Science*
C. Salter - *Galactic Continuum, AGN's, HI Absorption in Pulsars*
M. P. Sulzer - *Atmospheric Physics, Ionospheric Modification*
C. A. Tepley - *Airglow, Ionospheric Radar, Lidar Studies*
K. M. Xilouris - *Pulsars*
Q. Zhou - *Ionospheric Observations*

5.2 Cornell Staff

D. B. Campbell - *Planetary Radar*
J. M. Cordes - *pulsars, Interstellar Medium*
R. Giovanelli - *Extragalactic and Galactic Lines*
P. F. Goldsmith - *Molecular Clouds and Star Formation*
M. P. Haynes - *Extragalactic and Galactic Lines, Galaxies and Clusters*
M. C. Kelley - *Ionospheric Electrodynamics, Atmospheric Science*
Y. Terzian - *Planetary Nebulae, Interstellar Medium*

5.3 Summer Student Program

The Observatory conducts a Summer Student Program in astronomy and atmospheric sciences. For this program a small number of undergraduate and graduate students are chosen to spend the summer at Arecibo engaged in research programs under the supervision of staff scientists. Applications for the Summer Student Program should be submitted to NAIC by early February.

The Summer Students for the summer of 1997 were:
Francisco M. Acevedo, Embry-Riddle Coll.
Amanda Birmingham, Amherst Univ.
Brent Grime, Penn State Univ.
Christopher Hardin, Amherst Coll.
Zoe Leinhardt, Carleton Coll.
Melissa Nysewander, Agnes Scott Coll.
Anil Seith, Wesleyan Univ.
Arturo Yanez Navarrete, Univ. Puerto Rico

6. COMMITTEES

6.1 AU&SAC Committee

The Arecibo Users and Scientific Advisory Committee (AU&SAC) meets annually in Puerto Rico to advise the NAIC on the future needs for instrumentation and facilities. The current committee members are:

T. Bania, Boston Univ.
J. Breakall, Penn State Univ.
J. M. Dickey, Univ. Minnesota
D. Emerson, NRAO
C. Fesen, Dartmouth Coll.
R. Foster, Naval Res. Lab.
K. Groves, Phillips Lab.
T. Kane, Penn. State Univ.
M. F. Larson, Clemson Univ.
F. J. Lockman, NRAO
P. C. Myers, Harvard-Smithsonian CFA
P. Schloerb, Univ. Massachusetts

6.2 NAIC-VC Committee

The National Astronomy and Ionosphere Center Visiting Committee (NAIC-VC), appointed by Cornell to review the management and research programs of the Observatory, normally meets once a year. The current members are:

H. C. Carlson, Phillips Lab.
J. N. Hewitt, MIT
T. L. Killeen, Univ. Michigan
S. Kulkarni, Cal Tech
J. M. Moran, Smithsonian Astrophys. Obs.
P. Palmer, Univ. Chicago
J. E. Salah, Haystack Obs.
P. Schwartz, Naval Res. Lab.
S. C. Solomon, Carnegie Inst. of Wash.

7. PROGRAM HIGHLIGHTS

Telescope upgrade construction prevented tracking-mode observations during the entire reporting period. This restricted the observational astronomy program to drift-scan pulsar searches and participation in the inauguration of a new Space VLBI system. The remainder of the observing time was devoted to aeronomy programs, which are outside the purview of this report.

7.1 Pulsars

This reporting period saw the continuation of the drift-scan pulsar search programs that commenced with the start of the telescope upgrade in 1993. These searches were intended to make good scientific use of the telescope during those extended periods when there was no telescope tracking capability. The Arecibo sky was divided into declination strips and apportioned amongst five separate research groups that submitted proposals. As was the case for the last reporting period, this past year saw several extended interruptions to the search program due to upgrade-related conditions. This included periods when the 430 MHz feed was taken badly out of focus by the raising and lowering of the feed platform during tensioning of the main support cables and installation of the new tiedown cables. In spite of this, several hundred hours of good-quality search data were taken by the various groups. All of the data were taken using the Penn State Pulsar Machine (PSPM) as the backend processor. The PSPM is now a User-Owned/Public-Access instrument which is maintained by the Observatory and made available to any research groups using the telescope.

To date, the ''upgrade searches'' have resulted in (confirmed) discoveries of more than 60 pulsars. Most of the these confirmations were made earlier in the upgrade when the telescope could occasionally be used in tracking mode. We anticipate that the various search groups will use the telescope during the early post-upgrade period (which had just commenced in early November of 1997, when this report was submitted) to confirm the remainder of their pulsar candidates, which should result in a substantial increase in the total haul of new pulsars from the upgrade searches.

7.2 Space VLBI

Because of its great sensitivity, the Arecibo telescope is expected to become an important participant in the new field of Space VLBI. The observatory has recently become involved in the Japanese VSOP mission, whose space antenna (HALCA) was successfully launched in February of 1997. To function as a station in the VSOP network, the Observatory took loan of an S2 VLBI recorder from the Institute of Space and Terrestrial Sciences (ISTS) in Toronto, Canada. The first VSOP observations involving Arecibo were made in July 1997, and, despite the fact that the telescope was restricted to drift mode, fringes were obtained from the Arecibo baseline. Arecibo is expected to continue as a regular participant in VSOP observing programs, which includes general observing time as well as a 5-GHz survey of active galactic nuclei.

PUBLICATIONS

The following list of publications from NAIC staff and visiting scientists is not necessarily complete. These contributions appeared in the open literature or were in press during the period from July 1996 to July 1997.

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