NATIONAL ASTRONOMY AND IONOSPHERE CENTER

Arecibo Observatory

NEWSLETTER

October 1995, Number 17

Upgrade Project Status

Don Campbell

Site Activity

Despite three hurricane threats with two, Luis and Marilyn, requiring complete shutdowns of the observatory for several days, the structural reinforcement work on the suspended structure of the telescope and the assembly of the dome are proceeding at a rapid pace. The very tedious and time-consuming task of reinforcing almost every truss and gusset plate in the feed arm is finally approaching an end with completion expected in early October. The massive feed arm outriggers are now in place. Attached to them will be the eight new azimuth drive trolleys that support the weight of the feed arm and dome from the azimuth girder. Major tasks still to be completed before the dome can be lifted to the elevation rails are the re-alignments of the elevation rails, the girder which supports the elevation drive rack, and the 430-MHz slotted waveguide, plus the installation of the azimuth drive trolleys, wheels, and support platforms.

Down on the ground or, at least, on a 100ft x 100ft working platform constructed above the center of the primary reflector, the 86ft diameter dome is being assembled. The collar truss, a 40ft-diameter steel "donut" to which the elevation trolleys are attached and which supports the dome, secondary reflector, and feed tower, has been assembled on top of a 50ft-high tower above the working platform. The dome is now being built out from the collar truss and the upper sections of the secondary reflector back-up structure will be installed shortly. The

Tony Acevedo

Assembly of the Gregorian enclosure above the center of the reflector. The collar truss is complete, and the first ring of support ribs for the dome are being attached.

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The **NAIC** is operated by **Cornell University** under a
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415 panels of the secondary reflector will be installed starting in October.

The Reflector System

Approximately three quarters of the 415 secondary reflector panels have been fabricated at COMSAT-RSI's plant in Sterling, Virginia. Because of the asymmetrical shape of the secondary and tertiary reflectors (they have only a plane-of-mirror symmetry) every panel is unique. This, combined with the requirement for very lightweight reflectors, made panel production an extremely difficult process. The panels for the secondary reflector will have an average weight of 1.3lb per sq ft and an rms surface accuracy of 0.25mm. The total weight of the 5,800-sq-ft secondary reflector, including the back-up structure, will be less than 15,000lb, a very light-weight structure. It will be shielded by the dome from wind forces, and the 20° zenith angle coverage of the telescope means that it only rotates ±10° in the gravity field. COMSAT-RSI will be installing the secondary reflector before lifting the dome. Setting accuracy is expected to be less than 3mm. After dome lift, NAIC will check the surface accuracy to determine if the efficiency at 6cm will be acceptable. If not, the surface will be reset so that performance at this wavelength is satisfactory. A full refairing of the surface will be done at a later date to optimize performance at 3cm.

The 8m x 9m tertiary reflector and support structure are under final design by COMSAT-RSI with delivery to Arecibo scheduled for early April of next year. It has 60 aluminum panels plus an approximately 4ft vertex panel milled out of solid aluminum. Surface accuracy is specified to vary from 0.1mm for the vertex panel to 0.3mm for the edge panels. The 15dB taper in the illumination pattern for the tertiary at its edge means the power is very much concentrated towards the center of the tertiary, making a graded error very cost effective. The tertiary's support and control system will allow it to be translated and rotated in the plane of symmetry of the reflector system (i.e. in the plane parallel to the feed arm).

Cutaway view of the dome shows the backup structure and panels of the secondary subreflector and the 43ft entrance pupil through the protective wind screen.

The tertiary subreflector is attached to the bottom of the feed tower. Receivers will be mounted on the rotating feed turret, and the 1-MW S-band transmitter will be on the floor above, connected to its feed through a rotary joint.

Other Activities

Fabrication of the new azimuth, dome, and Carriage House I drive systems is proceeding with the first components, a temporary drive system for motion in azimuth once the new azimuth trolleys are installed, due in October. The factory acceptance tests for the 1MW S-Band transmitter are scheduled for November, and delivery in Arecibo of the 2.5MW turbine generator, the prime power source for the transmitter, expected in December.

Update on Receiver Electronics Systems Development

Paul Goldsmith

The receiver electronics for the Gregorian system include the receiver front ends and the IF/LO system that processes the signals and carries them to the control room for analysis by the various signal processing systems. This note summarizes recent progress on these systems. Work on the front ends is mostly taking place in Ithaca. Gene Lauria is working full time on this project and is being supported by Bill Genter and Kurt Kabelac. In Arecibo the IF/LO system work is being led by Eddie Castro and Bob Zimmerman, with the entire electronics department staff making major contributions.

Group I Receivers

The Gregorian allows continuous frequency coverage between approximately 300 MHz (limited by diffraction) and 10 GHz (set by primary reflector surface accuracy; this limit is not rigidly determined and may not be this high initially, but we hope it will gradually increase!). As a result of deliberations by various committees, etc., we have decided on the frequency coverage of the initial set, and work is proceeding on all these receivers. We expect this group to be available by the time of telescope "first light" in Spring 1996. We denote this first set of five as the Group I receivers.

The first of this group covers 400-450 MHz. It will employ a dual-mode feed horn that should give good beam patterns over this range. The dewar has been designed and fabrication should start shortly. The amplifiers have been received from the manufacturer and their specifications are extremely good--a noise temperature of less than 2 K! Obviously, the system temperature will be dominated by other factors. It will be very interesting to see how much of this bandwidth can actually be utilized given the Arecibo RFI environment.

The second receiver covers 1.1-1.7 GHz (approximately) and is mostly built from parts furnished by NASA. This system will be used with a broadband scalar feed horn. At the present time, the first trial cool-downs of the dewar are in progress. The feed horn has been designed, and will be fabricated in late Fall 1995.

The next receiver is the current S-band maser, which has to be refurbished and have its control electronics redesigned to be compatible with the new monitor-and-control system. The dual-channel system will be used with a scalar feed horn that has already been built and tested.

Moving up in frequency, we have the 4-6 GHz (nominal) receiver. Like all others except the maser, it uses HEMT amplifiers cooled to 15 K. This receiver has been completed and tested, and works well with a noise temperature about 15 K. We have built one feed horn, which has excellent beam patterns, but a dielectric insert adds a few K of noise. A horn without this insert has good patterns, but the beamwidth varies more systematically with frequency than with the dielectric. At the present time either horn can be used, but it appears likely that the detailed calculations that are in progress will show that the lower-noise horn will give superior performance.

Finally, the highest frequency receiver covers 8 to 10 GHz. This unit is also complete, and performs with noise temperature just over 20 K. Its feed horn lies inside the dewar and uses a window to allow the beam to emerge from the dewar. The original window seemed to be vignetting the beam slightly, so a new window has just been completed and tested.

These receivers have a more elaborate calibration system than what was previously employed. In addition to the LO and HI cals, the two polarizations can be sent calibration signals independently, or simultaneously with a 0- or 90-deg phase shift between the two. This scheme will enable better polarization calibration.

With the Group I receivers we will be ready to use the Gregorian in key frequency ranges and explore the performance of the system near its expected maximum frequency. The 8-10 GHz range may suffer initially from low efficiency, but we expect that data obtained with this receiver will be very valuable for improving the pointing and tracking of the system, as well as determining what needs to be done to improve the surface of the primary reflector.

Other Receivers

After we have achieved first light and have the Group I receivers functioning properly, we will turn our attention to other receivers to fill in the frequency gaps. These include, provisionally, 700-900 MHz, 2.6-4 GHz, and 6-8 GHz. The exact specifications and ordering of these systems will be a subject of discussions at the various visiting committee meetings in October at the Observatory.

IF/LO System

The name of this system is short for "intermediate frequency and local oscillator system," which is a historical accident in that mixers were operated by local oscillators (LOs) and the frequency output was lower than the input, and so was called the "intermediate frequency" (IF).

The IF/LO system is responsible for several tasks in the chain of signal processing that starts with the receiver itself. In each receiver there is about 70 dB (10^7) gain in power, but the signals are still at a fairly low level. The first part of the IF/LO system will be located in the receiver room of the feed tower (in the Gregorian enclosure). All switches, level adjustments, and local oscillator frequency settings will be computer controlled. We envision all setups of the IF/LO system to be storable as "templates" that can be invoked by the new user-interface software system. Thus, once you have found a satisfactory arrangement, you can store it, recall it when desired, and never accidently plug in the wrong BNC cable again!

The "upstairs" IF/LO system will carry out the following tasks:

(1) Selects the receiver to be used.

(2) Interchanges signals between two receiver channels and two following signal-processing channels for polarization work (the "Zeeman box"). The two signal channels can also be gain-balanced and delay-matched.

(3) Converts from linear to circular polarization or vice-versa, if desired.

(4) Amplifies, filters, and frequency converts the signals, including upconversion and downconversion, simple downconversion, or no conversion. For frequency conversion a Hewlett-Packard synthesizer will be employed.

(5) Adjusts signal levels.

(6) Sends the signals through coaxial cable or fiber optics cable to the control room.

The maximum instantaneous bandwidth is 1 GHz, which is transmitted using the optical fiber. Narrow bandwidth signals can alternatively use coaxial cable.

The "downstairs" IF/LO system takes the IFs sent from the antenna, then distributes and processes them for various signal processing instruments. There are four additional synthesizers that can be used to mix with different portions of the band (in each polarization)

For broadband applications, three segments with up to 500-MHz-bandwidth each can be placed anywhere within the passband. These can be used with broadband spectrometers, for example. These instruments will have their own downconverters that will start from the 0-500 MHz output of the downstairs IF/LO system. The outputs can also be sent to a VLBI recorder (100-500 MHz pass band, when we get one), radar decoder, and power monitor.

There are also a variety of narrower band outputs that can be used for pulsar and radar signal processing applications.

The basic philosophy here is as mentioned above. Computer controlled switches, synthesizers, and attenuators enable software definitions of standard configurations. There will, however, be a multitude of signal inputs and outputs (front panel SMA connectors) that can be used for monitoring, to create special configurations, or to connect equipment not foreseen in the basic design. We thus hope to accommodate those with special needs as well as routine observers. We have a clear intent to allow for remote observing if desired, in that the system templates should make it relatively easy to guarantee repeatable system configuration after initial tests.

The upstairs IF/LO system is essentially complete at this time, and the downstairs system is coming along rapidly. We hope to have a more-or-less full-scale system test and evaluation going on by mid-October, which will allow both hardware and control software to be tested.

Control Room Changes

Daniel R. Altschuler

In the past our control room was often crowded with operators, current observer(s), next observer(s), and other staff members competing for space. The receiver room served also as a passage to the control room and outside areas, jeopardizing the safety of equipment and the tranquility of work. The situation was aggravated when visitor equipment was added, sometimes filling up space to the point where it became difficult to work. We have therefore developed a plan to modify the control room in two phases, the first of which should be underway as you read this. The accompanying diagram shows the planned modifications that will be done in two phases.

During Phase I we are replacing the floor and ceilings in the control and adjacent areas, and cleaning up and removing old equipment. We have removed several miles of old cables, some of which had already forgotten what a current was. The power distribution system has been refurbished and old grounding problems have been eliminated.

A new passage to the control room, as shown in the figure below, will minimize traffic through the receiver room and will allow us to convert the current passage into a tape library.

The old console is almost gone, to be replaced by workstations and display monitors. What little hard-wiring required will be placed on desktop racks, which will make it easy to rearrange the layout as we gain experience with the new systems.

Finally, as a small detail, we shall replace the alarm bell in the control room, which has over the past years served to spill a few coffee cups in the middle of the night, by a new, more civilized sound. Phase I should be completed by the end of this year.

With the construction of the AOVEF we shall no longer need the enclosed area by the control room now used by our public visitors. Phase II of the project includes new areas as shown in the figure.

Layout of the modified control room.

The next-observer area will have workstations, manuals and references, tables, and chairs for the next observer(s) to be able to prepare for observing without interfering with the current observer(s) (unless this is needed to get her off the telescope). Engineers and computing staff will be able to use this area, as well as observers who need to finish up their work. A small kitchenette is also provided.

The office will be used by the head of telescope operations and/or the observer's friend in charge of absentee observing, and equipment brought by visitors will be placed in the user-supplied equipment area. The current receiver room will be used mostly for observatory equipment. Phase II should be completed by mid-1996.

Radio Astronomy Highlights

Chris Salter

Construction work on the Arecibo Upgrade continues to impact heavily upon astronomical observations made with the telescope. Over the complete period since the appearance of the last Newsletter, structural work involving the telescope platform has not only prevented tracking from being available to observers, but usually meant that NAIC has had no control over the positions at which the azimuth arm and the carriage house have been fixed. Presently (early Sep '95), the main astronomical observations taking place with the telescope are those at 430 MHz by F. Briggs (Groningen) and M. Davis (NAIC) for a deep survey to detect HI in the λ21-cm line at a redshift of 2.26 – 2.34. The experiment is also receptive to OH mega-masers at z ~ 2.9.

Pulsar equipment available at the telescope has taken a step forward with the appearance of the Arecibo Observatory Fourier Transform Machine (AOFTM), an NAIC facility instrument designed primarily as a pulsar search machine and matched to the 430-MHz line feed. It provides from 64 to 1024 frequency channels over a 10-MHz bandwidth, with corresponding integration times that are multiples of 6 to 102 μs, all under computer control. The machine has been built through a collaborative effort between NAIC, Cornell, and Harvard. It accepts I.F. inputs at 48.75 – 58.75 MHz, which are mixed to baseband and quadrature sampled in 8 mixer/digitizer (M/D) boards; these digital signals are spectrum analyzed on 16 spectrum/power-accumulator (SPA) boards; outputs from the SPA boards are compressed and summed on 4 data-packer boards (DPB); traffic control and communication with a SPARCstation 5 is done on a timing board. The aggregate data rate to the workstation (through a parallel SBus card) is 2.5 Mbytes/s. The M/D and SPA boards were designed by P. Horowitz & J. Weintroub (Harvard). The DPB and timing boards were designed by Cornell M.Eng. student, D. Koechner, & J. Cordes (Cornell); system integration was also done by Koechner.

The AOFTM was taken to NRAO, Green Bank, in early June 1995 for tests on the 85-3 and 140-ft telescopes, with D. Koechner, Z. Arzoumanian (Cornell), & J. Cordes participating. The AOFTM

Figure 1. *Top:* The strongest single pulses in the main pulse and interpulse of PSR B1937+21. The noise is $\chi^2(4)$ distributed, which accounts for the deep modulation.
Middle and bottom: The average shapes of the 60 strongest pulses in the main pulse and interpulse regions. The solid line represents total intensity, while the dashed and dotted lines give the linear and circular polarization respectively. The polarization position angle is shown in the lower panel. Dot-dashed lines represent the time-aligned average of all 1.7 million pulses. The data have 1.2 μs resolution.

Figure 2. Integrated pulse profiles of PSR J2229+2643 at 430 and 1408 MHz. The 430-MHz profile was obtained using pre-detection dispersion removal and has instrumental smoothing of only 20 µs. The 1408-MHz profile was obtained from filter-bank data and has a resolution of 100 µs.

obtained fast-sampled data on PSR B0329+54 and on the millisecond pulsar, PSR B1937+21. Folding of the data at the known pulsar periods yielded pulse profiles with the anticipated signal-to-noise ratios, demonstrating signal integrity throughout the system. The AOFTM was installed at Arecibo by Cordes & Arzoumanian during the week of 31 July 1995. The AOFTM still needs software development to interface it with the post-upgrade monitor and control system and to improve its functionality. It also needs retrofitting to improve cooling in its rack and to improve its internal clock signal. Routine data acquisition also requires a means for recording the data to tape. Its data rate is well matched to the Exabyte Mammoth tape drive (3 MByte/s) which will be "beta tested" soon.

In Nov 1994, I. Cognard, J.A. Shrauner, J.H. Taylor, & S.E. Thorsett (Princeton) used a pre-detection de-dispersion system to observe 1.7-million individual 430-MHz pulses from the millisecond pulsar, PSR B1937+21. They found that about one pulse in ten thousand has > 20 times the mean "pulse-on" flux density, and individual pulses as large as 300 times the average were observed. Comparable behavior is known to exist only for the Crab pulsar. Giant pulses from PSR B1937+21 are seen in both the main pulse and interpulse components, and their amplitude distribution has roughly a power-law shape. PSR B1937+21 exhibits a pulse or interpulse at least 100 times stronger than the mean signal level about once per 800,000 pulses. Strong pulses differ greatly from the average emission, being narrower, systematically delayed by some 40 – 50 µs, and many are nearly 100% circularly polarized (Fig. 1). The giant pulses may be useful for high precision timing measurements, their average pulse profile exhibiting a very short rise time, of order 5 µs. The giant pulses are also potentially important for elucidating the physics of the emission region, and these observers note that the Crab pulsar and PSR B1937+21 have the largest estimates of any pulsars for the strength of the magnetic field at the light cylinder (where co-rotation would occur at the speed of light).

F. Camilo, D.J. Nice & J.H. Taylor (Princeton) report on follow-up observations of three recycled pulsars discovered by them during a high-galactic latitude search made at Arecibo between Aug 91 and Dec 93. Timing of the unusual isolated 60-ms pulsar, PSR J2235+1506, yields a proper motion for the object which, together with its DM-estimated distance, provides a transverse velocity roughly parallel to the galactic plane of 100 ±40 kms^{-1}. Correcting the measured period derivative for this motion yields an inferred surface magnetic field of 2.6 $\times 10^9$ G and spindown timescale of 8.3 $\times 10^9$ yr. The few pulsars remotely near PSR J2235+1506 in the $p - \dot{p}$ diagram are all in double neutron star binary systems, suggesting that it was once in a bound system that disrupted with the second supernova explosion in the system. The 3.4-ms binary pulsar, PSR J2317+1439, proves to be in the most circular orbit of any kind known to date ($e < 1.2 \times 10^{-6}$), implying semi-major and semi-minor axes that differ by less than 1 mm! Its inferred surface magnetic field (9×10^7G) and spindown timescale (2×10^9 yr) are respectively the second lowest and second longest yet known. The latter is longer than the age of the galactic disk, implying that the initial spin period must have been ≥ 2.4 ms. This object has an implied transverse velocity of 70±30 kms^{-1} directed roughly perpendicular to the galactic plane, suggesting that it is returning to the plane after an oscillation about it. The 3-ms binary pulsar, PSR J2229+2643 (Fig. 2), is in a near-circular orbit with a companion of mass ~0.15 M_o. An optical search with the Mt. Palomar 200-inch telescope for the companions of this object, and of PSR J2317+1439, detected no star down to ~ 25 mag, placing lower limits of 10^9 yr on the cooling age for the assumed white-dwarf companions, and thus on the ages of the pulsars. PSR J2229+2643 has the longest spindown timescale of any pulsar (25×10^9 yr), again longer than the age of the galaxy, and suggesting a lower limit to its initial spin period of ≥ 2.1 ms. The very low $\dot{p}$ for this pulsar sets an upper limit on its transverse velocity of 100 kms^{-1}. Its low value of $\dot{P}$ also allows the placing of an upper limit on the possible rate of change of the

Figure 3. Scaled column densities as a function of declination offset (arcmin) in dark cloud B5 for ^{13}CO (solid line), $C^{18}O$ (dashed line) and OH (short dashed line).

Newtonian constant of gravity, $|\dot{G}/G|$ $< 3 \times 10^{-11}$ yr^{-1}. This limit is similar to estimates from solar-system measurements, and from binary pulsar evolution measurements, providing a tight constraint on the variation of G. As an interesting aside, the long-period pulsar, PSR J0006+1834, found in the same pulsar search, has been shown by these investigators to have the lowest measured average flux density of any known pulsar (0.2 mJy).

The unbiased drift-scan HI survey for extragalactic clouds and gas-rich galaxies carried out by E. Sorar & F. Briggs (Pittsburgh & Groningen) from Aug 1993 to Feb 1994 covered ~ 67 deg^2 out to a velocity of 7,400 kms^{-1}. It had a spectral resolution of 16 kms^{-1} after Hanning smoothing, and achieved a 5-σ level near 10^{18} H atoms cm^{-2}. A total of 61 galaxies, 32 of which were previously uncataloged, were detected, almost all the uncataloged detections having clear identifications with galaxies on the POSS prints. In follow-up observations, the VLA has been used in snapshot mode to image the Arecibo detections in order to refine their positions. These galaxies will be photographed at La Palma this fall.

P. Goldsmith (NAIC) & C. Carter (Cornell) have been analyzing the distribution of OH molecules in several dark clouds, in conjunction with the Submillimeter Wave Astronomy Satellite (SWAS) project which will observe the important related species, H_2O and O_2. The OH data were taken at Arecibo prior to removal of Carriage House 2. One source mapped in some detail is the dark cloud B5, which is at a distance of approximately 400 pc. The OH distribution has been compared with the column density distributions of ^{13}CO and $C^{18}O$. The peak column density of ^{13}CO is 4.3 x 10^{15} cm^{-2}, while those of $C^{18}O$ and OH are 1.2×10^{15} and 1.6×10^{14} cm^{-2} respectively. These values of the column densities agree quite well with the results of chemical modeling codes, but the distribution of OH is significantly more spatially extended than expected. It is evident (Fig. 3) that, unlike the $C^{18}O$, the OH follows the ^{13}CO distribution quite closely, indicating that it is not restricted to the dense, well-shielded central region of the cloud, and consequently that OH emission does not trace this region of the cloud very clearly. This clearly has implications for the use of OH as a tracer of the magnetic field via the Zeeman effect.

B.M. Lewis (NAIC), P. David, & A.M. Le Squeren (Meudon) recently showed that the frequency of detectable mainline OH masers from the oxygen-rich circumstellar shells of mira variables is correlated with their low resolution spectral type (LRS). Lewis has now tested the generality of a dependence in the incidence of masers on dust-type by compiling statistics from most extant observations of H_2O, SiO, and the 1612-, 1665-, and 1667-MHz OH masers. He finds that H_2O and the OH masers have a strong, and generally similar, dependence on dust type that is independent of the IR colors in thin shells, while SiO masers have at most a weak dependence on type. For each masing species the detection rates from LRS 20-25 type shells are intermediate between those of "featureless" (1*n*) shells and those of shells with a stronger 9.7-μm line, which always have the largest detection rates. When the joint occurrence of H_2O and mainline masers is considered, there is a factor of 5 difference between detection rates exhibited by the most disparate LRS types, that is not reduced much by treating all OH masers together, or by limiting the sample to objects from the more-sensitive OH searches of the Arecibo sky.

This LRS-type dependence in the incidence of masers is probably due to a gradual change in the UV extinction of circumstellar dust with type: this is expected when the size of dust grains about objects without silicate features is < 0.02 μm, so UV scattering is important. More of the UV photons are then available to degrade molecules, which reduces the possibility of their supporting a maser. The gradual change in the incidence of masers with type is tentatively attributed to an increase in the relative number of large, absorptive rather than scattering, grains as the silicate feature strengthens. Evidence for a UV wavelength dependence to the dust-grain extinction can be deduced for some miras from the unusual conjunction of strong mainline OH masers from shells that do not exhibit H_2O masers.

Atmospheric Science Highlights

Craig Tepley

A few atmospheric sciences programs at Arecibo can now be considered conventional or routine. Among them is the so-called World Day program. It is a coordinated effort among several radar and optical observatories, and involves both national and international studies. The program is designed to observe periodically the complex processes of the upper atmosphere. World Day campaigns at Arecibo have continued through the upgrade with minimal down-time. The 430-MHz incoherent scatter radar was used along with various optical systems that were operational except for a few brief periods. Besides World Day studies, several other, and sometimes more extensive, observational programs recently took place. We discuss those results next by atmospheric regions.

Protonosphere and Exosphere

Sixto González and Michael Sulzer of NAIC continued their studies of the topside ionosphere and exosphere. Their goal is to develop a better understanding of the behavior of the ion composition through observations of O^+, H^+, and He^+. The measurements compare favorably with model predictions of both the steady-state and the dynamical behavior of the high altitude ion distribution. The University of Sheffield model, developed by Graham Bailey and coworkers, can reproduce the behavior of the O^+ to H^+ transition region fairly well. In particular, the model can simulate the post--sunset collapse and the morning rise of the transition altitude.

Helium ion measurements at Arecibo show that He^+ forms a layer near the O^+ to H^+ transition altitude. The layer appears near 1200 km altitude during the day and 600 km at night, with a maximum concentration of roughly 15% of the total plasma. The Sheffield model simulates the helium ion layer reasonably well. The altitude of the layer peak is similar but several major differences exist. For example, the measured layer is much thinner, and during the night the simulated layer reaches a peak concentration ratio of only half of the measured value. These differences indicate that we do not fully understand the details of the physics and chemistry of He^+ layer formation. However, this work is very encouraging considering that conventional wisdom suggested that He^+ layer formation was not possible at these altitudes.

Even though high altitude radar observations were made at Arecibo since the late 1960s, certain features of the data that have faded away from interest are now being rediscovered with careful analysis. For example, Mike Sulzer has processed topside ionospheric spectra for unequal H^+ and O^+ ion temperatures. The standard analysis assumes $T_{O^+} = T_{H^+} \equiv T_i$ and determines T_e, T_i, and the fractional composition of H^+ and He^+ with respect to the electron concentration. The new analysis relaxes the equal-ion-temperature assumption and determines both ion temperatures with the other parameters. In both cases, T_{He^+} is assumed to be equal to T_{O^+}. The result confirms what one might expect, that is, the temperature of the lighter ion, T_{H^+}, is found to be greater than that of the heavier one, T_{O^+}, particularly in the O^+ to H^+ transition region below about 800 km. The fractional ratio of protons to electrons, and the electron temperature, T_e, essentially are unaffected. The two-ion-temperature analysis also suggests slightly larger estimates of the minor ion, He^+, in the transition region, where He^+ is observed to maximize and form a layer.

This high altitude work will continue through 1996 and successive years. The observational program will be immensely strengthened by supplemental measurements of the neutral exosphere, in particular by measurements of neutral hydrogen (by observing Hα at 656 nm) and helium (by observing the He resonance emission at 1083 nm). The helium measurement is made possible by Robert Kerr of Boston University who installed his infrared interferometer at Arecibo in September 1995. Kerr's "helium machine" will operate for about a year with our own instruments. Through this multi-instrumented program designed to observe the high altitude distribution of ionized *and* neutral constituents, they hope to elucidate the chemical and dynamical processes involved in hydrogen, and possibly helium, escape from the exosphere.

Ionosphere

Analysis also continues with older but very important data sets. Qihou Zhou of NAIC has examined the long-period atmospheric tidal features of the lower thermosphere from the January 1993, ten-day World Day study. He found strong evidence for a planetary wave feature with a two-day period. It was observed most distinctly in the meridional component of the neutral wind between 92 and 112 km altitude, although there is an indication of the two-day wave in the zonal component as well. Below 95 km the tidal components display predominantly diurnal behavior, whereas above 95 km the semidiurnal component is dominant. These two main modes merge within the 90-115 km altitude range. A longer period, six-day oscillation was also observed in the plasma temperature and in the electron concentration measured in the F-region ionosphere. This study of global tidal or planetary wave features was only possible by acquiring such an extended and continuous data set.

Zhou recently initiated two new studies of the ionosphere. The first is an investigation of so-called space debris. The work is an outgrowth of his meteor studies. This new study looks for coherent echoes having an effective scattering cross-section of the order of 10^{-7} m^2 at 500 km. Of interest are the particle size, altitude distribution, and the orbital characteristics of objects as small as a centimeter in radius. The results of this new study at Arecibo could be of value to the National Space Weather Program currently under development.

The second study in which Zhou is involved is an investigation of ambipolar diffusion within nighttime sporadic layers of ionization, commonly known as sporadic E, or E_s. Similar studies were performed many years ago (in the early 1970s) at Arecibo by Robert Harper, but these earlier measurements have faded from attention during the last two decades. The current work will yield new estimates of the ambipolar diffusion coefficient, and also the ion-neutral collision frequency, ion temperature, and nighttime ion mass within E_s layers. Recent measurements reveal a zero vertical ion drift within E_s layers, which strongly supports a wind-shear mechanism for layer formation compared with, for example, the operation of an electric field on the motion of the layer. Zhou's study will provide new insight concerning the validity of wind-shear mechanisms in the formation of sporadic ion layers, as well as help characterize the geophysical conditions required to produce sudden ionization layers.

Middle and Lower Atmosphere

Paul Castleberg of Cornell, and Jonathan Friedman and John Cho of NAIC have compared Rayleigh lidar observations with measurements made by other instruments such as the balloon-borne rawinsondes launched periodically from San Juan. Atmospheric density observed by the lidar often display various wave-like features, both at long and short wavelengths. The variances of the density fluctuations are small in the stratosphere and larger in the troposphere. This is consistent with the high convective stability of the stratosphere and the more widely turbulent nature of the troposphere.

The density variations ($d\rho/\rho_o$) in the atmosphere are to first order proportional to the temperature variations (dT/T_o), under the assumption that pressure variations are small in comparison, such that $d\rho/\rho_o = -dT/T_o$. Following this assumption, an appropriate figure of merit for the lidar system is to compare the vertical wavenumber spectra of the temperature perturbations from the San Juan balloon records with those of the lidar density fluctuations. When this was done, the two spectral densities showed good agreement in the general shape, but with differences in the specific peaks. Castleberg et al. will be investigating these differences in further analyses.

Soon we will begin an intense observing schedule using both the lidar and radar and expect to report the comparison of the winds measured by both instruments. Lidar activity is anticipated to accelerate in the coming years because of recent improvements to the frequency stability of the Rayleigh system, and with the recent acquisition of a tunable solid state, chromium-doped alexandrite (Cr:Be Al_2O_4) laser for resonance fluorescence studies and differential absorption lidar work.

The 1.95-MHz spaced antenna drift radar that is located in Aguadilla, PR is now producing reliable mesospheric wind and tide data. This system recently underwent a complete overhaul by the Australian manufacturer, and since June 1995 the radar has been continuously operating. It is primarily used (and maintained) by Hector Monroy of the University of Puerto Rico at Mayagüez and his students in their research program. A spectral analysis of a month-long time series of zonal and meridional winds measured by this instrument reveals many tidal features of the 70-100 km altitude region. For example, diurnal and semidiurnal tidal components and a longer period, two- to three-day wave are often evident in both wind components. There is sometimes a hint of the terdiurnal tide as well. The long-period wave components are similar to what have been observed with the incoherent scatter radar data by Zhou. This first look of the data from the refurbished system is quite encouraging. The 1.95-MHz radar should now prove to be a valuable asset to middle atmospheric research in Puerto Rico.

In May of 1995, Robert Palmer and his graduate student, Perry Howell, of the University of Nebraska, brought the receiver and data-acquisition system for the 430-MHz spatial-domain interferometer to Arecibo. The three towers that hold the receiving antennas are located behind the Optical Lab with the electronics inside the building. Interfacing the system to the antenna array and the timing and phase-locking signals of the transmitter went smoothly.

Before the 430-MHz radar was shut down for the azimuth bearing replacement, Palmer, Howell, and Cho ran the transmitter for several days and acquired initial test data with this new receiver. The results were presented in a poster at the 1995 CEDAR Workshop held in Boulder.

Another test was conducted by Howell, Cho, and Bob Zimmerman of NAIC during 20-26 August. Some hardware problems were discovered and fixed; the subsequent data appeared to be much improved over what they had obtained previously. Howell and Palmer are presently analyzing the data, which will be compared with the data obtained simultaneously with the normal monostatic receiving system. Further testing and refinement of the interferometer will continue through the end of the year and early next year. Eventually it will provide high time-resolution measurements of the three-dimensional wind vector throughout the lower atmosphere. This is a quantity not well measured by the conventional radar due to its slow beam steering and severe ground clutter.

One of the outstanding scientific problems in middle atmosphere dynamics is the role that stratospheric turbulence plays in the vertical transport of minor constituents such as ozone, water vapor, and aerosols from volcanic eruptions and supersonic jet planes. Because the turbulence occurs in extremely thin layers (due to the high convective stability of the stratosphere), its observation has been difficult. A stratosphere-troposphere (ST) radar typically has a maximum range resolution of 150 m, but stratospheric turbulence often has finer scale features of the order of tens of meters.

To overcome the range resolution problem, during the last decade Ron Woodman (Jicamarca Radio Observatory) and Mario Ierkic (UPR/Mayagüez) applied the Arecibo bistatic S-band planetary radar for stratospheric observations. They used a pseudorandom periodic binary code with very short baud length to achieve a 20 m height resolution. Their impressive initial results promised a great scientific return, but the work was not followed up, and the 100-ft auxiliary antenna used as the receiver has been taken out of commission. Currently there is no funding to re-install it.

Since March 1994, John Cho has been collaborating with Raymond Jurgens and Martin Slade of NASA's Jet Propulsion Laboratory to apply the same technique to the Goldstone planetary radar. After several experiments ironing out the various hardware and software problems, they succeeded in obtaining stratospheric data in August 1995. (Incidentally, this was the first time that the Goldstone radar was used to observe the Earth's atmosphere.) With an altitude resolution of 22 m and a time resolution of 15 s, Cho and coworkers observed many fine-scale features of the turbulent layer. A radar with 150-m resolution (such as the 430-MHz radar) would never see such features. In addition, oscillations in the observed vertical velocity had varying period, with the more rapid motions having a period of less than 2 minutes, which is significantly below the Brunt-Väisälä period. This implies that either these high-frequency waves are acoustic waves or they are gravity waves that have been Doppler shifted by the ambient horizontal winds. Further analysis will be forthcoming after rawinsonde data from a nearby station has been obtained.

An important weakness of both the Goldstone and the original Arecibo experiments is that the long baselines of the bistatic geometry restricts the beam intersection volume to be small. In other words, only a short segment (one or two turbulent layers) in altitude can be viewed simultaneously. We can eliminate this problem by reinstalling the 100-ft auxiliary antenna on site, closer to the main dish. This is a worthy project that has yet to receive funding. With the anticipated development of a lidar capable of measuring minor constituents with high resolution, Arecibo would be in a great position to conduct front-line research in the vertical transport of trace species in the stratosphere.

Optical Lab Report

Jonathan Friedman

The rate of activity in the optical laboratory is continuing its monotonic increase driven by both internal and external factors. Internally, the arrival of the first of the 30" telescopes for the lidar, coupled with the shakedown tests of the upgraded Doppler-Rayleigh lidar, kept the on-site staff busy. The arrival of the pulsed alexandrite laser for the resonance lidar on September 20 added to the excitement. This activity is expected to culminate in the construction of a new lidar facility, the plans for which are being drawn up now. Monthly 630-nm airglow observations, in support of and in preparation for topside helium observations, began at the end of 1994 and continued through early May 1995. Externally, the Los Alamos total electron content monitor continues to be operated with support from Cornell, the Boston University imager is completing its tenure, and topside hydrogen and helium measurements are set to begin this month.

First shakedown experiments of the wind measurement mode of the Doppler-Rayleigh lidar were conducted in May and June by Paul Castleberg, Jonathan Friedman, and Henry Roe (an REU summer student). Henry worked this summer on the lidar project improving the hardware, learning the data analysis, and developing a calibration method with a constant Doppler source, a.k.a. the "Paddle Wheel" experiment. In the Paddle Wheel experiment, the laser light is scattered from reflectors mounted on a fast-spinning wheel, and the Doppler shift of the return light is measured against a zero-Doppler in-lab reference. The in-lab test of the Paddle Wheel was successfully conducted during Henry's stay, and the field tests are pending. Meanwhile, Jonathan and Paul are working hard to prepare for the next wind profiling experiment, due to occur in early October.

Equipment malfunctions interrupted monthly 630-nm Fabry-Perot and photometer measurements in May. Final repairs are under way, and full 630-nm capabilities will accompany Hα and helium measurements beginning in September. This array of instrumentation is expected to be on-site for at least one year. The experiments are being conducted by Bob Kerr and John Noto of Boston University. Raúl García and Jonathan Friedman are also involved in these observations, which are complemented by Sixto González's topside radar measurements.

On September 20, the pulsed alexandrite laser arrived. It will be housed in the temporary resonance lidar facility by the tape warehouse. There, accompanied by the first of the 30" telescopes for the new lidar facility, it will be used to observe metallics in the mesopause region, and aerosols and pollutants in the troposphere and stratosphere. First light for the new facility is scheduled to occur in early October.

The Situation at the HF Facility

Mike Sulzer

The ground water level at the HF facility is normally held to two feet below the ground level by pumps at a station three miles from our facility. The station pumps water over a dike and into a channel that connects with the ocean. These pumps are run by the Puerto Rico Land Authority; they are very old and must be replaced. They have not been operating for the last several months and the water level has been rising, preventing normal use of the facility for many weeks. After the passage of Hurricane Marilyn, which brought about five inches of rain, the western section of the antennas is at least five feet under water, and the eastern section, which is higher, is at least 40% covered. The water level fluctuates a bit with the ocean tide, and at its highest is about 2 feet below the floor of the transmitter building. The level is not expected to go much higher because it is draining to the ocean at the current level.

A wooden bridge from dry land to the transmitter building has been built so that reasonable access can be maintained. This bridge has been extended as necessary as the water has risen. A generator has been placed on dry land near the beginning of the bridge and wires run to the building so that essential services can be maintained.

The land authority has put out a bid to upgrade the pump station. A reasonable estimate is about six months for the project to be completed and the water to be pumped to approximately normal level. It will then take some time for the land to dry so that we can begin repairing problems with the towers and the antennas. Also it will be necessary to carefully clean the transmitters and other equipment because it has not been possible to keep them completely free of salt during this period.

In the meantime there is danger that one or more tower anchors might come loose and result in a tower falling. It is now clear that there can be no campaign in January, 1996. This campaign will have to be postponed, and a new date has not been set.

Tony Crespo

Flooding under the new waveguides at the HF facility. The water level fluctuates with the ocean tide.

A Visit to Kharkov, Ukraine

Sixto González

On August 14-19, 1995, a delegation representing the U.S. incoherent scatter radar (ISR) community visited the Ukraine to attend the URSI summer ISR workshop and visit the Kharkov incoherent scatter facility. Representatives from most U.S. ISR facilities, the NSF, and various universities and government laboratories were present. The workshop was very successful and well attended by members of the Ukrainian and Russian ISR communities. In particular it was useful for us to learn how other ISRs solve their experimental difficulties as we all seem to have similar problems (e.g., contamination of the spectra by satellites). We also learned about an additional ISR facility in Irkutsk, Siberia. The Kharkov facility has a good complement of radio instruments:

1. 150-MHz fixed zenith antenna
2. 150-MHz steerable antenna
3. Frequency steering antenna
4. Heating facility
5. Digital ionosonde

At Arecibo, we look forward to collaborating with our colleagues at the Institute of the Ionosphere, in Kharkov, particularly in the areas of topside ionosphere and also heating experiments. It will be very useful to study the behavior of the O^+ to H^+ transition altitude in different longitude sectors, and to find out if the layering of helium ions we observe at Arecibo is present at higher latitudes.

The NAIC/Ithaca Staff

To familiarize our readers with the people who work for NAIC, we continue our series of profiles of the various personnel groups within the organization. In this issue we cover the NAIC staff at the main Cornell campus in Ithaca, New York. The research interests of the scientists are also listed.

NAIC Administration

• Eugene F. Bartell (Administrative Director).

• Donald B. Campbell (Associate Director, NAIC; Head, Radar Astronomy Group; Professor, Astronomy Dept.): Planetary studies; the microwave scattering properties of planetary bodies - imaging of asteroids and comets - the development of new radar imaging techniques.

• Paul F. Goldsmith (Director, NAIC; Professor, Astronomy Dept.): Structure and physical conditions of dense molecular clouds - large-scale star formation in the Milky Way and effects on molecular clouds - astronomical instrumentation, Gene Lauria

From left to right: Hope Walker, Gene Bartell, Phyllis Sutliff, Paul Goldsmith, Jill Morrison, Kurt Samuelson, Sandra Mack, Don Campbell, Pam Sieradzki.

esp. high sensitivity millimeter imaging systems - co-investigator on the Submillimeter Wave Astronomy Satellite to observe water and molecular oxygen in molecular clouds.

• Sandra L. Mack (Accounts Coordinator).

• Jerilyn T. Morrison (Administrative Assistant).

• Kurt D. Samuelson (Upgrading Project Manager).

• Pamela A. Sieradzki (Upgrading Project Administrator).

• Phyllis J. Sutliff (Executive Staff Assistant).

• Hope E. Walker (Upgrading Project Administrative Assistant).

R & D Laboratory

• Lynn A. Baker (Director, Laboratory Operations—Feeds).

• William T. Genter (Research Support Specialist).

• Jon B. Hagen (Director, Laboratory Operations—Receivers).

• Tami L. Jordan (Administrative Assistant).

• Kurt D. Kabelac (Senior Equipment Technician).

• Evan M. Kurtz (Upgrading Project Senior Electronics Engineer).

• Eugene F. Lauria (Research Support Specialist).

• Pierson C. Mosher (Research Support Specialist).

• David W. Overbaugh (Machinist).

Gene Lauria

From left to right: Gene Lauria, Lynn Baker, Jon Hagen, Bill Genter, Dave Overbaugh, Tami Jordan, Pete Mosher, Evan Kurtz, Kurt Kabelac.

Summary Student Program

Jo Ann Eder

This summer, along with construction everywhere on site, we were blessed with an influx of enthusiastic, dedicated students. The ten students came from many parts of the U.S. and the world to participate in the hectic life of a major research institution that is undergoing an upgrade. Each student worked on an individual research project under the supervision of a staff scientist. Also, a subgroup designed and implemented their own observing project with the assistance of Craig Tepley. Besides their research work, the students broadened their backgrounds through talks by the staff on the major areas of science pursued at the Observatory, through tours of the platform and the HF facility, and with trips to the local beaches and sights of Puerto Rico.

The NSF Research Experience for Undergraduates (REU) program sponsored seven undergraduates; the NASA Capability Enhancement program (administered by the University of Puerto Rico Resource Center for Science and Engineering) funded two students; and Yu-Ling Su, a graduate student from Taiwan, was sent by her university. The program administered by the Puerto Rico Community Foundation continued to support graduate student, José Francisco Salgado of the University of Michigan.

Since the 300-m telescope did very little astronomy this summer due to upgrade construction, the students decided to use the optical laboratory to conduct atmospheric studies. Spearheaded by the efforts of Genene Fisher of Boston University, a subset of the students wrote a proposal to utilize the Ebert-Fastie spectrophotometer to obtain intensity measurements of the OH (7-3) and O_2 (0-1) emissions and thereby derive their temperatures, and look at their oscillations in a time series. They hoped to detect the propagation of gravity waves in the mesosphere. Unlike observations in the radio regime, the students had to consider the moon phase and the weather. After many long nights spent waiting for the clouds to clear, the students were able to obtain quality data. Next, many of the available data analysis programs had to be updated, but the students persevered and were rewarded with their first "clean" spectrum. Genene continues the data analysis at Boston. The students are grateful for instrumental setup assistance from Raúl García and for consultations with Craig Tepley.

Typically, the AO Summer Student Program receives applications from many more talented, local undergraduates than the program can accommodate. This year we invited the local applicants from Puerto Rico to attend the special Summer Student Colloquia. Several expressed interest. Two students from the other end of the island came for two weeks to take Chris Salter's mini course in radio astronomy. They also received a tour of the Observatory and were able to talk science with the staff and the other students. We hope their interest in astronomy will be stimulated and they will apply again next year. We see this outreach as a means of expanding the impact of the REU program for the local budding scientists.

The students were again able to live on site in the Visiting Scientist Quarters (VSQ). A VSQ car was available for short trips to town for groceries, etc. To keep the students from feeling confined, car pools were organized for weekly pizza nights and trips to the beach. This summer three "field trips" were arranged for the "students and friends": one to Old San Juan, one to Fajardo and El Yunque, where the five ecosystems of Puerto Rico were explored, and the other to the small island of Vieques, where the students were able to swim in the world's best bioluminescent bay on a moonless night (a thrill for all of us!). The students provided us with an excuse to enjoy the island. Special thanks go to Susan Nossal, Mike Nolan, and Kiriaki Xilouris for their time and energy in organizing extracurricular events!

A history-making record: This summer, there were NO automobile accidents involving the students!!!

1995 Summer Student Projects

Marcel Agueros (Columbia), with Kiriaki Xilouris, investigated simultaneous, dual-frequency (2.3- and 8.6-GHz) observations of a sample of well-known pulsars in order to probe the magnetosphere close to the surface of the neutron stars. He will present their results at the AAS winter meeting in January.

José Bartolomei Díaz (UPR-Rio Piedras) pursued his interest in measuring the concentrations of greenhouse gases in the atmosphere above Puerto Rico. With Susan Nossal, he researched which water vapor spectral lines could be most effectively measured with the new Arecibo alexandrite lidar system, which will be installed soon. He and Susan will use the results of his studies to design an observing program with the AO lidar in the near future.

Ann Bragg (Rice) worked with Willem Baan on two projects concerning molecular line emission from galaxies. For the first, she constructed a cube of VLA (A-array) images of NGC 253 to search for formaldehyde absorption and possible emission in the nuclear region. Although no confirmation of the emission was possible, the absorption features were useful in determining the dynamics near the nucleus. For the second project, Ann analyzed Arecibo data taken with the 21-cm line feed to search for highly redshifted OH emission. She and Dr. Baan identified a new high-redshift galaxy at $z = 0.2$. They will present a poster at the AAS winter meeting.

Genene Fisher (Boston) worked with Sixto González on an analysis of incoherent scatter radar data. First, she wrote several useful routines to aid the analysis and then she moved on to study the dynamics of the helium ion layer in the topside ionosphere. Genene also acted as a "friend of the telescope" for visiting scientist Daniel Melendez-Alvira (NRL) who commended her for her invaluable assistance.

Evan Jones (SW Missouri St.), under the supervision of Tapasi Ghosh, compared the environments of radio-loud and radio-quiet Seyfert galaxies ($0.2 < z < 0.3$) by analyzing images from the Digitized Palomar Sky Survey. He found that the sample of radio-loud Seyferts had statistically larger diameters than the radio-quiet sample. However, the number and characteristics of companions within 750 kpc and of radius 0.3 to 1.7 times that of the sample galaxies showed no statistical difference between the two samples.

Antonio Juarbe (UPR-Mayagüez), a computer science and physics major, worked with Jorge Rodriguez and the aeronomy staff to convert a group of data analysis programs from the Harris computer to the Sun workstations. His accomplishments will be essential for performing experiments after the upgrade. Working on these programs gave Antonio a chance to use not only his considerable computer skills, but also his physics background.

Nicci Lloyd (Cornell), advised by Murray Lewis, pursued the "holy grail" of signal processing—extracting information from noisy data through statistical techniques. She tested two alternative methods: 1) the "runs" test (a non-parametric statistical test) and 2) modeling of an intrinsic baseline which would characterize the data, but found that neither method improved on normal statistics.

Kristin Nelson (Cornell), with Mike Nolan, created and examined synthetic images of an arbitrarily cratered sphere, in an attempt to measure the size-frequency distribution of craters from delay-Doppler images. They found that a maximum number are counted at 30° subradar latitude due to optimization of the Doppler resolution, and that observing two close phases results in better detections because small features can be registered as craters.

Henry Roe (Williams) worked with Jonathan Friedman on a number of design tasks related to the Raleigh Doppler lidar system, such as the alignment of the Fabry-Perot interferometer, a new method of frequency locking the seed laser, and the design of a paddle wheel reflector that can be used to calibrate the measurement of Doppler shift by the lidar.

José "Paquito" Salgado (Michigan) spent his time at AO developing a PhD thesis proposal. He will be conducting "A Systematic VLBA Study of the Distribution of Galactic Scattering Material" and will be supervised by Tapasi Ghosh and Chris Salter. Much of his research will be conducted at AO, so he will be dividing his time between Puerto Rico and Michigan.

Yu-Ling "Kate" Su (National Central Univ.-Taiwan) had studied many wavelength regions while completing her master's thesis, but had never explored radio astronomy. With her adviser, Jo Ann Eder, she attended the VLA workshop on aperture synthesis in Socorro and then used a VLA 21-cm spectral line dataset to search for continuum emission from a pair of possibly interacting galaxies that had been discovered at Arecibo Observatory by Carmen Pantoja. Continuum emission and infrared flux would be expected from star formation triggered by an interaction.

Susan Nossal

The 1995 summer students (from left to right): Ann Bragg, Evan Jones, Marcel Agueros (sitting), Genene Fisher, Henry Roe, Kate Su, Antonio Juarbe. Not pictured: José Bartolomei Díaz, Nicci Lloyd, Kristin Nelson.

Summer Student Program for 1996

Applications are now being accepted for the 1996 Arecibo Summer Student Program. Six to eight visiting research assistantships in the fields of radar and radio astronomy, and atmospheric science will be awarded. The assistantships include a stipend and round-trip air transportation to and from San Juan, Puerto Rico, from the student's respective home or school address in the U.S. This 10-week program is sponsored by the National Science Foundation.

ELIGIBILITY: Undergraduate student participants must be citizens or permanent residents of the United States and must be enrolled in a degree program (part-time or full-time) leading to a bachelor's degree. NAIC also anticipates funding for one or two additional unrestricted positions, to be awarded to those who will be first- or second-year graduate students in academic year 1996-97.

RESPONSIBILITIES: Students will work with the Observatory's scientific staff, participating in research projects such as searches for pulsars, studies of galaxies, giant stars, or the interstellar medium, investigations of the neutral and ionized parts of the Earth's atmosphere, and studies of the surfaces of asteroids, planets, and planetary satellites.

APPLICATIONS: For an application packet, write to:

Office of the Director
NAIC, Space Sciences Building
Cornell University
Ithaca, NY 14853-6801

Or via e-mail to:

morrison@astrosun.tn.cornell.edu

Applications, including three academic references, official transcripts, and statement describing interest and relevant experience must be submitted no later

Tony Acevedo

AOVEF construction site. The retaining wall zigzags around the edge.

than February 15, 1996. Successful applicants will be notified on or around March 1, 1996.

Status of the AOVEF project

Daniel R. Altschuler

The firm of Hector M. Varela was selected as the contractor, and construction of the "Fundacion Angel Ramos Center" began in July 1995.The above photo shows the construction site. Completion is expected by mid-1996.

Zalisk Martin Associates of Cambridge, Mass. and Design Craftsmen of Midland, Mich. have been contracted to design and manufacture the exhibits for this modern center. We will establish a bilingual educational program centered on the theme "More Than Meets the Eye--Exploring the Invisible Universe," which will reflect the general idea that we can study our world with tools that extend our direct sensory experience. The proposed program will explore the unseen sky and, in particular, the objects that fall under the scrutiny of a radio telescope. Specifically, the program will introduce the visitors to the electromagnetic spectrum as a means of exploration, will offer a framework of basic astronomy and atmospheric science, and will provide understanding of the function and operation of the Arecibo radio telescope. Some of Arecibo's most exciting new discoveries in the fields of radio astronomy, solar system radar astronomy, and atmospheric science will be presented. The bilingual exhibits will concentrate on the following:

• Convey the concept of an invisible world, one that exists outside the realm of direct human sensory perception and can be explored by remote sensing.

• Demonstrate the function, history, and operation of the Arecibo radio telescope.

• Present the basics of astronomy and atmospheric physics as a framework with which to understand the purpose of observational research, particularly that done at the Arecibo Observatory.

If funding permits we will also feature a "hyper-exhibit" based on a network of computers running a hypertext browser where visitors will be able to delve deeper into topics of interest. We have approached Sun Microsystems for a donation of equipment to implement this idea.

Theater

In the theater, we will feature a 10-minute audiovisual show entitled "A Day in the Life of the Arecibo Observatory." The show will tell the story of the people who make Arecibo possible, from the guards and kitchen staff to the telescope operators, staff, and visiting scientists. The audiovisual piece will move comfortably and creatively back and forth between science, tools, and technology, and the many people who make science possible at Arecibo.

Funding

We have raised a total of $2,582,500 that is being utilized to finance the design work, site preparation, parking lot development, design and fabrication of exhibits, and the building construction contract.

Funds are still needed to complete parking areas, outside building areas, the theater program, the elevator, exterior exhibits, a vehicle for the handicapped, landscaping, and miscellaneous expenses all estimated at about $350,000. We are pursuing different avenues to raise these funds.

The Cornell Club of Puerto Rico has embarked on a fund-raising initiative as explained in the enclosed brochure. We have already "sold" 18 of our auditorium seats and I hope you will consider helping us with a "purchase." The first 97 names will go on the seats; after that we will inscribe them on a bronze plaque in the auditorium.

35 Years Ago: A Short Photo Essay

Daniel R. Altschuler and Chris Salter

Introduction

The introduction to the December 1958 Engineering Report No. 3 of the School of Electrical Engineering of Cornell University by W. E. Gordon, H. G. Booker, and B. Nichols entitled "Design study of a radar to explore the Earth's ionosphere and surrounding space" reads as follows:

Figure 1. Before construction.

Figure 2. December 30, 1960.

Figure 3. February 1961.

Figure 4. July 10, 1961.

Figure 5. March 23, 1962.

Figure 6. October 23, 1962.

All photos from the AO archives.

"The discovery that free electrons in the Earth's ionosphere incoherently scatter signals that are weak but detectable with a powerful radar makes possible the exploration of the upper atmosphere and surrounding space by radar. The fact that the radar components, while sensitive, are all within the state of the art means that the exploration can begin as soon as the radar is assembled.

The radar for the first time will measure directly the electron density and electron temperature as functions of height and time through the ionosphere not only in the recognized layers but also between and above them. The formation and disappearance of these layers, their structure and the diurnal and seasonal changes in them will be observed. These observations should contribute substantially to our understanding of the ionosphere and its effect on radar waves.

In addition to exploration of the ionosphere, the radar has the following exciting capabilities: a) the observation of transient streams of charged particles traveling through space near the earth, b) the search for the existence of a ring current around the earth, c) radar observation of the planets Venus and Mars and an improved measurement of the astronomical unit of distance, d) the possibility of radar observation of the sun and its irregular atmosphere, e) the sensitivity to observe heretofore undetected radio stars in a limited region of the sky."

Originally, a fixed parabolic reflector was envisioned, pointing in a fixed direction with a 500-foot tower to hold equipment at the focus, and only later was the design modified to a spherical reflector with the ability to point more generally, therefore opening the future for planetary radar and radio astronomy. In the summer of 1960, machines and men moved into a sinkhole formed in the karst region about 12 miles south of Arecibo, Puerto Rico. Three years later the Arecibo Ionospheric Observatory (AIO) was in operation under the direction of William E. Gordon, having been built by Cornell University under contract with the Air Force Cambridge Research Laboratories funded by the

AO archives
Bill Gordon

Advanced Research Projects Agency (ARPA). The formal opening ceremony took place on November 1, 1963.

Gordon's research during the fifties had led him to the idea of radar backscatter studies of the ionosphere, and his persistence culminated in the construction of the Arecibo radar/radio telescope at a cost of about $9,000,000. The Department of Defense was at first mildly interested in this project, but became very interested when it was pointed out by John Kraus that it was expected to detect the trails of ionization created behind rockets and Sputniks [*Drake, 1983*].

Site

The site was required to be near the equator, since then a radar capable of studying the ionosphere could also be used to study nearby planets. The Arecibo site offered the advantage of being located in karst terrain, with large limestone sinkholes that provided a natural geometry for the construction of the 305-meter reflector.

Despite the general shape of the sinkhole into which the telescope was built, (Fig. 1, the site before construction) nature had to be improved upon by excavating 270,000 cubic yards of soil, some of it rock requiring blasting. The contractors for this, Alpha Burke and Wilhelm, and Raymond Construction of Puerto Rico, also had to place 200,000 cubic yards of compacted fill to shape the excavation. Fig. 2 is an aerial view of the site after excavation. Fig.3 shows an early stage of the operations building (Building 1).

Towers

Each of the three concrete towers was poured in a slip form that was raised at a rate of about 9 inches/hour. Tower 12 can be seen in its growth stage in Fig. 4. New concrete was exposed less than 5 hours after pouring. A 266-foot tower took 375 hours to pour (about 16 days of continuous pouring). Each tower sat on a reinforced concrete footing 36 x 38 ft by 15 ft deep. This part was built by Caribbean Wikstrom Corp. which also built the concrete anchors. In Fig. 5, all three towers are completed, as is the operations building and a long staircase to the VSQ. Pieces of metal are being assembled at the center of the bowl. Note that our Building 2 was built later in 1965.

Feed Platform

The feed platform had a total weight of 550 tons. (It will increase to about 900 tons after the Gregorian upgrade.) Harada Corp. of San Juan assembled the platform at the center of the bowl. A cable spider was strung between the towers (Fig. 6), which supported a block and tackle to raise the platform. The blocks were made of 100 tons of concrete embedded in the ground. Fig. 7 depicts the pulleys attached to the corners of the platform for lifting.

The lift at the end of October 1962 (Fig. 8) proceeded at about 40 feet per hour during which a delicate balance was kept between the backstays and the spider and main cable so that tower deflection stayed within the permissible limits of ±2 inches. This was the most critical operation of the entire project; it took three days.

After the platform lift the main cables, which had been hanging from the three corners of the platform, were attached to the tops of the towers. After this, the ring girder, holding the azimuth track and the

Figure 7. October 1962.

Figure 8. October 29, 1962.

Figure 9. December 4, 1962.

Figure 10. March 3, 1963.

Figure 11. August 24, 1962.

Figure 12. June 13, 1963.

Figure 13. August 14, 1963.

All photos from the AO archives.

feed arm, were raised to the platform. Fig. 9 shows a piece of the ring girder being lifted; below, the azimuth arm is being assembled. The azimuth arm is raised to the platform in Fig. 10; in the background the concrete rim for the reflector is visible.

Reflector

The contractor for the reflector, R.P. Farnsworth of New Orleans, proceeded with construction after the platform was in place. The reflector consisted of 16 x 19 gauge standard 1/2-inch square mesh soldered at every joint and held by a network of cables suspended from the concrete rim of the reflector. (Workers prepare the concrete rim in Fig 11.) Six hundred small anchorage in the bowl help to pull the cable grid into a spherical shape. In Fig. 12 the telescope reflector is placed over the supporting cables.

Finally on August 14, 1963, the first 96-foot line feed operating at 430 MHz was lifted through the center opening of the reflector and attached to the receiver and transmitter (Fig. 13).

The first radar contact with Mercury was achieved on April 7, 1964, under the leadership of Gordon H. Pettengill, then associate director of the Observatory. Observations of Mercury on April of 1965 led to a determination of its rotation rate, which instead of 88 days turned out to be 59 days [*Pettengill and Dyce, 1965*].

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Courtesy of NOAA.

Satellite picture of Hurricane Luis on 5 September 1995. The westernmost rainband is over eastern Puerto Rico. The width of the image is approximately 1200 miles.

Luis and Marilyn Come By

Daniel R. Altschuler

I write this as the eye of Hurricane Marilyn is located about one hundred miles north of Arecibo. A lot of rain is falling and many areas in Puerto Rico are flooded, including our HF facility, which

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Workers cover the control room window with hurricane panels. Note that the old console has shrunk in anticipation of the post-upgrade monitor and control system.

has been under water for quite some time due to the failure of the pumps (see article by Mike Sulzer). Again, as happened two weeks ago with Hurricane Luis (see image above) we were spared the worst, when these two violent visitors whose trajectories seemed to bring them into Puerto Rico decided to veer north at the eleventh hour. Luis and Marilyn wrought great damage in the Lesser Antilles, the Virgin Islands, and Vieques and Culebra, and represented a scary threat to the main island of Puerto Rico, and in particular to our Observatory. Luis affected mainly the islands of St. Martin/Maarten, Barbuda, and Antigua, devastating them with 140-mph winds, killing dozens and wounding hundreds. Marilyn, smaller than Luis and with winds of "only" 110 mph, passed east of St. Croix and over St. Thomas, inflicting heavy damage, and causing several deaths and many injuries. The U.S. government estimates that 40% of the homes on St. Thomas were destroyed, while another 40% were damaged. [Ed. note: In a sad coincidence, the only direct casualty in Puerto Rico was Jack Strickland, a divemaster on Culebra who was known by those of the scientific staff that have gone scuba diving with him. He sank with his boat as he tried to ride out Marilyn aboard it.]

The VLBA antenna on St. Croix was subjected to heavy winds but fortunately did not suffer any damages.

On September 5 and again on September 15 we implemented full hurricane procedures at the Observatory, something which we had not done since September of 1989 when Hurricane Hugo caused great destruction in the eastern part of Puerto Rico.

Under these procedures, directed by José N. Maldonado, the assistant director for facilities and utilities, our maintenance crews work to secure the telescope platform and the site in the following ways: The large line feeds are lowered if necessary; this time the bottom section of the 430-MHz line feed was removed. (The 318-MHz line feed was lowered for the season.) Our site is secured by covering up the most vulnerable windows (see photo), tying down anything that could be carried off by high winds, and moving all inside equipment away from windows. When everything is ready our employees are sent home so they can prepare their homes for the hurricane.

The only person left on site waiting for Luis and Marilyn was Rey Velez, head of telescope operations, who volunteered to remain. He was ready to broadcast any emergency and acted as a link to the outside world. We appreciate this selfless gesture. Matters were complicated by the fact that we have a large amount of construction gear on site. The different contractors secured their own staging areas and construction sites.

One Observatory casualty was the postponement of the workshop, Pulsar Science with the Upgraded Arecibo Telescope, scheduled for September 8 and 9. It has now been rescheduled for October 28 and 29. 25 people had planned to attend this meeting, which focuses on the most efficient use of the upgraded telescope for pulsar research. Almost all of these people have indicated that they will still be able to come. The proceedings from the workshop, containing current trends in pulsar instrumentation and science, will be available to the wider pulsar community. Updated information can be found in the Arecibo Observatory home page (http://www.naic.edu/).

This has been a very active hurricane season and it is not over yet. I hope that I will not write about hurricanes in the next Newsletter!

Don Esteban Retires

Daniel R. Altschuler and Rey Medina

Esteban Vásquez, the loyal driver for the Arecibo Observatory, has retired after 30 years of service and taken up permanent residence in Deltona, Florida. One of the oldest member of the staff, he was born in Sabana Hoyos near the Observatory and began work at the Observatory in 1965 as a guard. Esteban became our driver in 1970. As such he was indirectly responsible for the accomplishments of our scientific visitors, providing entertainment during long rides to and from the San Juan airport, and catering to the

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A familiar face to AO visitors.

needs of our guests, be it stopping for prosciutto sandwiches, coffee, or more mundane needs. During this time he drove about three times from here to the moon without an accident, a significant accomplishment, especially in Puerto Rican traffic. We will all miss him and wish him well, and hope for a safe return from the moon.

Roger Burnside

On the 24th of August 1995, Dr. Roger Burnside died peacefully at the home of his parents in Port Alfred, South Africa. After he graduated from the University of Michigan in 1984, Roger joined the atmospheric sciences group at Arecibo in October 1985 and worked as a staff scientist until October 1991. During the later years of his tenure, he suffered from multiple sclerosis, which became a long and difficult struggle, eventually resulting in his leaving the Observatory.

AO archives

Roger Burnside circa 1986.

At Arecibo, Roger worked in many areas of research, but in particular, in studies of the dynamics of the thermosphere and the energy balance of the ionosphere. He successfully merged observations of neutral winds made with a Fabry-Perot interferometer with those derived from incoherent scatter radar measurements. From this effort, he deduced a new factor for the O^+ to O collision cross-section what has become known to the aeronomy community as the *Burnside Multiplicative Factor*. In a very short time he advanced the field considerably, but unfortunately did not have the opportunity to enjoy his research, or his life, for very long. It goes without saying that he will be missed by many of his colleagues and friends.

A Note from the AO Director

Daniel R. Altschuler

It has been now three years since we resumed publication of our Newsletter which goes to about 1000 addresses of which about 600 are individuals. I am very happy with the Newsletter, and the effort the editors and those who write for it have made.

However a newsletter is only as good as the readers perceive it to be independent of how much work and care we put into its production. I have yet to receive one single comment regarding the Newsletter and might interpret this as meaning that it is so good that nobody finds a fault with it (unlikely) or maybe nobody reads it (also unlikely). Well then maybe you just have not felt strongly enough one way or the other to write. Nevertheless a short e-mail message to me (daniel@naic.edu) with your comments would be most welcome and will help gauge our work. Thank you in advance.