NATIONAL ASTRONOMY AND IONOSPHERIC CENTER
ARECIBO OBSERVATORY
Cornell University

Research Experience for Undergraduates Program

PROGRESS REPORT SUMMER 2009
(Written by Diana Prado & Christiano Brum, coordinators)

1. The Arecibo Program

Introduction

The Arecibo Observatory has conducted a summer student program since 1972. It was initially funded through NAIC's operating funds from the NSF but since 1987 most students have been funded under the NSF REU program. Every year, the Arecibo Observatory organizes a REU summer program to give students the opportunity to experience the life of real scientists. The program has a duration of ten weeks, starting at the end of May until mid August. During this period the students are exposed to real research situations in the different fields of study such as electric engineering, astronomy and atmospheric sciences. Each student is individually mentored for ten weeks while he or she participates in a scientific (or engineering) project, and gains direct experience of scientific research and its methods. At the end of the summer, every student makes a presentation about his/her project to the scientific staff and their peers. The National Science Foundation REU Grant supports the REU Program.

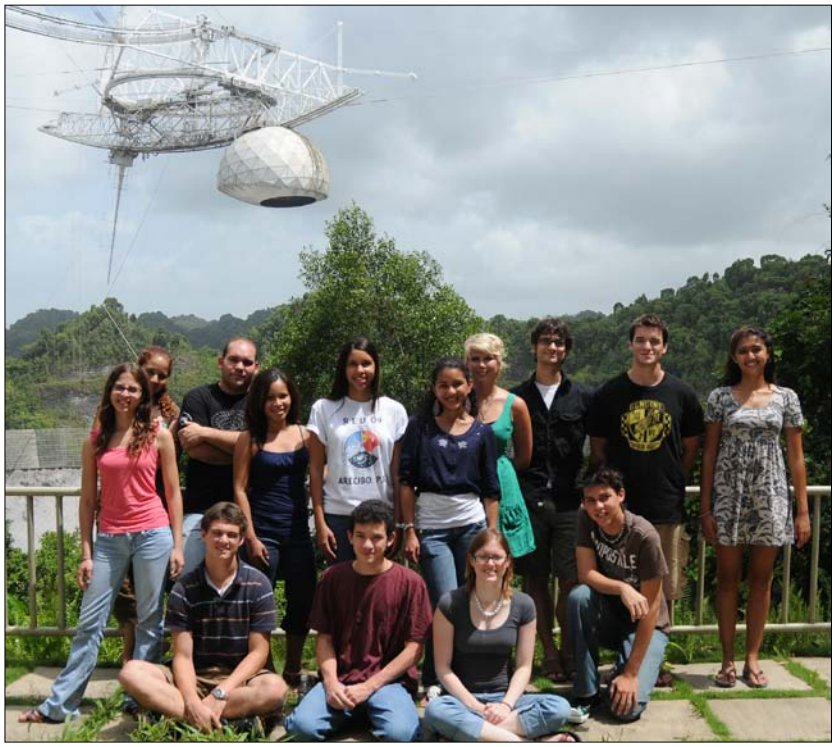


Fig. 1: 2009 Summer Students. Back row: Cristina Padilla Cintron, Melissa del Pilar Rivera Flores, José I. López Pérez, Aleshka Carrion Matta, Yaritza de J. Arce, Diana C. Centeno, Daria Auerswald, Christopher Faesi, Alex Macomber, Danna N. Qasim; Front row: Alexander L. Hackett, Victoir Veibell, Ali Bramson, Eframir Franco Diaz.

There were 15 students in the summer program of 2009 (Fig. 1), nine under the NSF REU program, two funded from NAIC funds, and four under the NSF's Louis Stokes Alliances for Minority Participation (LSAMP) program through the University of Puerto Rico at Rio Piedras. Most of the students, including all the REU funded students, were selected in a competitive process from 117 applicants (84 indicated preference for Radio/Radar Astronomy; 18 for Atmospheric Science; 6 for Computer Sciences and 9 for Electronics). In addition to the REU students there was one teacher from the local Arecibo Public School system under the Research Experience for Teachers (RET) part of NAIC's REU grant.

Members of the staff provided a series of seminars specifically for the summer interns, on topics related to recent research in astronomy, planetary astronomy, atmospheric sciences, electronics, and even the geology of Puerto Rico. The speakers included Michael Sulzer, Chris Salter, Robert Minchin, Tapasi Ghosh, Ellen Howell, Murray Lewis, Mike Nolan and Jonathan Friedman, not to mention the exciting visit of the astronauts Joseph Acaba and Steve Swanson whom the students had a chance to meet. The interns also had the opportunity to visit the 150-m high telescope platform and explore the entire Observatory site. During July, some of the interns chose to participate in the Single-Dish Radio Astronomy Summer School (SDSS), which provided them with a detailed overview of the art, experience with the techniques via observations with both Arecibo and, remotely, the 100-m Green Bank Telescope, and knowledge of many of the research applications of single-dish radio astronomy.

Every intern had the opportunity to participate in a hands-on-experiment with the 305-m telescope. The astronomy interns all participated as did a couple of the interns with primary interests in computing and engineering. The astronomy students also joined with their mentors while they were making observations in their own programs.

As part of the REU experience, students were required to make a twenty-minute presentation at the end of the program to describe their project, its development, data acquired and its analysis/interpretation. This summer five of the interns attended the CEDAR (Coupling, Energetic and Dynamics of Atmospheric Regions) meeting that took place in Santa Fe, New Mexico, where two presented their posters in the poster competition session: one related to Analysis of Arecibo dual Beam World Day Data and the Results from the Weakest Solar Minimum since 1928, presented by Edvier Cabassa; the other on a FPGA-based Multi-purpose Radar Controller for Aeronomy Science, presented by Alexander Hackett. Ali Bramson presented a poster at the October 2009 Division of Planetary Sciences conference in Fajardo, Puerto Rico. Daria Auerswald, Christopher Faesi, Danna Qasim, and Yaritz de Jesus Arce will present posters at the January 2010 AAS Meeting in Washington, DC.

This summer our students were very diverse and active, therefore, to make sure that students had entertainment; several activities were organized on site as well as outside of the facilities. Activities within the premises included a safety and conduct seminar conducted by Wilson Arias and Maria Judith Rodriguez (respectively) followed by a welcome BBQ with all the staff. Also, Diana Prado held yoga classes every Tuesday and Thursday afternoon. During the month of July, the students received a visit from REU students working in the El Yunque Tropical Rainforest.

The Arecibo Observatory is set in forested, limestone karst terrain, and is approached by a winding road along a valley between small hills. While these help isolate the site from radio frequency interference, the nearest "village" (Barrio Esperanza) is ten minutes away by car, while Arecibo is about half an hour away. As has been the norm for the past few years, all the students stay on site in the Observatory Visiting Scientist Quarters. This is helpful for their

research activities, but it does limit their ability to travel on the Island, as most students are younger than 25 and find it difficult to hire a car economically. The Arecibo program therefore ensures that a couple of shopping trips are available each week for necessities, and an event is normally organized for every weekend to allow students to get away from the Observatory to sample the life and sights of Puerto Rico. Based on suggestions, the students make the choice about what they want to do. Activities outside the Observatory facilities included a visit to the Camuy Caves and its river, surfing lessons in different places around the island such as Isabela, Arecibo and San Juan, hiking and cave tubing in the Tanama River, trips to San Juan to explore the nightlife of the metro area, music festival in Cabo Rojo, salsa festival in Hatillo, scuba diving lessons in Aguadilla, a visit to the REU students at El Yunque, and a weekend trip to Culebra island.

We acknowledge and thank the Observatory staff members, Wilson Arias, Carmen Segarra, Carmen Torres, Jose Cordero, Maria Judith Rodriguez, Lucy Lopez, and all the guards for their cooperation and time in assisting with the day-to-day needs of the students. Also, special thanks to Dr. Ji-hyun Kang, Eva Robles and Dr. Robert Minchin for their collaboration with the summer students and to Jill Tarbell (NAIC/Ithaca) for managing the application process and student travel arrangements.

2. Summer Students Projects.

REU Funded Students:

ALEXANDER HACKETT is an electrical engineering student from Penn State University who worked under the supervision of Luis Quintero. His task consisted of implementing and documenting an open-source FPGA-based radar controller with the help of Ryan Seal, a former Arecibo engineer. The programming portion of the project entailed both the C++ and Verilog computer languages on a Gentoo Linux system. His documentation includes both a user's manual and technical code documentation for future development of the system. Alexander participated in the poster session competition at the CEDAR meeting in Santa Fe. His poster was titled "*An FPGA-based Multi-purpose Radar Controller for Aeronomy Science*".

ALEX MACOMBER attends the St. Anselm College, New Hampshire, where he majors in electrical engineering. Alex was mentored by Dana Whitlow, and his project was to analyze the design of a new 4-GHz bandwidth IF/LO system for the Observatory. This will enable the new "Mock" Spectrometers to process up to 2.1 GHz of bandwidth from a single-pixel receiver. Alex used the RF and Microwave Design Software Genesys to test the various aspects of the design, including its noise figure, power output and undesired inter-modulation products. Using scattering "S" parameters, he was able to characterize the linear components of the design; using spectral propagation and root cause analysis he was able to characterize the nonlinear aspects of the design. Along with testing the IF system design, Alex was active in testing the incoming components for the

design in the laboratory using a Vector Network Analyzer. On several occasions, Alex also assisted in setting up the 430-MHz radar transmitters to transmit the dual beam mode during the summer.

ALI BRAMSON attends the University of Wisconsin at Madison where she is majoring in physics. Ali worked with Drs. Ellen Howell and Mike Nolan with data from the Hayabusa spacecraft, which encountered asteroid 25143 Itokawa in September of 2005. This provided ground truth on this asteroid's shape. Radar data had also been obtained from the Observatory and Goldstone (DSS-14) in 2001 and 2004 to assist in the rendezvous, by producing a preliminary shape model. In hindsight, the irregular shape of Ikotawa made radar-based modeling of the asteroid before the encounter difficult. Modeling the data from the spacecraft shows that the asteroid has two distinct components, attached by a "neck", whereas the ground-based radar model displays a more subtle transition from "body" to "head". Ali looked at the discrepancy between the radar shape estimation and the spacecraft model.

CHRISTOPHER FAESI is an astronomy student from Indiana University mentored by Dr. Murray Lewis. Christopher's work referenced a complete sample of IRAS color selected sources that had been searched for 1612-MHz OH masers: just a quarter exhibit the maser. The mid-IR (MIR) color distribution of these has a distinct blue cutoff. Initially the task was to use the public radiative transfer code DUSTY to evaluate the sensitivity of the 53 µm flux

generated by the circumstellar shell that pumps this maser to effective temperature, optical spectral type, and to the mass-loss rate and its history. Christopher found that none of these parameters mattered much. He went on to generate a grid of models to explore the distribution of objects in the NIR v MIR color-color plots, which are respectively sensitive to the immediate and to the long-term mass-loss rate, and found (i) that this strongly suggests that most sources do not exhibit modulated mass-loss; (ii) that the temperature of the hottest dust is much cooler in objects without masers, which is suggestive of a different dust composition. Christopher went on to cross-reference the optical spectral types where available, and the variable type from the General Catalog of Variable Stars with maser status. He finds that the great majority of objects without masers are semi regular or L-type (slow irregular) variables, whereas most with masers are Miras or have an M spectral type.

DANNA QASIM attends the Northern Arizona University. The focus for her work in radio astronomy used the technique of interferometry under the supervision of Dr. Tapasi Ghosh. The MERLIN telescope (an aperture synthesis telescope located in England) was used to collect data from methanimine molecules in the ultra-luminous infrared galaxy, Arp 220. Danna studied the flux density of methanimine using the software AIPS (Astronomical

Image Processing System). For Arp 220, she looked at frequencies circa 5.1GHz. After carefully calibrating her data, she produced excellent images of her results.

DARIA AUERSWALD is an astrophysics student from San Diego State University, who worked with Dr. Ji-hyun Kang on a project involving the mapping of the Galactic Super Nova Remnant (SNR) G54.4–0.3/HC40 in neutral hydrogen (HI). While analyzing data taken from the IGALFA survey, they found evidence for a high velocity HI shell in the region. From this data, they derived several physical parameters pertaining to the shell, and studied the interaction of the shell with the interstellar medium.

DIANA CENTENO is a physics student from the University of Puerto Rico, Humacao campus. She worked with Dr. Nestor Aponte on data from the F2 region of the ionosphere. First, she calibrated the data using ionosonde data, together with Matlab and ASP routines. She generated processed files by separating the MRACF from the topside data, so she could generate the '.outs' files. These were then used to make plots to establish the amp scale number for fitting the curve. Later, she used the calibrated data to generate plots of the different parameters for the study of the ionosphere such as electron density, peak height, ion and electron temperature, and hydrogen, helium and oxygen ion fractions from the topside and MRACF data.

VICTOIR VEIBELL studies at Embry-Riddle Aeronautical University in Arizona. He worked under the supervision of Dr. Arun Venkataraman in restructuring the fiber-optic network backbone within the Observatory, to improve its bandwidth and efficiency. Also, he had the opportunity to work with Dr. Sixto González on fixing the Online Data Monitor, the CADI database, and the Aeronomy Online database.

YARITZA DE JESUS ARCE is an electrical engineering student at the University of Puerto Rico, Mayaguez Campus. Yaritza worked with Drs. Robert Minchin, Tapasi Ghosh and Chris Salter in determining the synchroton radiation contribution to the flux of galaxies in the SCUBA Local Universe Galaxy Survey. To achieve this objective, she analyzed the NRAO VLA Sky Survey (NVSS) results together with Arecibo observations that were made using the Wideband

Arecibo Pulsar Processor (WAPP). First, she fitted the data, using Interactive Data Language (IDL) programs, for over 230 galaxies to determine the flux detected at Arecibo at S-band (2150 MHz), C-band (4500 MHz), C-high (6750 MHz) and X-band (8550 MHz). She calculated the average flux of the two polarizations to plot the logarithmic flux as a function of frequency, and hence calculated the spectral index and power law spectrum index from these plots for each galaxy.

ISAIRA RODRIGUEZ (RET Teacher) is a teacher in the Arecibo public school system. She initially read selected publications by astronomers observing with the Arecibo planetary radar system about our solar system. From this material she developed 90-minute workshops about near-Earth-asteroids (NEAs) at levels suitable for students in years 7–9 and 10–12. The content of workshop materials was matched to the PR Department of Education Standards for Excellence. The workshop materials were designed to immerse the students in general information about our Solar System and the various discoveries made by astronomers using the Arecibo radar system focusing on asteroids and their potential threat to Earth. The workshop deliveries included a Power Point presentation, a teacher/student workshop manual, a Standard of Excellence matching matrix and three well-developed hands-on activities. The workshop was tested with two high school groups of 30 students each and achieved very positive results. The workshop will be added to the Visitor Center workshop offerings for visiting school groups.

Isaira was very enthusiastic about the project assigned to her and very thankful for the opportunity. She mentioned that the experience gained during her RET appointment at the Observatory helped to develop her skills on curriculum design in many positive ways. She also mentioned her gratitude at being able to work closely with scientists, which was for her a unique career experience.

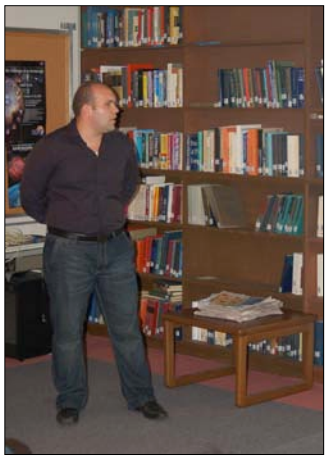
NSF LSAMP Funds:

ALESHKA CARRION MATTA is a physics student at the University of Puerto Rico, Rio Piedras Campus. During her participation in the program, she learned to use the International Reference Ionosphere model (IRI). Her task was to compare data taken from the IRI model (URSI and CCIR coefficients) with the incoherent scatter radar data, and the Arecibo Observatory ionospheric model (2009 version), by comparing the variability of the peak density in the F region of the ionosphere. Data was sorted by season and compared with the decimetric solar flux for both the current and previous solar cycles. Aleshka worked under the supervision of Dr. Christiano Brum.

CRISTINA PADILLA CINTRON is a physics student at the University of Puerto Rico, Rio Piedras Campus. She worked with Dr. Sixto Gonzalez on a project comparing the Arecibo Observatory topside data with the International Reference Ionosphere (IRI). The main objective was to adjust the existing models of the upper atmosphere, so that in future we might be able to predict the behavior of the Earth's ionosphere. Part of her project involved programming with Matlab. She attended the CEDAR meeting in Santa Fe, which gave her the opportunity to learn different aspects of the atmospheric

sciences. She also spent a week in the University of Texas at Arlington working with Dr. Ramón López. His research interest is based on magnetospheric physics. She learned how to create simulations of the magnetosphere using VPython and CISM_DX. VPython is the Python programming language plus a 3D graphics module called "visual" developed by David Scherer in 2000. CISM_DX is a community-developed suite of integrated data, models and model explorers, for research and education.

EFRAMIR FRANCO DIAZ had just graduated from the Pedro Mercado Bougat high school in Humacao, and plans to attend the University of Puerto Rico at Humacao to major in applied electronic physics. This summer he worked with Dr. Nestor Aponte on the ionosphere and its interaction with the solar wind. He also learned how to calibrate data from the radiotelescope using Matlab and Asp software. His particular project consisted in comparing the resulting topside ionosphere total electron content with data derived from operating GPS receivers.



JOSE LOPEZ is an undergraduate student from the physics department at UPR, Rio Piedras Campus. Along with Melissa Rivera, Jose worked on a project based on the design and implementation of a helical antenna that works at a 7.14-GHz frequency and has a specific impedance of 50 ohms. The purpose was to obtain circular polarization, which is characteristic of this type of antenna. A network analyzer was used to measure the working frequency and the impedance. During the experimental process results were as expected, giving the antenna a keen sensitivity and good response to electromagnetic flux within its limits. After the finalization of this project, the antenna is going to be analyzed at the Lunar Reconnaissance Orbiter Research Laboratory at John Hopkins University. Jose was supervised by Mr. Ganesh Rajagopalan, Electronics Department Head.

NAIC Funds:

EDVIER CABASSA-MIRANDA is a graduate student from the electrical engineering department at the University of Puerto Rico, Mayaguez Campus. He worked on calibrating the World Day data in order to update the aeronomy database. He learned how to use ASP, get the MRACF records from the datafiles and to calibrate them using the site's ionosonde. He made a poster of this work, which he presented at the CEDAR meeting in Sante Fe. In his poster, Edvier compares his data to the Observatory's Ionospheric Model. After the meeting, he worked on programming in MATLAB to generate a GUI to automate the process of calibrating the power records for Arecibo data. Once finished, he then compiled and calibrated the data from 1999 until 2009 using his GUI.

MELISSA RIVERA graduated from the electrical engineering department at the University of Puerto Rico, Mayaguez Campus. Along with Jose Lopez, Melissa worked on a project based on the design and implementation of a helical antenna that works at a 7.14-GHz frequency and has a specific impedance of 50 ohms. The purpose was to obtain circular polarization, which is characteristic of this type of antenna. A network analyzer was used to measure the working frequency and the impedance. During the experimental process results were as expected, giving the antenna a keen sensitivity and good response to electromagnetic flux within its limits. After the finalization of this project, the antenna is going to be analyzed at the Lunar Reconnaissance Orbiter Research Laboratory at John Hopkins University. Melissa was supervised by Mr. Ganesh Rajagopalan, Electronics Department Head.

3. 2009 staff and visitor talks and students presentations.

REU seminars were regularly scheduled each Monday and Thursday and all the staff was invited to attend.

Date:	Speaker:	Title:
May 26	**Julia Deneva** (Cornell University)	**Elusive Pulsar Populations Intermittent Pulsars and Pulsars near the Galactic Center**
May 27	**Ben Bussey** (Applied Physics Lab)	**Initial Results from Chandrayaan – 1**
June 2	**Lou Nigra** (Univ. Wisconsin-Madison)	**The Agents of Aging on the Magellanic Stream**
June 8	**Sixto Gonzalez, Mike Nolan and Wilson Arias** (Arecibo Observatory)	**Orientation about conduct, safety and security inside our facilities and Welcome BBQ**
June 11	**Michael Sulzer** (Arecibo Observatory)	**Incoherent Scatter Radar I**
June 15	**Michael Sulzer** (Arecibo Observatory)	**Incoherent Scatter Radar II**
June 15	**Gregg Hallinan** (National University of Ireland Galway)	**Ultracool Dwarf Pulsars**
June 18	**Chris Salter** (Arecibo Observatory)	**The Radio Sky**
June 25	**Robert Minchin** (Arecibo Observatory)	**Galaxies**
July 6	**Tapasi Ghosh** (Arecibo Observatory)	**Molecules and Space**
July 9	**Ellen Howell** (Arecibo Observatory)	**The Geology of Puerto Rico**
July 20	**Murray Lewis** (Arecibo Observatory)	**The Transience of OH/IR stars**
July 22	**Mike Nolan** (Arecibo Observatory)	**Asteroids**
July 29	**Aaron R. Parsons** (U. California, Berkeley)	**PAPER : 16-Station Results**
July 30	**Jonathan Friedman** (Arecibo Observatory)	**The Mesospheric Refrigerator**

REU Presentations:		
July 31	**Christopher Faesi**	**OH/IR Mimics: Modeling Conditions Leading to the Presence or Absence of 1612-MHz OH Masers in AGB stars in the Context of Stellar Evolution**
	Alexander L. Hackett	**An FPGA-based Multipurpose Radar Controller for Aeronomy Science**
	Danna N. Qasim	**MERLIN Imaging of Methanimine in the Ultra Luminous Galaxy Arp 220**
August 4	**José I. López Pérez & Melissa Rivera**	**Design and calibration of a 7.14-GHz helix antenna for the Lunar Reconnaissance Orbiter tracking at the Arecibo Observatory**
	Ali Bramson	**The Hayabusa Spacecraft Model of Itokawa: Lessons Learned for Radar Shape Models**
August 6	**Victoir Veibell**	**Upgrading the network backbone**
	Yaritza de Jesus Arce	**Determining the synchrotron radiation contribution to the flux of galaxies in the SCUBA Local Universe Galaxy Survey**
	Alex Macomber	**IF System Upgrade at Arecibo Observatory**
	Cristina Padilla Cintron	**Comparison of Arecibo‘s composition, densities and temperatures in the ionosphere with IRI models**
	Aleshka Carrion Matta	**Comparative study of NmF2 using AO, IRI and ISR ionospheric models during solar maximum and minimum**
	Eframir Franco Diaz	**Comparison of TEC Data using the Arecibo ISR and GPS Receivers**
	Diana C. Centeno	**Comparison of Arecibo‘s composition, densities and temperatures of the ionosphere, with the IRI models**
August, 14	**Daria Auerswald**	**An I-GALFA HI Study of Supernova Remnant G54.4–0.3/HC40**

4. Student's experience in their own words.

"*… I had fun exploring the island of Puerto Rico, meeting new people, and working on multiple different projects that are relevant to my fields of interest (being Computer Science and Space Physics). The hands on observing that I was able to participate in was a great introduction to the field of radio astronomy and has sparked an interest in me to pursue it further, possibly for a senior Physics project. My other projects worked with the display and presentation of the data, and gave me a good understanding of how all of the observations are put together in a manner that allows them to be understandable and presentable to others. This also has created some interest for my senior Computer Science project. I have also been offered the opportunity to return in the future and continue working on various projects, an opportunity that I would very much like to take advantage of. Overall it was an excellent and invaluable experience …*"
Victoir Veibell

"*… The REU assistantship program at the Arecibo Observatory was definitely one of the most incredible experiences of my life. Not only was it a chance to work with some leading edge scientists and engineers, it was also a great way to meet, work, and explore the tropical island Isle of Enchantment with aspiring scientists and engineers. Outside of work, I had a great time surfing, hiking, visiting the rain forest, SCUBA diving, barbecuing, and just hanging out with the REU group …*"
Alexander Hackett

"*… I had a great experience with the Arecibo Summer Program. I was put into the planetary radar group, my first choice! I had no previous experience in the field and really enjoyed it! I get to present at the DPS meeting in the fall and am really excited to see all the research going on in the field of planetary sciences. I was hoping to find a field of astronomy that I could see myself going to graduate school in and I think I may have found it this summer. The weekly seminars allowed us to see the diversity of research conducted at the observatory, as well as by talking with all the graduate students and researchers that come in and out throughout the summer to observe. I made a lot of friends this summer that I hope to keep in touch with. We all got along great and had so much fun together surfing, scuba diving, doing yoga, BBQing, and much more. I grew more as a person in these 10 weeks than I thought I could. I pushed the boundaries of my comfort zone by coming here and it really paid off! I couldn't be more pleased with my decision to be a part of this program …*"
Ali Bramson

"*… This experience has been an amazing opportunity for me. Not only has it introduced me to an entire new field of science, atmospheric science, away from the one that I'm basing my studies on, Physics, it has also given me the chance to share all this time with amazing people. From the Observatory staff, which have been more than mentors for all of us, to the other REU students, which are like a little new family for me, but also the people that come here to observe for a few days and have been kind enough to share their experience with us. Being here has help with the big decision of deciding in which area I want to base my graduate studies. I have learned lot of techniques, from how single dish radars work to develop my programming skills. I'm really grateful for the opportunity that NSF and the Observatory of Arecibo have given me because I get out of this program having grown as an individual and as a student…*"
Diana Centeno

"*… I am very grateful for given me the opportunity to work as a Research Assistant in the Radio Astronomy Group at Arecibo Observatory. This summer has been a wonderful and unique experience, educational and professionally, because I worked with great recognized astronomers; Dr. Robert Minchin, Dr. Tapasi Ghosh and Dr. Chris Salter. As an Electrical Engineering student, I learned and acquired a lot of knowledge and skills about Astronomy, which can be useful in my engineering field, specifically in the communications and antennas fields…*"
Yaritza de Jesus

"*… This summer experience was amazing because I met people with different backgrounds. Also I had a good time during the guided tour at the platform. The seminars were interesting because they helped me to learn other topics that were not related to my research area. I learned to compare data from different models and make a statistical analysis of this data, something that was new for me…*"
Aleshka Carrion

"*… This was a very fun summer here in the Arecibo Radio telescope. This was a real challenge for me because I am going to start my freshmen year in August and didn't know a lot of the things they used here. I started to read about the topic of Atmospheric Science and asked a lot and could understand some of it. I know that the parts I didn't understand would be explained once I start the University. What was also good of this internship was meeting people that work with the radio telescope every day. This could be useful for future investigations. I also learned to use Macs and the UNIX programming language. It was a place I enjoy because I love science and learning new things. Thanks for letting me participate in this summer program. I enjoyed it very much …*"
Eframir Franco

"… The REU program at the Arecibo Observatory is hands down the best the NSF has to offer. Any student considering Arecibo should send in their acceptance without hesitation. You will not find a better atmosphere, better places to visit or a bigger telescope anywhere in the world…"
Alex Macomber

"… This experience allowed me to be aware of other scientific projects and I had the prompt opportunity to be involved. Learning is not only packaging a few things in our mind, is about understand the subject and build up with those things another new one; so, this research experience provide me the tools to develop my practical and theoretical knowledge…"
Cristina Padilla

"… I would say it has been one of my best experiences. I learned a lot these past 10 weeks, and it gave me the opportunity to see how the work at the real life is. The knowledge and experience I obtain working with people very well prepared had been very valuable and enriching to my professional career. All the experiences I had contribute to give me the necessary tools, in order to make my way on my life…"
Edvier Cabassa

"… In addition to extensive work on my project, my time in Puerto Rico was well spent, both at the Observatory and exploring the island proper. Immediately upon arriving I found the local staff to be friendly, highly competent, and always willing to go beyond the call of duty to be helpful. I was made to feel welcome and a part of the family by scientists, telescope operators, and site staff alike, and that fact has been one of the most rewarding of the

summer. In July I was able participated in the Single Dish Summer School in which fifty-odd graduate students and others come to Arecibo to attend multiple seminars and work on a short hands-on project over the course of a week. This experience was extremely rewarding and has both greatly expanded my background in radio astronomy and allowed me to get to know many other scientists in the field. Most weekends I left the site and traveled to various parts of the island, visiting Old San Juan, the El Yunque rainforest, and several beaches, participating in hiking, kayaking, snorkeling, biking, and attending festivals. I had an incredible time here on La Isla del Encanto and will carry those experiences - scientific, social, and cultural - with me for the rest of my life…"
Christopher Faesi

"… From working with a remarkable mentor and gaining valuable research experience in Astronomy, to living onsite at the observatory and having a chance to explore Puerto Rico, the REU program at Arecibo Observatory has truly been an amazing opportunity. The time that I have spent at Arecibo this summer has allowed me to develop a greater understanding of Radio Astronomy and how research in the field is conducted. I am truly grateful to have been able to participate in such an incredible experience that has been undoubtedly informative, challenging and exceptionally rewarding..."
Daria Auerswald

"… Our experience at the Arecibo Observatory was very educational and enriching. We were part of the Electronics Department, where the personnel received us kindly. Several projects were assigned to us, like antenna design and equipment shielding for RFI emissions. These projects were useful in such way that we acquired priceless knowledge and comprehension of technical skills in our respective academic fields. We will always be thankful to the staff of the Electronics Department, for being helpful and for giving us the opportunity to develop a new perspective by which we can apply practical solutions to situations that can be valuable for professional achievements…"
Melissa Rivera & Jose Lopez

5. Papers presented at meetings and conferences to date.

Edvier Cabassa-Miranda, **Diana Prado Garzón**, **Ali Amirrezvani**, **Diana Centeno**, **Eframir Franco**, **Aleshka Carrion**, **Cristina Padilla**, Mike Sulzer, Christiano G. M. Brum, Nestor Aponte and Sixto A. González. ***Analysis of Arecibo dual beam world day data. Results from the weakest solar minimum since 1928***. Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) meeting – 2009, Santa Fe, N.Mexico

Alexander Hackett, Ryan Seal, Julio Urbina, Sixto Gonzalez, Mike Sulzer and Luis Quintero. ***An FPGA-based Multi-purpose Radar Controller for Aeronomy Science***. Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) meeting – 2009, Santa Fe, N.Mexico

Diana Prado, Christiano G. M. Brum, Sixto Gonzalez, Nestor Aponte, Ezequiel Echer. ***Topside ionosphere responses to a moderate geomagnetic storm***. Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) meeting – 2009, Santa Fe, N.Mexico

Eva Robles, Christiano G. M. Brum, Pedrina terra, Sixto Gonzalez, Nestor Aponte, Craig Tepley and **Cristina Padilla Cintron**. ***Oxygen densities derived from Arecibo ISR (or MSIS vs. Burnsider Factor and alternative hypothesis for the O-O^+ cross section adjustment)***. Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) meeting – 2009, Santa Fe, N.Mexico

Ali Bramson, Chris Magri, Ellen Howell, Michael C. Nolan and Patrick A. Taylor, ***The Hayabusa Spacecraft Model of Itokawa: Lessons Learned for Radar Shape Models***, Division of Planetary Science meeting, October, 2009

There will be additional presentations at the January, 2010 AAS meeting in Washington.

6. Extra-Curricular Activities:

DATE	ACTIVITY
Saturday, June 6	Visit to Camuy Caves and river
Monday, June 8	Welcome BBQ near the pool
Sunday, June 14	First surfing lessons at the lighthouse beach, Arecibo
Sunday, June 21	Hiking and Cave Tubing in Tanama River
Friday, June 26	Sightseeing in San Juan
Saturday, June 27	Surfing in San Juan
Saturday, July 3	Cabo Rojo Music Festival
Saturday, July 11	Surfing at Jobos Beach, Isabela
Thursday, July 14	Salsa Festival in Hatillo
Saturday, July 16	Hosted El Yunque REU students for BBQ, tours and volleyball on site
Sunday, July 17	Started Scuba Dive training in Aguadilla
Friday, July 22	Sightseeing in San Juan
Saturday, July 23	Trip to Institute of Tropical Studies at El Yunque
Sunday, July 24	Finished scuba dive training in Aguadilla
Saturday, August 1st	Trip to Culebra Island
Thursday, August 6	Farewell BBQ near the pool

Also, the students had yoga classes with Diana Prado near the pool every Tuesday and Thursday at 5:00pm.

Shopping trips for groceries occurred every week, according to the needs of the students.

7. REU, Other Summer Students & RET Participant statistics:

Participants Status	1972-2008	2009	Total
Undergraduate Level	**267**	**13**	**280**
Graduate Level	**65**	**2**	**67**
RET	**9**	**1**	**10**
		Total Number of Participants:	**357**

Participants Status	1972-2008	2009	Total
Minorities	**74**	**6**	**80**
Women	**142**	**9**	**151**
		Total Number of Participants:	**231**

Number of REU, Other Summer Students & RET Participants – Scientific Field

Scientific Field	1972-2008	2009	Total
Radio/Radar Astronomy	**201**	**5**	**206**
Atmospheric Science	**90**	**5**	**95**
Computer Sciences	**21**	**1**	**22**
Electronics	**18**	**4**	**22**
Education	**11**	**1**	**12**
		Total Number of Participants:	**357**

8. Educational Institutions Represented in the NAIC Summer Student Program:

(1972 through 2009)

Agnes Scott College
Amherst College
Arizona State University
Bates College
Bethel College
Boston University
Brigham Young University
Bryn Mawr College
California Institute of Technology
California Polytechnic State University
Cambridge University, UK
Carleton College
Carthage College
Case Western Reserve University
Centenary College of Louisiana
City College of New York
Clemson University
Colgate University
Columbia University
Cornell University
Dartmouth College
Ecole Normale Superieure of Lyon
Embry-Riddle Aeronautical University
Georgetown University
Globe Institute of Technology
Gorky University, Russia
Harvard University
Haverford University
Indiana University
Interamerican in Bayamon
Johns Hopkins University
Lehigh University
Louisiana State University
Massachusetts Institute of Technology
McGill University, Canada
Miami University, Ohio
Missouri State University
New College of Florida
New Mexico State University
New Mexico Tech
North Carolina State University
Northern Arizona University
Northwestern University
Oberlin College
Oxford University, UK
Pennsylvania State University
Pomona College
Princeton University
Purdue University
Rensselaer Polytechnic Institute, NY
Rice University
Rutgers University
Saddlebeck University
Saint Anselm College
San Diego State University
Smith College
Southwest Missouri State University
St. Andrews University
Stanford University
SUNY Albany
SUNY Binghamton
Texas Technological College
Trinity College Dublin, Ireland
Universidad Interamericana de PR
Universidad Metropolitana, San Juan
University of Akron
University of Alabama
University of Arkansas
University of British Columbia
University of California, Berkeley
University of California, Los Angeles
University of California, San Diego
University of California, San Luis Obispo
University of California, Santa Cruz
University of Chicago
University of Colorado
University of Georgia
University of Grenoble, France
University of Hawaii
University of Houston
University of Illinois, Urbana-Champaign
University of Iowa
University of Maryland
University of Massachusetts (Amherst)
University of Michigan
University of Minnesota
University of Montana
University of Missouri in Columbia
University of Nebraska-Kearney
University of Northern Iowa
University of Pennsylvania
University of Puerto Rico, Arecibo
University of Puerto Rico, Humacao
University of Puerto Rico, Mayagüez
University of Puerto Rico, Río Piedras
University of Rochester
University of Texas, Austin
University of Texas, Dallas
University of Toronto (Canada)
University of Virginia
University of Washington
University of Wisconsin-Madison
Utah State University
Vassar College
Villanova University
Virginia Polytechnic Institute
Washington & Lee University
Wellesley College
Wesleyan University
Western Washington University
Williams College
Wittenberg University
Yale University

9. NAIC Summer Student Participants:

(1972 through 2009)

Most affiliations listed below, particularly for the most recent years, refer to the students' affiliations at the time of their REU program. Current affiliations for some former students or teachers are given (if known), particularly for the earlier years. The following is representative of those students/teachers who have attended the NAIC's program at the Arecibo Observatory:

Participant:	Affiliation:	Year
Dr. Vincent J. Abreu	University of Michigan	1972
Dr. Linda Dressel	Space Telescope Science Institute	1972
Dr. Alan Hirshfeld	Univ. of Massachusetts, Dartmouth	1972
Dr. Thomas Balonek	Colgate University	1973
Dr. James Cordes	Cornell University	1973
Dr. Lee Hartmann	University of Michigan	1973
Dr. Martha Haynes	Cornell University	1973
Dr. William Newman	Univ. of California Los Angeles	1973
Dr. James F. Vickery (deceased)	Stanford Research Institute	1973
Dr. Randy Kimble	NASA/Goddard Space Flight Center	1974
Dr. James Breakall	Pennsylvania State University	1974
Dr. Matthew Malkan	Univ. of California @Los Angeles	1976
Dr. Bruce Wilking	University of Missouri, St. Louis	1976
Dr. Kristen Sellgren	Ohio State University	1976
Dr. Richard L. White	Space Telescope Science Institute	1976
Dr. Robert J. Hanisch	Space Telescope Science Institute	1977
Dr. Keith D. Horne	University of St. Andrews, Scotland	1977
Dr. Leslie Hunt	Arcetri Observatory, Italy	1978
Dr. Emilio Falco	Smithsonian Inst., Whipple Observatory	1979
Dr. Jacqueline Hewitt	MIT	1980
Dr. Richard Edelson	UCLA	1981
Dr. Michael Bicay	NASA/Ames Research Center	1982
Dr. Perry Hacking	Jet Propulsion Laboratory	1982
Dr. Brett Isham	Univ. Interamericana de Puerto Rico	1983
Dr. Michael A. Strauss	Princeton University	1983
Dr. Douglas O. Wood	NRAO Socorro	1983
Dr. Blaise Canzian	L-3 Communications/Brashear	1984
Dr. JoAnn Eder	Arecibo Observatory (retired)	1984
Ms. Inge Heyer	Joint Astronomy Centre, Hawaii	1984
Dr. Steven T. Myers	NRAO-Socorro	1984
Dr. Joshua Roth	Winchester High School, Mass.	1984
Dr. Myeong-Gu Park	Kyungpook National Univ., Korea	1985
Dr. Daniel Holden	Los Alamos National Laboratory	1985
Dr. William Reach	Caltech	1985
Dr. Nicholas Stacy	Surveillance Research Lab, S. Australia	1985
Dr. Leila Belkora	Self-employed	1987
Dr. Peter Lawson	Jet Propulsion Laboratory	1987
Dr. Brian A. McLeod	Center for Astrophysics	1987
Dr. Margaret Meixner	Space Telescope Science Institute	1987
Dr. John M. Carpenter	Caltech	1988

Dr. Tracey Evans	Caltech	1988
Dr. Sixto González	Arecibo Observatory	1988
Dr. Richard Collins	University of Alaska	1988
Dr. Margaret Murray Hanson	University of Cincinnati	1988
Dr. Joseph Lazio	Naval Research Laboratory	1988
Dr. Crystal L. Martin	UC Santa Barbara	1988
Dr. Bruce Campbell	National Air & Space Museum	1989
Dr. Jayaram Chengalur	NCRA-TIFR, Pune, India	1989
Dr. Eric Schulman	NRAO Charlottesville	1989
Dr. Adam Showman	University of Arizona	1989
Dr. Thomas E. Vaughan	University of Oklahoma	1989
Dr. Jonathan Williams	University of Florida	1989
Dr. Rachel Akeson	Caltech	1990
Dr. Bryan W. Miller	Gemini Observatory, Chile	1990
Dr. Liese van Zee	Indiana University	1990
Dr. Jeremy Heyl	Caltech	1991
Dr. Jenny Patience	UCLA	1991
Dr. James Rhoads	Arizona State University	1991
Dr. Keith Rosema	Blue Operations, LLC	1991
Dr. Shoko Sakai	UCLA	1991
Dr. Jose F. Salgado	Adler Planetarium, Chicago	1995
Dr. Nestor Aponte	Arecibo Observatory	1992
Ms. Heather Elliott	Michigan State University	1992
Mr. Adam Trotter	Harvard University	1992
Ms. Lorraine Allen	Center for Astrophysics	1992
Mr. Jason Johnson	Harvard University	1992
Ms. Vanessa Galarza	New Mexico State	1992
Ms. Erin Hatch	George Washington University	1992
Mr. Antonio Algaze	Ohio State University	1993
Mr. James Anderson	US Geological Survey	1993
Mr. Yevgeniy Dorfman	MIT	1993
Dr. Mayra Lebrón Santos	Univ. of Puerto Rico-Rio Piedras	1993
Dr. Ben R. Oppenheimer	American Museum of Natural History	1993
Dr. Alison Peck	ALMA, Chile	1993
Mr. Christopher DeVries	University of Massachusetts	1994
Mr. Mark Lemon	Letter Press Software	1994
Ms. Rebecca Morley	Japan	1994
Dr. Marcel Agueros	Columbia University	1995
Dr. Ann Bragg	Marietta College	1995
Dr. Genene Fisher	American Meteorological Society	1995
Ms. Nicole Lloyd	Stanford University	1995
Ms. Kristin Nelson	University of Rochester	1995
Ms. YuLing Su	Steward Observatory	1995
Mr. Matthew Schwartz	Princeton University	1996
Mr. Brent W. Grime	US Air Force	1997
Dr. Zoe M. Leinhardt	University of Cambridge	1997
Ms. Melissa Nysewander	Univ. of North Carolina, Chapel Hill	1997
Mr. Albin Alonso Rosario	University of Puerto Rico	1997
Mr. Anil C. Seth	University of Washington	1997
Mr. Angel Alejandro Quinones	University of Houston	1998
Dr. Monique Aller	ETH Zurich-Institute for Astronomy	1998
Ms. Yira Cordero Lebron	UPR Humacao	1998
Ms. Ingrid Daubar	University of Arizona	1998

Mr. Simon DeDeo	Princeton University	1998
Mr. David Kaplan	UC Santa Barbara	1998
Mr. Dale Kocevski	University of Hawaii	1998
Ms. Myriam Lopez	Escuela Intermedia Barahona, Morovis	1998
Mr. Benjamin D. Oppenheimer	University of Arizona	1998
Mr. Felix Mercado Cortes	UPR Río Piedras	1998
Ms. Celia Salmeron	University of Houston	1998
Ms. Heidi Brandenburg	Caltech	1999
Mr. Carlos Vargas Alvarez	University of Wyoming	1999
Mr. Shawn M. Allison	Penn State	2000
Ms. Sarah Boswell	University of Wisconsin	2000
Dr. Alyson Brooks	Caltech	2000
Ms. Diane Chin	Binghamton University	2000
Dr. Laura J. Hainline	University of Maryland	2000
Mr. Justin B. Kinney	Cornell University	2000
Dr. Ruth Murray-Clay	Harvard-Smithsonian CfA	2000
Mr. Homero Cersosimo	UPR Humacao	2000
Mr. Miguel F. Irizarry	Arecibo Observatory	2000
Dr. Karin Menendez-Delmestre	Carnegie Observatories	2000
Ms. Sun Mi Chung	Wesleyan University	2001
Mr. Daniel Dougherty	University of Alabama	2001
Ms. Lindsay DeRemer	Wellesley College	2001
Ms. Natalia Figueroa	UPR Mayaguez	2001
Mr. Marko Krco	Cornell University	2001
Mr. Mike Nicolls	Cornell University	2001
Ms. Betzaida Ortiz	University of Puerto Rico	2001
Ms. Val Phillips	University of Colorado	2001
Ms. Karin Sandstrom	UC Berkeley	2001
Ms. Ivelisse Cabrera	Johns Hopkins University	2001
Mr. Homero Cersosimo	UPR Humacao	2001
Mr. Mike Eydenberg	New Mexico Tech	2001
Mr. Derek Kopon	Cornell University	2001
Ms. Esther Santos	UPR Mayaguez	2001
Mr. Carlos Vargas Alvarez	UPR Mayaguez	2002
Dr. Martha Boyer	University of Minnesota	2002
Ms. Laura Chomiuk	Univ. Wisconsin-Madison	2002
Mr. Jose Gerena	Luis Munoz Marin Public School	2002
Dr. Andrew Helton	Univ. Minnesota-Twin Cities	2002
Mr. Chi-Feng (Daniel) Kao	Penn State	2002
Ms. Stephanie Morris	University of Chicago	2002
Ms. Danielle Moser	Univ. of Illinois, Urbana-Champaign	2002
Mr. Martin Rodgers	Miami University, Ohio	2002
Ms. Rebecca Wilcox	University of Washington	2002
Dr. Julia Deneva	Arecibo Observatory	2002
Ms. Ingrid Pla Rodriguez	UPR Mayaguez	2002
Ms. Samantha Stevenson	Wesleyan University	2002
Mr. Graham Alvey	University of Illinois, Urbana-Champaign	2003
Ms. Jaqueline Hodge	UC Davis	2003
Mr. Adam Mott	Arizona State University	2003
Dr. Catherine Neish	Johns Hopkins University	2003
Mr. Matthew Phillips	University of Colorado	2003
Mr. Kristopher Reilly (deceased)	New College of Florida	2003
Ms. Elizabeth Schmidt	Carthage College	2003

Ms. Coral Wheeler	University of Akron	2003
Ms. Nerlyn Echevarría	UPR Mayagüez	2003
Mr. Carlos Trinidad	Daskalos Middle School	2003
Dr. Romina Nikoukar	University of Illinois, Urbana-Champaign	2003
Mr. Michael Jouteux	Ecole Normale Superieure, Lyon, France	2003
Ms. Laura Chomiuk	Wesleyan University	2004
Ms. Megan DeCesar	Pennsylvania State University	2004
Ms. Laura Kinnaman	Wittenberg University	2004
Ms. Melissa Rice	Wellesley College	2004
Mr. Karles Saucedo-McQuade	Oberlin College	2004
Mr. Drew Turner	Embry-Riddle Aeronautical	2004
Mr. Jan Ulrich	University of Texas-Austin	2004
Ms. Yang Yang	Miami University	2004
Mr. Harus J. Zahid	University of California-Berkeley	2004
Mr. Jose Casillas	UPR Mayagüez	2004
Ms. Regina Flores	Columbia University	2004
Ms. Giselle Miranda	Wesleyan College	2004
Mr. Evan J. Anzalone	Louisiana State University	2005
Ms. Fonda Day	University of Colorado	2005
Mr. Casey Dreier	Oberlin College	2005
Ms. Igneris Franco	UPR Mayagüez	2005
Ms. Rhea C. George	University of California, Berkeley	2005
Mr. Israel Gonzalez Perez	UPR Mayagüez	2005
Ms. Talia Kohen	Cornell University	2005
Ms. Laura Kushner	University of Washington	2005
Mr. Iain Mansfield	Cambridge University	2005
Mr. Alex J. Rivera Irizarry	UPR Mayagüez	2005
Mr. Anthony Salvagno	SUNY-Albany	2005
Ms. Sarah Scoles	Agnes Scott College	2005
Mr. Brandon Taylor	University of Texas, Austin	2006
Mr. Clinton Mielke	University of Arizona, Tuscon	2006
Mr. Daniel Rucker	University of Arkansas, Little Rock	2006
Mr. David Bowen	Cornell University	2006
Ms. Heather Hanson	University of Wyoming	2006
Ms. Heidi Brooks	Reed College	2006
Ms. Isobel Ojalvo	Rensselaer Polytechnic Institute, NY	2006
Mr. Kevin Graf	Cornell University	2006
Ms. Knicole Colon	College of New Jersey	2006
Ms. Sonia Buckley	Trinity College Dublin, Ireland	2006
Ms. Ximena Fernandez	Dartmouth College	2006
Ms. Mellisa Rivera	UPR, Mayaguez	2006
Mr. Edvier Cabassa	UPR, Mayaguez	2006
Mr. Israel Gonzalez	UPR, Mayaguez	2006
Ms. Gloria Isidro	UPR, Rio Piedras	2006
Ms. Megan Ansdell	University of St. Andrews, Scotland	2007
Mr. John Barrett	University of Massachusetts, Amherst	2007
Mr. Charles Cheung	Cornell University	2007
Mr. Jamie Gardner	McGill University, Canada	2007
Ms. Diana Husmann	Massachusetts Institute of Technology	2007
Ms. Rouwenna Lamm	Smith College	2007
Mr. John Lee	Columbia University	2007
Ms. Amanda Sheffield	Purdue University	2007
Ms. Camille Smith	Utah State University	2007

Mr. Matthew Sunderland	Penn State University	2007
Ms. Catherine Wu	New Mexico State University, Las Cruces	2007
Mr. Ali Amirrezvani	C.College of NY	2008
Mr. Ethan Engle	Case Western Reserve University	2008
Ms. Diana Prado	UPR Mayaguez	2008
Ms. Darlene M.Nieves	Interamerican in Bayamon	2008
Mr. Elvin Vega-Vega	Interamerican in Bayamon	2008
Mr. Anthony Allen Smith	University of Missouri in Columbia	2008
Ms. Tracy Becker	Lehigh University	2008
Ms. Kristin Jones	University of Wisconsin-Madison	2008
Mr. Victoir Veibell	Embry-Riddle Aeronautical School	2009
Ms. Danna N. Qasim	Northern Arizona University	2009
Mr. Alexander L. Hackett	Penn State University	2009
Ms. Yaritza de Jesus Arce	UPR Mayaguez	2009
Ms. Diana C. Centeno	UPR Humacao	2009
Ms. Ali Bramson	University of Wisconsin at Madison	2009
Ms. Aleshka Carrion Matta	*UPR Rio Piedras*	2009
Mr. Eframir Franco Diaz	*Petra Mercado Bougart High School*	2009
Mr. Edvier Cabassa	UPR, Mayaguez	2009
Mr. Alex Macomber	University of Notre Dame in Rhode Island	2009
Ms. Cristina Padilla Cintron	UPR Rio Piedras	2009
Mr. Christopher Faesi	Indiana University	2009
Ms. Daria Auerswald	San Diego State University	2009
Mr. José I. López Pérez	UPR, Rio Piedras	2009
Ms. Melissa Rivera	UPR, Mayaguez	2009
Ms. Isaira Rodriguez (RET)	Arecibo Public School System	2009