Building a Competitive STEM-C Workforce in a Minority Spanish Institution

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***Abstract*—Although quite recently our diversity and inclusion core values were challenged, we should not forget to recognize the importance and value of bringing together students from underrepresented minorities and their different perspectives into our various workplace processes one day. Unfortunately, most of the outreach efforts in Science, Technology, Engineering, Mathematics and Computer Science (STEM-C) fields are designed only to help students coming from economically disadvantaged backgrounds to catch up with other students. What if instead of only making up for the opportunities they had missed, we could provide at least some of them with the cutting-edge education? In this paper, we present how Student Research Development Center's of Ana G. Mendez University System (AGMUS) in San Juan, Puerto Rico will achieve that the 14 Panel Advanced Modular Incoherent Scatter Radar (AMISR) becomes a base for an educational program for undergraduate and graduate students from Puerto Rico. Having AMISR belong to a Spanish Minority Institution is the first step in the right direction of putting together a scientific team, within AGMUS that will offer competitive research opportunities in Atmospheric Sciences to STEM-C majors from Puerto Rico and Latin America.**

Keywords—non-formal and formal education; Puerto Rico; project-based learning; advanced modular incoherent scatter radar; underrepresented minorities; economically disadvantaged students

I. Introduction

Students can receive formal, non-formal, or informal education in Science, Technology, Engineering, Mathematics and Computer Science (STEM-C) fields in-school and out-of-school settings. Namely, if a learning process is taking place in schools, then it is called *formal* education, if learning occurs in a somewhat planned, but a highly adaptable manner out-of-schools, then it is called *non-formal*, otherwise it is referred to as *informal* [1]. Although learning outcomes and goals are strictly defined only for in-school education, STEM-C fields are too wide and too complex for one single educational institution to cover all areas [2]. Moreover, school curricula are already jam-packed and it is virtually impossible to add new content, making thus non-formal education a necessity.

However, unlike school teachers and university professors who are paid for the job they do, educators involved in out-of-school STEM-C outreach programs are usually volunteering and are not financially compensated for their work. This is certainty a limiting factor because due to limited resources, out-of-school programs either have to be a shorter-term to involve more students, or if longer, then only a few can participate [3]. Additionally, most of time they are oriented towards motivating students to become more interested in STEM-C fields (e.g. [4]–[6]), rather than providing them with the cutting-edge education in a certain topic. This becomes especially true when it comes to underrepresented students and minorities (e.g. [7]).

We argue, however, that a part of STEM-C outreach programs should be oriented towards providing students coming from disadvantaged backgrounds with the cutting-edge education and not only to help them catch up with other students. In this paper, we describe our work-in-progress in which we will involve students from Ana G. Mendez University System (AGMUS) in San Juan, Puerto Rico to work on the 14 Panel Advanced Modular Incoherent Scatter Radar (AMISR-14) [8]. The AMISR-14 is a transportable ultrahigh-frequency phased-array radar system for studying the Earth's upper atmosphere and ionosphere, which was installed at the Jicamarca Radio Observatory in 2014. To date, the aforementioned system was used in two studies [9], [10] and this year for the first time we are planning to include a group of senior engineering students to work on this radar technology.

The rest of the paper is organized as follows. Section II gives a background of our STEM-C outreach program started in 1985 when we received the first U.S. National Science Foundation (NSF) grant, following by others grants totaling over 30 million USD. In Section III, we explain the main characteristics of the AMISR-14 system, together with the history of its deployment. A work plan for non-formal education in Atmospheric Sciences of senior engineering students from AGMUS is presented in Section IV, while Section V concludes the paper and provides our plan for future work.

II. Background

The development of this project follows the best practices of the Model Institutions for Excellence program[1] which enabled AGMUS to make a significant impact on the progress and success of economically disadvantaged and first-generation students in Puerto Rico [3]. Taking on research that showed benefits of including pre-college students and undergraduates in research [11], not only did we create these opportunities for Hispanic students in Puerto Rico, but also shared our best practices with the Universidad Catolica de Nicaragua from Managua, Nicaragua [12]. Moreover, related studies showed that students who become involved in research experiences are more persistent in pursuit of an undergraduate degree [13]. Although, we do acknowledge the problem of inclusion and retention of especially underrepresented racial and ethnic groups studying in STEM-C fields [14], we also argue that we should provide those students with more than just preventing them from dropping out of universities. The contribution of this paper is thus to show how we can contribute towards building a more competitive STEM-C workforce in a minority Spanish institution by providing them with cutting-edge research opportunities in Atmospheric Sciences.

III. AMISR-14 System Description

The AMISR-14 is a transportable radar system for studying the Earth's upper atmosphere and ionosphere. The radar is highly programmable and can be operated over a 20 MHz frequency range centered at 440 MHz. Both coded and uncoded pulses can be transmitted with pulse widths from 1 microsecond to 2 milliseconds and with pulse repetition intervals as short as 1 millisecond. Antenna steering is accomplished via phase shifting (not physical antenna motion) and can be done on a pulse by pulse basis. The modularity of the system allows the major components (please refer to Figure 1) to be readily disassembled, transported, and reassembled multiple times over the lifetime of the system. Various system configurations are also possible, allowing optimization for given locations and specific sets of scientific objectives.

The overall control of the system is driven from an Operation and Control Center that houses general-purpose computers as well as low-level radio frequency signal conditioning modules that comprise the AMISR-14 Control System (ACS). The prime power for the radar is routed through two Utility Distribution Unit (UDU) vans. The radar runs off of aircraft-standard 400 Hz power. The majority of radar components are distributed on the steel array structure. Fourteen identical AMISR panels are nominally arranged in a densely packed in linear configuration as shown in Figure 1. Each panel contains a Panel Control Unit (PCU) for state control and monitoring the condition of the 32 Antenna Element Units (AEUs) on that panel. The PCUs each include a fully programmable Linux computer, so that the functionality of the array can be adjusted and upgraded over time. Each AEU consists of low-level radio frequency circuitry for phase control on transmit and receive, a low-noise amplifier that sets the overall system receive sensitivity, a Solid State Power Amplifier to generate the radio frequency transmitter, a power supply, and digital control and communications electronics.

[1] The Model Institution for Excellence: http://srdc.suagm.edu.

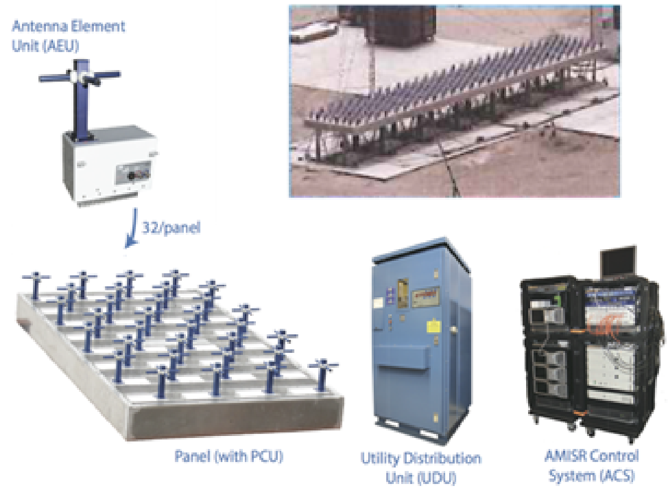

Fig. 1. AMISR-14 components.

The AMISR technology was developed by Stanford Research International (SRI) at Menlo Park, California [8] and in particular the 14 Panel AMISR was funded by a NSF grant to Universidad Metropolitana (UMET), a sister institution of AGMUS. Initially, the plan was to deploy the system in Argentina. Namely, Argentina Ionosphere Radar Experimental Station with the support of the Argentina National Science and Technical Research Council were interested to install the AMISR-14 panel in Chascomus, Buenos Aires Province, Argentina. However, due to technical and logistical reasons the system was shipped to Callao, Peru in the end and assembled in the facilities of Jicamarca Radio Observatory (JRO) at the geomagnetic equatorial line in September, 2015.

IV. Initial results

Observations of the upper atmosphere using the AMISR-14 system began in November 2015, but due to anomalies in the power supply were interrupted for eight months until July 2016. Since then, the system has been in operation for about 4,500 hours. However, abnormalities are affecting the modules and limiting the capability of collecting relevant data. Namely, thirty percent of the transmitters of the 14 Panel AMISR are not working at 100%. This paper will illustrate the efforts of a team of electrical engineering students and scientists from Puerto Rico, to repair the broken modules in cooperation with the team of engineers from the JRO, Peru.

A. *Phase 1*

In December 2016, Dr. Juan F. Arratia and the Director of the Electrical Engineering Department of Universidad del Turabo, Dr. Jose Colon led a team visiting JRO to identify the reason of the AMISR-14 system not working at its full capacity. On the site, the team was informed by the technical staff of JRO that the functionality of the modules was down to 70%. The team examined the modules and selected three modules for shipping to Puerto Rico – (i) module that never transmitted, (ii) module that seemed to work fine and (iii) module that was transmitting at a level of 50% of its nominal output.

B. Phase 2

The modules arrived in Puerto Rico in March 2017, followed by forming of a group of six engineering students with different backgrounds (two undergraduates majoring in Computer Engineering, three undergraduates majoring in Electrical Engineering, and one graduate student majoring in Computer Engineering) to join our team. Although students had different backgrounds, they were not that familiar with the used technologies and had first to learn about radar technology. Furthermore, as SRI never delivered UMET a full operational manual of the system, students had first to document all component of the AMISR-14 system. The technology is very advanced and compact, but we supported our students to do a re-engineering at the module level. Figure 2 shows the circuits boards of one of the modules. Students checked the system performance of each board and identified the electronic components that were no longer working.

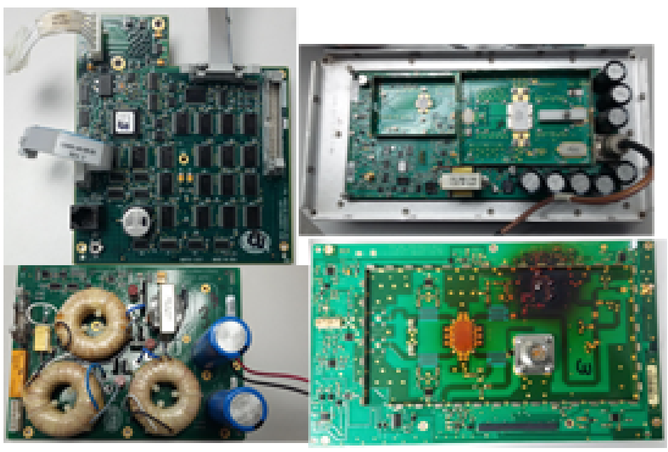

Fig. 2. Circuits boards of an AMISR-14 module.

C. Phase 3

In the third phase, the team developed a block diagram (i.e. blueprint) of each circuit board (see Figure 3). Although limited information on the matter was available in publication and presentations by SRI members to the atmospheric science community (e.g. [8]), most of the work needed to be done from a scratch. The whole system has 448 modules, where each module has a transmitter, receiver, and an antenna, and only three are physically present in Puerto Rico.

D. Phase 4

We are currently in phase 4 which main goal is to develop a "test-bed" for testing the circuit module of the 14 Panel AMISR. The specific sub-tasks are: (1) measuring signals of active modules that are 100% operational on site in Peru; (2) repeating these measurements at the lab in Universidad del Turabo using the "test-bed"; (3) discovering the circuit component(s) that are not working right, replacing them or redesigning the whole board. In addition to the "test-bed" approach used for troubleshooting in Puerto Rico, students are going to travel to Peru beginning of June 2017 to continue the troubleshooting with the broken modules of the 14 Panel AMISR. We expected students to finish with the repairing tasks by the end of July 2017.

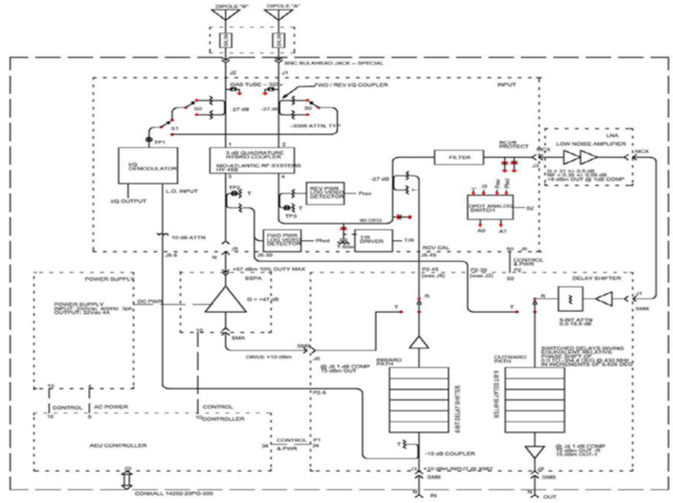

Fig. 3. AMISR-14 module general circuit diagram.

E. Phase 5

During the last phase, students are going to learn how to use the AMISR-14 system to perform experiments and observations. Following this learning process, they will perform experiments with the 14 panel AMISR system at the JRO. Dr. Marcos Diaz, from Universidad de Chile, in Santiago, who is interested to use the AMISR-14 in mapping of the derby and satellite tracking at the geomagnetic equatorial line, is going to mentor the team doing these projects. The team will present their work and findings at the Summer 2017 Research Symposium to be held at the JRO beginning of August 2017. The symposium will be organized by the staff of the SRDC in San Juan, Puerto Rico and will have speakers from the Atmospheric Science community of the U.S. and Latin America who will participate in the symposium.

F. Our student team

After a very competitive selection process in which candidates had to present their academic records, resumes, official transcripts, two letters of recommendations, personal statements and were interviewed in person, we chose six undergraduates and graduates to help us with the project. Their group photograph is shown in Figure 4.

Fig. 4. Group photograph of the AMISR-14 team.

In the beginning of the project we asked our students to share with us their reasons why they wanted to join our efforts. Here are some of their answers:

- I would like to gain experience in engineering research. I have worked in chemistry, biology, atmospheric, and computer science, but this will be my first research in engineering. I'm looking forward to working and achieving great things with this research. Additionally, this project will give me the opportunity to travel to Peru, a Latin country with a rich history.
- I would like to gain knowledge in the development of research in engineering. Radar technology is new for me, and I believe that this research will open the doors for future endeavors.
- I would like to gain experience working in engineering and learn how does an engineer work look like in a real world. I hope I can learn a lot from this experience and keep on improving my skills for future projects.
- From this project, I would like to acquire experience in the work field and engineering research. I would like to learn new concepts concerning the nature of the project. I look forward to achieving and learning great things through this research experience in Puerto Rico and Jicamarca Radio Observatory in Peru.

We are planning to do the same in the end of project, especially focusing on things students liked or disliked in order to make this a more enjoyable experience for future students.

V. Concluding remarks

Not only do we strongly believe that in order to build a more competitive STEM-C workforce in minority institutions, we need to give students opportunities to work with the cutting-edge technologies (e.g. the AMISR-14 system), but also to present them with the real-world challenges. Project-based learning has been one of core values of Student Research Development Center's of Ana G. Mendez University System for the past more than 30 years. In partnerships with public and private high schools across Puerto Rico and the U.S. Virgin Islands during that time we have impacted more than 4,550 students from 225 schools. The model has a very successful track record of transferring almost 100% of the participants into college, and a rate of 85% of them into STEM-C fields.

Building on top of our previous experience with project-based STEM-C outreach activities, in this paper, we presented our current efforts in which students rather than start with how to conduct a research, have to repair the equipment first. We were lucky enough to get highly motivated students to work with. For example, one of the team members is a senior Computer Engineering major student with a good track record of research experiences at Massachusetts Institute of Technology and Ames Research Center. However, they did not have almost any prior knowledge or experience in the field, so we had to teach them the basics first. At this point they are half way through with the project and once they came towards the end, they will know how the AMISR-14 system works in details, which will definitely help them conduct significant research in Atmospheric Sciences using the equipment.

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