

## A. Overview

Located close to the city of Arecibo in the western part of the island of Puerto Rico, The Arecibo Observatory is the world's most sensitive radio telescope and is a key component, not only of the global research infrastructure, but also of the local educational and socioeconomic environment of Puerto Rico. The Arecibo Observatory is currently owned by the National Science Foundation and operated by SRI International, under a Cooperative Support Agreement, supported by major sub-contractors The Universities Space Research Association and Universidad Metropolitana. (See Appendix 1 for a brief description of each organization.)

The Arecibo Observatory (AO) is a leading research institution established in Puerto Rico in 1963. It is supported by the National Science Foundation (NSF) and also receives funding from the National Aeronautics and Space Administration (NASA). The Observatory conducts world-class scientific studies in three principal areas: radio astronomy, planetary radar, and atmospheric sciences. The scientific results are published in the world's most prestigious scientific journals and are summarized in annual reports prepared by the operations staff. Its principal astronomical research instrument is a 305-meter fixed spherical radio/radar telescope – the world's largest radio telescope. Its frequency capabilities range from 50 megahertz to 10 gigahertz and its transmitters include an S-band (2,380-megahertz) radar system for planetary studies and a 430-megahertz radar system for aeronomy studies. The AO has a permanent staff of scientists, engineers, and technicians who are available to help visiting investigators with their observation programs.

In 2011, NSF competitively awarded the management of the AO to a new and innovative team: SRI International (as the lead partner), the Universities Space Research Association, and the first Puerto Rican managing partner, Universidad Metropolitana. These partners manage both the scientific installation and the many outreach activities hosted at the AO's Angel Ramos Foundation Science and Visitor Center. The annual budget for the AO is around \$13M a year: \$12M from federal agencies and 1M from revenue from the Science & Visitor Center. NSF funding of \$8.2M/year is divided almost equally between its Division of Astronomical Sciences and the Division of Atmospheric and Geospace Sciences. NASA provides \$4.2M from the Planetary Science Division. This budget supports the 100 personnel, including scientists, engineers, and technicians, as well as supporting staff.

Among its many accomplishments, the world's largest single-dish telescope has detailed properties of the ionosphere, spotted the first planets discovered outside our solar system, and helped confirm the general theory of relativity. Perhaps Arecibo's most significant discovery to date, which earned Joseph Taylor Jr and Russell Hulse the 1993 Nobel Prize in Physics, was the 1974 discovery of the pulsar PSR B1913+16. Pulsars— rapidly rotating, highly magnetized neutron stars formed during the supernova explosions of massive stars—had been discovered seven years earlier by Jocelyn Bell and Antony Hewish at the University of Cambridge. At the start of the 1990s upgrade, Alex Wolszczan undertook a pulsar search and found the first known extrasolar planetary system, PSR B1257+12, a pulsar orbited by three planets. By now, some

2000 pulsars have been identified, many of them discovered at Arecibo. ALFA is presently searching for new pulsars on the galactic plane and has made 123 new discoveries.

The Arecibo Observatory planetary radar is the world's most powerful instrument for post-discovery characterization and orbital refinement of near-Earth objects. Arecibo radar observations are critical for identifying asteroids that might be on collision course with Earth and, if necessary, preventing a collision. Radar can provide detailed physical characterizations of NEAs. If a small body is on course for an Earth collision in this century, Arecibo radar measurements could show this, and would dramatically reduce the difficulty and cost of any mitigation effort by defining the object's size, shape, mass, spin state, and orbit, and by revealing if it is one body or a two-body system. Radar investigations of many NEAs are roughly equivalent, in their science content, to space flyby missions, but have a much lower cost (five orders of magnitude)

Radar is invaluable in determining the orbits of potentially hazardous NEAs. Range-Doppler radar measurements complement optical observations by providing line-of-sight positional astrometry with precision as fine as 10 m in range and 1 mm/s in velocity, with a fractional precision 100 to 1000 times finer than that of typical optical measurements. Radar data increase the average interval of predictability (relative to optical-only orbit solutions) by up to 370 years and can provide warnings of impact during the initial discovery period, whereas two widely separated observations are needed for optical-only orbits. Radar data can quickly eliminate collision false alarms caused by optical-only data. These unique capabilities of radar are critically important for meeting the 2005 Congressional mandate of detecting and characterizing 90% of NEAs down to 140 m in size.

Arecibo was originally constructed to study the upper atmosphere using a radar technique called Incoherent Scatter and continues to this day to be the most sensitive such radar anywhere in the World. The extreme sensitivity of the system provides unique measurements of the plasma physics environment of the ionosphere and has motivated the recent commissioning of a new high-power, low frequency, transmitting system at the Observatory which provides scientists with tools to conduct even more detailed studies of the basic physics of this important region - including the nationally important areas of 'space weather'.

The long time series of atmospheric observations made at the Observatory also provide a very sensitive measure of long term changes in the upper atmosphere, akin to space climate, and provide an important reference in characterizing those changes across the whole global environment.

The Arecibo Observatory has an impact beyond the confines of its 120-acre site. Scientists from around the world compete for the observation time and access the facilities remotely, with the support of the AO staff. The scientific output of the AO is well known in the research community. The STEM outreach activities impact students in k-12 schools from around the island and the summer research programs offer opportunities to undergraduates and teachers in Puerto Rico and from the mainland, as well. The vision and approach of the AO is to maximize the opportunities to strengthen research, education, and support for STEM careers.

## B. Regulations that Limit the Opportunities for Expanding the STEM Economic and Educational Impact of the Arecibo Observatory

In October 2015, the National Science Foundation (NSF) published a Dear Colleague Letter (#16-005) to “request community responses on viable concepts for the future continued operation of the Arecibo Observatory.” In this request, NSF established the intent to “substantially reduce” NSF funding. (See Appendix I.) Shortly thereafter, in 2016, NSF held public hearings related to the processes of an Environmental Impact Study.

It has become apparent that NSF is interested in reducing funding to the AO. Our underlying assumption is that NSF has established that other newer projects need funds in these fields. These statements have limited the potential of AO to obtain funds from other sources, including federal and foundation, because there is a perception that the AO is no longer a vital scientific instrument and will close in the near future. However, multiple reviews and surveys, conducted by leading scientists in the fields of research supported by the AO, highlight the importance and relevance of the AO in World-class research as reported in the Observatory’s Annual Reports and Program plans.

Nevertheless, the bad press that these latest events have caused on the island cannot be underestimated. The population is currently suffering the effects of economic upheaval. Hearing about the possible closure and decreased funding of a site of which the people on the island are very proud has had a negative psychological effect in the island. The AO is known throughout the island for its research facilities and also for its contributions to the STEM initiatives it has implemented.

## C. Recommendations to NSF

The National Science Foundation receives advice from many sources including committees and panels comprising leading scientists from both its user and general scientific communities, from Congressional Committees which oversee its funding, from the operators of its facilities (including the Arecibo Observatory), and from other interested public groupings and institutions.

Many such entities have interests in the development and future of the Arecibo Observatory within the particular current circumstances faced by the Commonwealth of Puerto Rico and would wish that NSF should continue the same level of funding for AO until the economy of PR has been recovered, at least for another five-year cycle. Nevertheless, it is clear that it would be advantageous if NSF would more actively engage other federal agencies to use and sponsor this incredible research facility and if NASA would allocate more funds to promote research projects and stimulate STEM education on the island.

## D. Recommendations to PROMESA

### 1. Development of a STEM-related Economic Development Zone around the Arecibo Observatory

This idea is seen very favorably by UMET, for a variety of reasons. First of all, it presents a viable alternative for expanding the impact of the AO; second, it underscores the importance of

the AO and its relationship to STEM workforce development, in particular for an entire region of underrepresented US citizens in STEM fields; and third, it meets the goals of a variety of federal agencies. The agencies that we believe could be involved or targeted for STEM initiatives related to the development of this zone are NSF, NASA, DoD, EDA, DOL (ETA) and the US Dept. of Education.

There is ample justification for this type of initiative. First of all, this initiative would be in sync with the existing priorities of the government through PRIDCO (P.R. Industrial Development Company) and its Aerospace Cluster. This zone also could meet the goals and the White House Office of Science and Technology Policy. NSF is investing resources and efforts in broadening participation in STEM initiatives. The US Department of Labor and the reports of the National Academies have pointed out the importance of the development of our STEM workforce. Despite the current challenges, the AO continues to be a leading research facility with proven successes and with a new, broader impact on STEM workforce/pipeline development in Puerto Rico since 2011.

Regarding the expertise to organize and participate in the development of regional workforce areas, Sistema Universitario Ana G. Méndez (SUAGM) and Universidad Metropolitana have extensive experience in these matters. UMET was instrumental in the development and designation of the INTENOR initiative, a regional multi-sector effort in favor of economic development in the northern area of the island, in particular the region to which the AO belongs.

## **2. Encourage the formalization of the role of other federal agencies explore formalizing strengthening of the AO mission and STEM projects.**

After its initial construction by ARPA the Arecibo Observatory was transferred to NSF who remained the principal funding agency until the need for measurements of NEOs brought a Congressional mandate to NASA to exploit the capabilities of the Arecibo Planetary Radar. However, the facility is also used by researchers funded by a variety of other federal agencies and there is considerable potential to expand the capabilities and use of the facility to support such interests. Should the funding base be formally extended to include other Federal Agencies, the load on the NSF's strained resources would be reduced and the foundation of continued Observatory operations would be considerably strengthened. Such a diversification of the funding base might include transfer of the main responsibility for the facility to another agency if that were more appropriate.

## **3. Establish federal incentives to industries that join the aerospace cluster, utilize the research facilities located in AO and/or generate scientific entrepreneurship.**

Multiple federal studies and initiatives are emphasizing the importance of scientific entrepreneurship and projects that take the creation of new knowledge and move it into commercialization and education outreach. The Observatory presents many opportunities to create an innovative ecosystem geared to promote STEM research and education, as well as economic development. Non-traditional approaches can be explored to foster R&D in these areas, which is sorely underfunded on the island; provide incentives to current and emerging industries and start ups, and create a culture of innovation that can effectively maximize the use of a successful research and education facility at the Arecibo Observatory.

## **4. Empower local higher education through new initiatives**

The Arecibo Observatory, supported by the Angel Ramos Science and Visitor Center is a unique and irreplaceable resource for Puerto Rico education, scientific, and technical interests and can readily support enhanced programs in all these areas. Federal incentives would encourage potential users to locate resources in the area to directly exploit synergies with the Observatory, its staff, and user communities. In addition, initiatives that bridge and establish collaborations with universities on the mainland could strengthen the activities of the Observatory and offer new opportunities for local universities, as well.

## Appendix 1: Background Information on the Arecibo Management Partners

### 1. SRI International

SRI is a nonprofit, independent research center serving government and industry. SRI works on some of the world's most important problems, collaborating across technical disciplines to spark new ideas and solutions. SRI research and innovations have led to new industries and products that impact people's lives every day—from the computer mouse and interactive computing to medical ultrasound, cancer drugs, and much more.

SRI moves R&D from the laboratory to the marketplace to create high value and real innovation. The platforms SRI staff build today are designed to meet tomorrow's needs. For example, an artificial intelligence project for DARPA led to the development of Siri for Apple's iPhone. Millions of lives have been improved or saved by SRI innovations.

SRI has performed \$4 billion in sponsored R&D in the last decade with current annual revenue of \$540 million. SRI has 2,100 employees worldwide (in 20 locations), 4,000 issued patents, 69 years of contributions to society, and has created 60 spin-off companies

Sponsored R&D is at the center of SRI's integrated business models. The focus is always on meeting client and market needs to create and deliver new value, whether the outcome is an R&D solution, technology license, new product or spin-off venture.

As a nonprofit research institute, SRI is driven by impact, not shareholder value. The revenue generated by our R&D projects, commercialization activities, and marketplace solutions is reinvested in SRI capabilities, facilities, and staff to advance our mission and to continue to meet client and partner needs.

### 2. USRA (Universities Space Research Association)

USRA is an independent, nonprofit research corporation where the combined efforts of in-house talent and university-based expertise merge to advance space science and technology. USRA works across disciplines including biomedicine, planetary science, astrophysics, and engineering and integrates those competencies into applications ranging from fundamental research to facility management and operations. USRA engages the creativity and authoritative expertise of the research community to develop and deliver sophisticated, forward-looking solutions to Federal agencies and other government sponsors.

USRA was founded in 1969, near the beginning of the Space Age, driven by the vision of two individuals, James Webb (NASA Administrator 1961-1968) and Frederick Seitz (National Academy of Sciences President 1962-1969). They recognized that the technical challenges of

space would require an established research base to develop novel concepts and innovative technologies. Together, they worked to create USRA to satisfy not only the ongoing need for innovation in space, but also the need to involve society more broadly so the benefits of space activities would be realized.

Today, USRA works across a wide spectrum of disciplines stemming from the range of challenges originally posed by the space program. From biomedicine to astrophysics, from basic research to facility management and operations, USRA is helping enable the study of the Universe from ground, airborne, and orbiting observatories, the study of Earth from space-based platforms, the development of advanced technologies for complex spacecraft, the human exploration of space by astronauts, and much more.

Key to USRA's capabilities is the role of universities. In 2015, more than 350 universities were directly involved in USRA activities. The USRA business paradigm is to engage the creativity and authoritative expertise of university faculty and their students and deliver to government sponsors sophisticated, forward-looking solutions, on schedule and within budget. USRA objectively focuses on sponsor needs in these key areas: Fundamental Research; Engineering & Technology Development; Operations & Management; and Workforce Development. Universities are also a part of USRA's governance structure. 105 universities, all major research institutions, provide oversight solely as a public service. All USRA activities are conducted without bias or preference.

### **3. Universidad Metropolitana (UMET)**

Universidad Metropolitana (UMET) is a private non-profit Hispanic Serving Institution, with academic offerings that range from professional certificates to doctoral degrees. It was founded in August 1980 and since then has been licensed by the Puerto Rico Council on Education and accredited by the Middle States Commission on Higher Education. UMET is one of four (4) universities that comprise the *Sistema Universitario Ana G. Méndez* (SUAGM),<sup>1</sup> a private, not-for-profit university system under the laws of the Commonwealth of Puerto Rico and the Federal Government. SUAGM also includes Universidad del Turabo, Universidad del Este, the Ana G. Méndez Virtual University, and Sistema TV – the only PBS station in Puerto Rico. In the fall of 2015, the total enrollment at UMET was 13,420 (as reported to IPEDS), with students distributed throughout 95 academic programs and different campuses, to include the main campus in San Juan (Cupey), four (4) Additional Locations in Puerto Rico (Aguadilla, Bayamón, Jayuya and Comerío), three (3) Branch Campuses in Florida (Orlando, Miami and Tampa Bay), one (1) Branch Campus in Wheaton, Maryland, and one (1) Branch Campus in Dallas, Texas. The institution has solid experience with sponsored projects and has successfully implemented initiatives funded by foundations, local and state agencies, and also federal agencies, to include the National Science Foundation, the National Institutes of Health, the U.S. Fish & Wildlife Service, the U.S. Forest Service, the U.S. Environmental Protection Agency, and the U.S. Department of Education, among others. In the field of education alone, the institution implemented 101 projects from 2005 to 2016 to offer professional development training to teachers and school principals across the island.

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<sup>1</sup> In English: Ana G. Méndez University System

UMET is the local partner of the Arecibo Observatory (AO) Management Team and is responsible for the operations of the Observatory as well as the educational and public outreach component. As part of this effort, UMET established the AO Council of Chancellors and Stakeholders that has been instrumental in the local support to this research facility and the active participation of the local universities in projects related to the AO research agenda.

A key partner in the educational and outreach component is the Angel Ramos Foundation. Its support provided the funds for the establishment of the Angel Ramos Science and Visitor Center, which receives close to 100,000 visitors a year. The Center underwent a \$2.1M remodeling of the education exhibits with additional support from the Angel Ramos Foundation (\$900,000) and from UMET (\$1.2M).

## Appendix 2: Dear Colleague Letter: Concepts for Future Operation of the Arecibo Observatory (nsf16005) | NSF - National Science Foundation

DATE: 10/26/2015

NSF 16-005

Dear Colleague Letter: Concepts for Future Operation of the Arecibo Observatory

October 26, 2015

Dear Colleague:

This Dear Colleague Letter (DCL) requests community responses on viable concepts for future continued operation of the Arecibo Observatory.

The Arecibo Observatory is a scientific research and education facility located in Puerto Rico, owned by the National Science Foundation (NSF). In 2011, NSF awarded a five-year Cooperative Agreement to SRI International (SRI), who together with Universities Space Research Association (USRA) and Universidad Metropolitana (UMET) formed the Arecibo Management Team to operate and maintain the Arecibo Observatory on behalf of the NSF. The Arecibo Observatory enables research in three scientific disciplines: Space and Atmospheric Sciences, Radio Astronomy, and Solar System Radar Studies. A key component of the Arecibo Observatory research facility is a 305-meter diameter, fixed, spherical reflector, located on approximately 120 acres of U.S. Government-owned land in Barrio Esperanza, Arecibo, Puerto Rico, 10 miles inland from the city of Arecibo. The Arecibo Observatory infrastructure includes instrumentation for radio and radar astronomy, ionospheric physics, office and laboratory buildings, a heavily utilized visitor and education facility, and lodging facilities for visiting scientists. More information is available at [1]<http://www.naic.edu> .

The purpose of this DCL is to request viable concepts for the future of the Arecibo Observatory, specifically including strategies and goals for continued operations that involve a substantially reduced funding commitment from NSF. The Arecibo Observatory serves the interests of a diverse group of stakeholders, all of which are keenly interested in the Arecibo Observatory's continued long-term productivity and return on investment. As the owner, the National Science Foundation is now conducting a feasibility study that will help inform the scope of the necessary environmental reviews for any change to operations of the Observatory or possible transfer of title of the Observatory to another party.

In 2012, the NSF Division of Astronomical Sciences' Portfolio Review Committee recommended that "continued AST involvement in Arecibo ... be re-evaluated later in the decade in light of the science opportunities and budget forecasts at that time." (Report available at [2] [http://www.nsf.gov/mps/ast/ast\\_portfolio\\_review.jsp](http://www.nsf.gov/mps/ast/ast_portfolio_review.jsp)). This DCL follows up on that recommendation, in light of the upcoming expiration of the initial 5-year cooperative agreement with SRI. Responses to this DCL are not intended to be limited in any way or directed toward a specific solution in terms of management or operations concepts. NSF is seeking responses based on both traditional single-organization management concepts, along with less-traditional, multi-partner concepts, possibly involving joint public-private partnerships. NSF remains open to concepts involving some level of NSF participation. Responses may also include concepts involving the assumption of title and ownership of the Arecibo Observatory by the responder, including all ancillary facilities and infrastructure.

Responses should include the following:

- A clear description of the operations and activities an interested party would propose to conduct at the Arecibo Observatory, along with a description of which current scientific and educational activities would and would not continue to be conducted.
- A conceptual business, financial, and managerial outline for the Arecibo Observatory, including a clear description of how much and for how long NSF financial support and participation would be sought to make this plan viable.
- If applicable, an outline of the ways and means of effectively planning and managing the receipt of the title transfer for parts or all of the Arecibo Observatory, including ancillary facilities and infrastructure to the responder.

Please submit responses by 15 January 2016. Responses to this request do not bind NSF to any further or specific actions related to this topic. This DCL is not a formal solicitation for proposals, and conveys neither a financial commitment nor a reflection of a final decision of the disposition of the Arecibo Observatory. To the extent that the sender plans to provide any information that it considers proprietary, such status must be unambiguously communicated and clearly marked.

Responses, along with questions and comments, should be submitted in electronic form, via e-mail, to the Arecibo Observatory Program officer of the NSF Division of Astronomical Sciences, Dr. Ralph Gaume.([3]gaume@nsf.gov).

Sincerely,

James S. Ulvestad  
Division Director, MPS/AST

Paul B. Shepson  
Division Director, GEO/AGS

#### References

1. <http://www.naic.edu>
2. [http://www.nsf.gov/mps/ast/ast\\_portfolio\\_review.jsp](http://www.nsf.gov/mps/ast/ast_portfolio_review.jsp)
3. <mailto:rgaume@nsf.gov>