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Board Statement on the Future of the Arecibo Observatory

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The Arecibo Science Advocacy Partnership (ASAP, https://areciboscience.org/) strongly supports the continuation of the STEM education programs in which the Arecibo Observatory has excelled, and which have benefited thousands of Puerto Rican students at all levels (up to 30,000 a year before the COVID-19 pandemic) as well as students from the fifty states and around the world [1].

However, if the National Science Foundation (NSF) goes forward with its plan to dismantle the Arecibo Observatory's scientific mission, leaving just a STEM education center, NSF will unwisely cede U.S. leadership in astronomical, planetary, and atmospheric radar and radio science to FAST, the Square Kilometer Array, EISCAT-3D, and other cutting-edge instruments in Europe, Asia, Africa, and the rest of the world.

The United States has the opportunity to create a new, cutting-edge, multi-disciplinary observatory in Puerto Rico, which will complement and surpass all other current and planned facilities. A new Arecibo radar and radio telescope will build on the millions of dollars of investment in instrumentation, techniques, facilities, and personnel that have been made at Arecibo over the past sixty years.

A new Arecibo Observatory is essential to U.S. national priorities:

- ***Planetary defense*** is an ever-greater concern, and has relied on Arecibo's highly detailed mapping and tracking of near-Earth asteroids. NASA has shown that it can alter the trajectories of asteroids [2], but the world's most powerful radar is needed to allow us to determine which asteroids are a threat. See for example the recent results from Arecibo observations of asteroid Phaethon's changing rotation rate, one of more than two thousand classified as "potentially hazardous" by NASA [3]. In 2019 alone, the Arecibo radar successfully observed 123 near-Earth asteroids [4], which is approximately double the number that the existing radar infrastructure is able to observe. In addition, design concepts for a new Arecibo telescope include multi-frequency radar systems for asteroid research and exploration of lunar resources, and would double the reach of Arecibo's radar from Saturn to Uranus, a top priority of the recent planetary decadal survey [5]. The Arecibo radar was the best in the world by a factor of 15 over the next most powerful space radar, and a new Arecibo telescope would improve on that margin. In addition, the existing facilities with radar systems are oversubscribed and therefore not a sufficient asset for the increasing demand as the new survey telescopes discover more asteroids that require either multiple nights of optical tracking or one radar observation to refine the orbit information and thus prevent losing track of them.

- ***Climate change:*** Arecibo is located in the Atlantic hurricane corridor, traversed by the storms that annually reach U.S. shores at the U.S. Virgin Islands, Puerto Rico, and the Gulf and Atlantic coasts. Atmospheric studies done at Arecibo can help to predict and thus prevent billions of dollars in damage caused by these storms. The Arecibo Observatory has contributed uniquely to the enormous long-term, high-resolution data sets, spanning the atmosphere through the ionosphere, required by current and future climatologists. Advanced atmospheric radars are now coming on line in Europe, Asia, and South America. A new Arecibo could match and far surpass their capabilities.

- ***Space weather:*** Arecibo has been the Caribbean link of the American meridional upper atmospheric radar chain, which extends from the equator to the geomagnetic north pole. In addition, Arecibo is located below the northern conjugate point of the South Atlantic geomagnetic anomaly. Both of these make Arecibo a key location for the study of space weather and the effects of geomagnetic storms on spacecraft, communication and navigation systems, and electric power grids on Earth. The Arecibo high-power high-frequency (HF) transmitter, along with the incoherent scatter radar and other instruments, made Arecibo a leader in the experimental study of the fundamental physics of space weather, including the nonlinear interactions between plasma waves and energetic electrons, the formation of plasma density irregularities, and controlled ionization. In addition, Arecibo's abilities to measure the Sun and solar wind allow space weather storms to be studied from their earliest beginnings.

- ***Radio astronomy:*** As the largest single-dish radio telescope in the world, Arecibo made invaluable contributions to the discovery of exoplanets and earth-like worlds, to the search for extraterrestrial life, to discoveries of new pulsars and their application to research into gravitational waves and general relativity, to investigations of extreme astrophysical regions including active galactic nuclei and fast radio bursts, to studies of dark matter in order to improve our understanding of the nature of the universe and test the standard model of high-energy physics, to probing dark energy by measuring the cosmic distribution of matter, and to studies of star formation, stellar physics, and the origins of the universe.

- ***National security:*** Arecibo was built in part to detect the ionospheric signatures of nuclear detonations, and has since played a role in many other national security areas, including planetary defense, climate change, and space weather, as discussed above. In addition, the Arecibo radar was capable of higher resolution and more extensive coverage than any other atmospheric observatory, and was used to validate the measurements of a variety of other instruments as well as the results of computational models. Measurements made at Arecibo can play a key role in improving over-the-horizon radar observations of the strategic Caribbean region, which has among the world's highest traffic in vessels and marine cargo. The upper atmosphere over Puerto Rico is among the most pristine locations in the world. Along with Arecibo's unique radar and radio capabilities, this has assisted scientists at the Department of Defense in studies of radio propagation and of ionospheric disturbances created by spacecraft engine burns and powerful radio transmissions. A new Arecibo can additionally play a key role in solving the serious and urgent crisis of space debris [6], and in the development of radar methods for the detection and monitoring of cislunar spacecraft and hypersonic vehicles.

- ***Space exploration and colonization:*** Space missions to asteroids, the Moon, and the planets have relied on detailed orbital, rotational, and surface mapping information about these objects provided by Arecibo radar data. Arecibo's former capabilities in planetary and space exploration are unsurpassed and unreplaced. Although the remaining and planned Earth-based radar systems can image and map near-Earth asteroids, their sensitivity is not sufficient for more distant asteroids, moons, and planets, and their higher transmission frequencies cannot image the surface of Venus due to greater attenuation in its thick atmosphere.

- ***Unpredictable game-changing discoveries:*** A new Arecibo telescope will continue the type of unanticipated discoveries that the original Arecibo telescope was famous for, such as the indirect detection of gravitational waves (which earned the 1993 Nobel Prize in Physics) and the discoveries of the first exoplanet, ice in the craters of Mercury, the connection between ocean waves and waves in the upper atmosphere, and many others. The recent detection of a gamma ray burst, originating 2.4 billion light years away, which perturbed the ionosphere and induced ground currents, could have been studied with Arecibo [7]. The unique interdisciplinary scientific culture of Arecibo Observatory was encouraged by the amazing adaptability of the huge radio dish. A new and improved Arecibo telescope will broaden the discovery space for humanity.

- ***Public engagement and outreach****:* Over its long history, the Arecibo telescope was central in a long list of outreach activities, from blockbuster movies to programs to engage the imagination of the public. For example, in 1974 Arecibo transmitted the most powerful broadcast ever beamed into space as a symbolic gesture to demonstrate humanity's achievements in science and technology. This transmission has been highlighted in astronomy and astrobiology books, magazine articles for the general public, and documentaries.

- ***Meaningful STEM education:*** The Arecibo Observatory has long maintained STEM programs for high school and undergraduate students, and educational programs and workshops for graduate students and early career scientists. In 1987, Arecibo was among the original NSF Research Experience for Undergraduates (REU) sites, and Arecibo's summer student programs preceded the NSF initiative by many years. More recently, the Observatory has been collaborating in the establishment of a remote instrumentation site just minutes away from university campuses in northwestern Puerto Rico. For Puerto Ricans, Arecibo has been an iconic, cutting-edge research facility, showing that world-class science can be done by and for them.

NSF's proposal would remove all of the advantages that have helped make Arecibo's STEM program so successful. Without an active research program, the viability of a STEM center at a former observatory is highly questionable.

We challenge the NSF to revise its call and to reassert U.S. leadership in the astronomical, planetary, and atmospheric radar and radio sciences by:

- Affirming science as the Arecibo Observatory's primary mission, with world-class STEM education inspired by that mission.

- Reinstating funding for the existing instruments whose research is ongoing, including the Arecibo lidar facility and 12-meter dish.

- Approving plans for temporary, low-cost repairs of the collapsed 305-meter dish and related equipment, to allow the resumption of high-frequency (HF) radio experiments and perhaps incoherent scatter and low-frequency planetary radar and radio astronomy.

- Planning for a new Arecibo telescope, to complement and surpass existing instruments, as Arecibo did for more than fifty years.

We ask that Congress hold hearings about these possibilities, so that the world's most powerful radar and radio telescope can get back to work.

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