

ARECIBO OBSERVATORY (AO)**\$26,000,000**
-\$19,060,000 / 42.3%**Arecibo Observatory Funding**

(Dollars in Millions)

FY 2020 Actual	FY 2021 Estimate ¹	FY 2022 Request ¹	Change over FY 2021 Estimate	
			Amount	Percent
\$6.51	\$45.06	\$26.00	-\$19.06	-42.3%

¹ The FY 2021 Estimate includes \$37.43 million and the FY 2022 Request includes \$20.0 million in supplemental funding for cleanup of the Arecibo site following the collapse of the platform above the 305-meter telescope in December 2020.

Brief Description

Arecibo Observatory is a center for multidisciplinary research and education with advanced observational facilities. AO's principal facility was one of the world's largest single-dish radio/radar telescopes, a 305-meter diameter reflector located near the town of Arecibo in western Puerto Rico on approximately 140 acres of NSF-owned land. AO is currently operated and managed by the University of Central Florida (UCF) and subrecipients, Yang Enterprises, Inc. (YEI) and Universidad Ana G. Méndez (UAGM, formerly Universidad Metropolitana), under a cooperative agreement with NSF that began on April 1, 2018. The 305-meter telescope suffered an uncontrolled collapse of its suspended receiver platform on December 1, 2020, after the failure of several supporting cables. Cleanup activities began immediately and comprise the bulk of the increase in funding since FY 2020. NSF has provided funding for cleanup efforts under the current award to UCF, with the primary efforts led through a sub-award to the engineering firm Thornton Tomasetti. In addition to the work being performed by subcontractors under the direction of Thornton Tomasetti, specialists from Jacobs Engineering have been brought in to provide oversight of environmental and historical preservation work on NSF's behalf.

Scientific Purpose

Despite the collapse of the 305-meter telescope platform, AO is not closed, and science continues with archival data and other facilities. The Light Detection and Ranging (LIDAR) facilities onsite conduct observations of metal ions and atoms in the upper atmosphere, at altitudes around 100 kilometers, which are critical for our understanding of atmospheric composition and chemistry. The optical facilities on site at AO and in Culebra are being used to measure optical emissions from the upper atmosphere at multiple wavelengths and to study neutral dynamics and structure of the upper atmosphere. Repairs to other AO scientific assets damaged by the 2017 hurricanes, such as the 12-meter radio telescope, are under way, and are expected to contribute to the scientific program in FY 2022. Potential future extensions of the science that has been supported by the 305-meter reflecting dish in the past are being explored with community input, and an extended workshop to discuss future options with the scientific and educational communities is taking place over several weeks in June.

Status of the Facility

In 2020, AO continued repairs from damage caused by Hurricane Maria in Fall 2017 with \$2.0 million awarded by NSF in Summer 2018 and \$12.30 million awarded in Summer 2019.¹ The initial award was completed in Spring 2020 with repairs for the most critical activities post-Hurricane. The remaining repair tasks were to be accomplished over a four-year period. However, before beginning to implement many of these repairs, AO was impacted by several events outside of its control in 2020. Beginning in early FY 2020 there were many earthquakes near the southern coast of Puerto Rico (Arecibo is closer to the northern coast), including 11 greater than magnitude 5. These caused some minimal damage on the AO site, which led to facility closure for a short period of time. COVID-19 led to island-wide closures and curfews. AO quickly re-established scientific observations with new protocols in place, but the Visitor's Center was closed for a longer period. A cable/socket failure on the 305-meter telescope then occurred in August 2020 and another cable failed in November 2020, leading to a prolonged closure for stabilization efforts and repairs. After the November failure, NSF announced plans to begin decommissioning the telescope as there was no longer a pathway to stabilize the facility safely. Prior to implementing the decommissioning, the suspended platform experienced an uncontrolled collapse on December 1, 2020. Since then, efforts have shifted to cleanup and debris removal in a safe and environmentally sound way, historical preservation, and evaluation of possibilities for the future.²

As mentioned above, AO continues to support scientific research. Current scientific activities have been focused on restoring immediate scientific productivity, including prioritizing those technologies that are already operational and those funded for restoration using normal operations and maintenance funds. Repairs to some facilities (such as the 12-meter telescope and LIDAR facility) were originally budgeted in the Hurricane Maria repair funds; those repairs are also proceeding. Ongoing scientific and related activities include use of the LIDAR facility to study the composition and motion of the ionosphere along with maintenance of the roof of the facility and modernization of the laser equipment. In addition, scientific staff continue to work on analysis of data in the historical archives, operations of the remote Culebra optical facility, and restoration and use of the 12-meter radio telescope. NSF is assessing future possibilities for AO after the collapse of the 305-meter telescope.

Meeting Intellectual Community Needs

AO continues to support an array of optical instruments, including the LIDAR systems and interferometers, to make measurements of the ionosphere and thermosphere. These instruments are operated as often as possible when sky conditions are optimal, and staffing is available. In addition, the 12-meter radio telescope will be available at both 2.4 and 8 GHz for scientific use via competitive observing proposals. Access to archival data from the decades of Arecibo observations (approximately 3 petabytes) will be facilitated by a new agreement amongst the Texas Advanced Computing Center (TACC),³ UCF, AO, and several NSF-supported cyberinfrastructure projects including the Engagement and Performance Operations Center, the Cyberinfrastructure Center of Excellence Pilot, and Globus at the University of Chicago. This consortium will establish a backup of all AO 305-meter telescope data to TACC's Ranch, a long-term data mass storage system, and plans to provide a cloud-based user interface to facilitate use of the data for new and ongoing research. The ability to review archival data has proven invaluable in several scientific studies, the most notable example being the discovery and characterization of fast radio bursts (FRBs).

¹ Funds provided by the Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123).

² See www.nsf.gov/news/special_reports/arecibo/ for more details.

³ www.tacc.utexas.edu/

One area in which AO continues to excel, regardless of instrumentation, is educational and public outreach programming at all levels. Once the site is restored to a safe condition, both in terms of emergency clean-up and COVID-19 considerations, programs that are currently taking place remotely will be able to resume in-person STEM learning curricula. These include the long-running NSF-funded Research Experience for Undergraduates and the NASA-funded STAR Academy programs. In addition, the Visitor's Center—which normally hosts nearly 100,000 visitors a year, many of them local K-12 school groups—will reopen following minor repairs.

NSF is convening members of the scientific and STEM education community in June 2021 for a workshop exploring novel ideas for future activities at AO following the collapse of the 305-meter telescope platform. The workshop will focus on finding actionable and innovative ways to support, broaden, and strengthen the radio science community across Puerto Rico and to create or enhance the opportunities for scientific, educational, and cultural activities and public outreach at AO. The workshop is expected to generate innovative design ideas for AO for the short (1–3 years), medium (3–10 years), or long term (10+ years).

Governance Structure and Partnerships

NSF Governance Structure

The lead NSF program officer in the MPS Division of Astronomical Sciences (AST), in close cooperation with a program officer in the GEO Division of Atmospheric and Geospace Sciences (AGS), provides ongoing oversight. The NSF program officers make use of detailed annual program plans, long-range plans, quarterly technical and financial reports, and annual reports submitted by the management and operations awardee. Program Officers also attend awardee governance committee meetings, as appropriate. To address issues as they arise, program officers work closely with other NSF offices such as the Office of the General Counsel and the Division of Acquisition and Cooperative Support and the Large Facilities Office in the Office of Budget, Finance, and Award Management. The MPS facilities team and the Chief Officer for Research Facilities also provide high-level guidance, support, and oversight. AST and AGS program officers conduct periodic site visits and frequent, regular teleconferences with the managing awardee.

NSF oversight increased during the Fall of 2020 with efforts to stabilize and repair the structure. Post-collapse, NSF program officers, AO staff, contracted experts, and the engineer of record from Thornton Tomasetti have weekly meetings to discuss the status of the emergency cleanup work. In addition to the work being performed by subcontractors under the direction of Thornton Tomasetti, specialists from Jacobs Engineering have been brought in to provide oversight of environmental work on NSF's behalf. NSF and UCF have also recognized the need to address concerns about historical and cultural preservation. NSF has remained in contact with the Puerto Rico State Historic Preservation Office and the Advisory Council on Historic Preservation since the day of the collapse to consult on the protection and preservation of historically important elements of the site. These meetings, along with periodic site visits, provide critical information to ensure compliance with all federal and local environmental and historic preservation laws.⁴

External Governance Structure

Funding is via a cooperative agreement with UCF and its sub-awardees, UAGM and YEI. The awardees provide management and oversight through their own advisory and visiting committees, a Scientific User Advisory Committee, and a Scientific Management Advisory Committee. The award Principal Investigator is a senior employee of UCF. The AO Director, based at the telescope site, oversees daily operations of the facility, while the engineer of record from Thornton Tomasetti oversees the cleanup efforts and coordinates subcontracted work on the site. Since the collapse, NSF's Office of General Counsel and Jacobs Engineering (with the support of Thornton Tomasetti, its subcontractors, and UCF) have reached out to federal agencies, including the Environmental Protection Agency, the Council on Environmental Quality,

⁴ See www.nsf.gov/mps/ast/env_impact_reviews/arecibo/eis/305-meter_collapse.jsp for more details.

Major Research Facilities

and the U.S. Fish and Wildlife Service, to assure full compliance with the National Environmental Policy Act and the National Historic Preservation Act in the cleanup of the site. NSF and AO staff have also provided notifications to the Puerto Rico Department of Environment and Natural Resources.

Partnerships and Other Funding Sources

Since FY 2010, the NASA Near Earth Object Observation Program has committed funds annually to AO for the planetary radar program; their contribution in FY 2021 was approximately \$4.65 million. Additional support in FY 2021 included funds from UAGM, private foundations, pay-to-observe, grants from NASA focusing on education and public outreach and modest income from the Visitor's Center and cafeteria.

Funding

The FY 2022 request is \$26.0 million. AO O&M is jointly supported by AST and AGS. Additional funding was provided in FY 2021 for cleanup activities following the collapse of the 305-meter telescope platform, including debris removal, environmental mitigation, and historical and cultural preservation. Cleanup and recovery activities are expected to continue in FY 2022 as efforts to restore AO's scientific, cultural, and educational programs ramp up based on recommendations from the June 2021 workshop and other input from the scientific and Puerto Rican communities.

Total Obligations for AO

(Dollars in Millions)

	FY 2020	FY 2021	FY 2022	ESTIMATES ²				
	Actual ¹	Estimate	Request	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027
Operations & Maintenance (MPS)	\$3.75	\$3.79	\$3.00	\$3.00	\$3.00	\$3.00	\$3.00	\$3.00
Operations & Maintenance (GEO)	2.76	3.83	3.00	3.00	3.00	3.00	3.00	3.00
Cleanup ³	-	37.43	20.00	-	-	-	-	-
Total	\$6.51	\$45.06	\$26.00	\$6.00	\$6.00	\$6.00	\$6.00	\$6.00

¹ The FY 2020 Actual includes \$437,500 in GEO for continuity of operations into FY 2021; \$1.50 million of FY 2020 operations costs in GEO were obligated in FY 2019.

² Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in March 2023.

³ Supplemental funding for cleanup of the Arecibo site (see narrative for details) includes \$28.88 million in MPS and \$8.55 million in GEO in FY 2021 and \$15.0 million in MPS and \$5.0 million in GEO in FY 2022.

Reviews

In January 2017, NSF issued a solicitation requesting proposals to provide continued operations and management of AO for five years, but at reduced funding.⁵ Proposals received in response to this solicitation were afforded extensive NSF internal review together with formal review by a panel of external experts in AO management and operations, leading to the current award to UCF. Additionally, AST and AGS jointly conduct annual external reviews of AO program plans. The next formal annual external review of UCF's management is scheduled to take place in early Summer 2021.

Renewal/Recompetition/Termination

The current cooperative agreement with UCF for the management of AO was awarded on April 1, 2018, when UCF succeeded the previous managing organization, SRI International. This followed a competitive process for a new five-year cooperative agreement, consistent with NSF policy. The first annual external review of UCF's management took place in April 2020. The review in 2019 focused on the plans for the

⁵ The reduced funding profile was in alignment with NSF's 2017 Record of Decision regarding AO, which documented NSF's decision to pursue collaboration with interested parties for continued science-focused operations with reduced funding from NSF.

hurricane repairs. The timeline for potential recompetition is uncertain, pending further definition of the scope of future AO operations.