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Arecibo's Collapse Sends Dire Warning to Other Aging Observatories

The iconic telescope's tragic end foreshadows future battles over the fate of various legacy facilities

By Robin George Andrews

Arecibo Observatory, in operation during its better days, with the Milky Way overhead.

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THE U.S.'S FAMED ARECIBO OBSERVATORY SURVIVED ALL MANNERS OF THREATS since its construction in a bowl-shaped natural sinkhole in the forested hills of Puerto Rico in 1963. It persisted through everything from hurricanes and earthquakes to wild swings of the federal budgetary scythe. That history made it all the more shocking last December when the catastrophic failure of multiple massive suspension cables sent a 900-ton (817-metric-ton) equipment platform plummeting straight through the 305-meter radio dish that was Arecibo's heart, shattering it beyond repair. As news of the observatory's ignominious end spread, people around the globe—many professional astronomers among them—mourned almost as if they had lost an old friend.

That loss, however, was most keenly felt by the generations of Puerto Ricans who saw in Arecibo something more than a cultural fixture akin to the island's rain forest and rum. "As a world-renowned scientific facility that provided invaluable data to the defense of our entire planet, Arecibo was the gateway to science for many Puerto Ricans," says Edgard Rivera-Valentín, a planetary scientist at the Lunar and Planetary Institute in Houston, whose career, like many, was shaped by the observatory. "It took me a while to even be able to look at the video of the platform falling."

In the aftermath, an uncomfortable question remains: What happens now? As officials hover over the observatory's grisly remains, they must decide whether to rebuild and upgrade it, no matter the cost, or to abandon all hope of any resurrection, channeling money that might otherwise be spent financing Arecibo's reconstruction into new projects that, just maybe, could fill the gaps that this legendary facility leaves behind.

The dilemma is emblematic of an existential question looming over the entire astronomy community, especially in the U.S.: Is it really possible to strike a balance between maintaining existing observatories and building innovative new ones in an era of flat or shrinking federal funding? In other words, must we grind up the old to make way for the new? The death and attempted resuscitation of Arecibo is a distilled encapsulation of this conflict and perhaps one that provides a window into the future of the nation's legacy observatories.

ARECIBO, THIS IS YOUR LIFE

Until China's Five-Hundred-Meter Aperture Spherical Radio Telescope, or FAST, was completed in 2016, Arecibo boasted the largest radio dish in the world—capable of hearing the feeblest whispers of radio waves emanating from all kinds of astrophysical things that go bump in the cosmic night. And unlike FAST and every other radio telescope in the U.S. (save for California's Goldstone Deep Space Communications Complex, notes Megan Bruck Syal, a planetary defense researcher at Lawrence Livermore National Laboratory), Arecibo was not only capable of receiving radio waves from the great beyond but also of transmitting them. This made the observatory one of the few facilities able to bounce radar beams off planets, moons and asteroids to make remarkably high-resolution measurements of their shapes and surfaces.

Across the decades, researchers used Arecibo's superlative capabilities to perform one stunning feat of space science strength after another. These included providing the first piece of evidence for the presence of gravitational waves, as well as detecting the first repeating fast radio burst. The facility played a key role in confirming one of the very first known exoplanets. And it was the source of the Arecibo message, a cosmic communiqué beamed into intergalactic space in 1974 that, at its specific wavelength, briefly outshone the sun.

But as time passed, technology progressed, and the need for new observatories with breakthrough capabilities became clear, Arecibo's chief funder and steward, the National Science Foundation (NSF), began to perceive the observatory as being past its prime. A 2006 senior review report recommended that unless another entity

Prior to its collapse, Arecibo's radio dish had already been crippled by several snapped cables, setting the stage for further calamity.

RICARDO ARDUENGO *GETTY IMAGES*

stepped in to fund it, Arecibo should be decommissioned after 2011. Pressure from the scientific community, as well as from politicians and locals, saved the observatory from this fate, but the NSF has been draining it of annual operational funds and threatening it with decommissioning ever since.

By 2017 the NSF paid about two thirds of Arecibo's $12-million annual budget, with NASA making up the remaining third. But by federal fiscal year 2019 the facility's annual funding for operations and maintenance was down to about $7 million. NASA's level of support at that time was around $4 million. (That year the NSF also gave more than $12 million to Arecibo for hurricane-related repairs through a congressional act.) This funding decline was set to continue into the 2020s, a clear signal that, one way or another, the NSF was going to rid itself of Arecibo eventually.

The problem, says Casey Dreier, senior space policy expert at the Planetary Society, is that when adjusted for inflation, the NSF's budget for basic research that funds Arecibo (and much else) has remained relatively flat over the past 10-plus years. This funding is essentially determined by Congress, and the NSF has to do what it can to achieve the most pertinent scientific goals of the moment with whatever it is given.

So what is a cash-strapped agency with lots of aging but scientifically capable observatories to do?

"In planetary defense, Arecibo has unparalleled capabilities to characterize the detailed shapes of near-Earth asteroids."
—Megan Bruck Syal

ONE OF A KIND

Because of its singular capabilities and shocking demise, the case of Arecibo is particularly extreme, but it still aligns with the shared plight of many other legacy astronomy facilities: Do we keep them going for as long as possible or, at some point, accept that they are not worth it anymore?

The case for Arecibo's reconstruction, now championed by many in the astronomy community both within and outside Puerto Rico, leans on the uniqueness of its capabilities. What, exactly, could Arecibo do that others could not?

Chiara Mingarelli, a gravitational-wave astrophysicist at the University of Connecticut, is part of the NANOGrav project, which looks for nanohertz-frequency gravitational waves via subtle variations they should induce on the arrival times of metronomelike radio pulses from large numbers of pulsars scattered across the heavens. Such waves—which have yet to be conclusively seen via this "pulsar timing array" method—are thought to come from merging pairs of supermassive black holes. Arecibo had been monitoring half of NANOGrav's targeted pulsars.

"We can still do [pulsar timing]. It's just that Arecibo was really good at it," Mingarelli says. "We lost our star quarterback." International collaborations with other radio telescopes elsewhere in the world—in Europe and Australia, for example—will help make up for that shortfall a little, she adds. Newer players able to study pulsars—such as China's FAST, South Africa's MeerKAT and India's Giant Metrewave Radio Telescope—are all capable of helping. But the loss of Arecibo is not trivial. "We don't only need one of those telescopes," Mingarelli says. "We need lots of those telescopes so we can look at the whole sky."

Paulo Freire, an astronomer at the Max Planck Institute for Radio Astronomy in Bonn, Germany, hunted pulsars using Arecibo from 2001 to 2009. At the time, it was the world's most sensitive telescope for such work. Other telescopes do not yet compare, he says.

FAST is more sensitive, but for now at least, it can't act as a perfect replacement for Arecibo because of various issues. For one thing, any international collaboration with the telescope requires navigating a complex political gauntlet, a series of checks and bureaucratic barricades that may be a flex of China's growing soft power.

Conversely, Arecibo's policy was very open. "You submit a proposal. If it has merit, it gets time on the telescope. That's it. They don't care where you come from," Freire says. Fortunately, MeerKAT can help out in the pulsar hunt. "For pulsars, the location where you want to see is in the Southern Hemisphere because the center of our galaxy is in the Southern Hemisphere. And there, the sky is full of pulsars," he says. "But still, [MeerKAT] has about a third of the sensitivity that Arecibo has—or had." FAST also has a bit more of a restricted frequency range, compared with Arecibo. And unlike the latter facility, it does not have multiple transmitting radar systems. "For the U.S. at the moment, there's no facility that's going to replace the capabilities of Arecibo—not in terms of high-sensitivity astronomy," Freire says.

Arecibo could tune in to the activity of nearby stars. Such observations gave scientists such as Abel Méndez, director of the Planetary Habitability Laboratory at the University of Puerto Rico at Arecibo, an idea of how hostile or harmless a planetary neighborhood's stellar furnace was likely to be. If a world around one of our sun's neighboring stars had potent auroras or perhaps even a technological civilization, Arecibo's sensitivity was sufficient to give it a chance of detecting the resulting radio chatter. The FAST facility should offer similar sensitivity, Méndez says, but he worries about logistics—particularly the difficulty of traveling to China for potential on-site work.

Arecibo was also one of our foremost sentinels monitoring dangerous space rocks. Although ill suited for searches for such objects, the observatory excelled at characterizing individual specimens: if another telescope spotted an asteroid or comet on a possible collision course with Earth, Arecibo could take a closer look.

"In planetary defense, Arecibo has unparalleled capabilities to characterize the detailed shapes of near-Earth asteroids," Bruck Syal says. Knowing a threatening asteroid's shape, in turn, helps to predict how it might react to deflection attempts using nuclear explosives or kinetic impactors. Arecibo could also nail down the position of near-Earth asteroids very precisely so their orbital paths could be more accurately predicted. "That's essential for driving down the uncertainty on whether an asteroid might impact Earth in the future or not," Bruck Syal says.

NASA's Deep Space Network, a collection of radio telescopes used to speak to spacecraft across the solar system that includes the Goldstone observatory, also has transmitting capabilities, says Alessondra Springmann, a planetary science doctoral student at the University of Arizona, who spent two years at Arecibo. That makes it suitable for various planetary radar observations, including asteroid characterization. "But you can look at 20 times more asteroids, I believe, with Arecibo," she says. "Arecibo is 18 times more sensitive than Goldstone. And Arecibo has a degree of scheduling flexibility that Goldstone and the Deep Space Network lacks."

Even the telescope's location is unique. Puerto Rico is a hotspot for strong earthquakes and hurricanes. But in the island's favor is its large limestone sinkholes, a great fit for giant radio dishes. And unlike most other potential sites for hosting an ultralarge observatory, Puerto Rico offers preexisting infrastructure, from roads to power lines. Reconstruction would be tough and costly, Springmann says. But it would still be easier than making a big new radio telescope elsewhere.

The most compelling argument to rebuild Arecibo, however, may come down to its connection to everyday Puerto Ricans. For decades the observatory was a nexus for science education and outreach, and it reliably boosted the local economy by bringing in well-paid jobs and a steady flow of tourists. "When we work to build scientific facilities toward that endeavor and engage the public through that facility, we enter into a social contract and incur those responsibilities," Rivera-Valentín says. In other words, the harm from abandoning Arecibo could reach well beyond the rarefied realm of astronomy.

A GRIM REALITY

Even in death, Arecibo demonstrates that the NSF has an intractable problem with its aging observatories.

Tony Beasley, director of the National Radio Astronomy Observatory, headquartered in Charlottesville, Va., says that our society supports astronomy for four main reasons: conducting science to find our place in the universe; learning fundamental physics by comparing astrophysical phenomena with local events; producing new generations of scientists, engineers and savvy members of the lay public; and sparking technological advances. "When you think about Arecibo, it was still doing three of those fantastically. It was doing pretty good on the science one as well," he says.

"That's the quandary the NSF has with these facilities. All of them are doing great at looking at weird places in the universe, producing fantastic people and technology, and all that kind of stuff," Beasley says. "The science may or may not be *New York Times* front-page [material], but it's fantastic. They're all bricks in the wall."

And whereas in recent years optical and infrared astronomy have been the hotbeds of research activity, Arecibo has helped keep the radio telescope community alive and well, Freire says. Furthermore, he adds, despite the observatory's advanced age, its many upgrades over the years almost made Arecibo a new telescope over and over again.

But there are limits to telescopic add-ons, Beasley says. It is a bit like adding improved lenses to the camera on your smartphone: eventually the phone's immutable architecture will limit the type and quality of the photographs you can take. Arecibo was a literal and figurative giant in radio astronomy thanks to its vast dish size and associated astounding sensitivity. But the trade-offs for that massive dish will not be fixed by upgrades: a limited frequency band in which it could observe and a reduced view of the sky, for example—nested in its sinkhole, Arecibo's dish cannot be steered to point anywhere in the heavens. Such restrictions mean that even upgraded with wondrous new bells and whistles, its sensitivity will not significantly change.

Sadly, Arecibo's implosion now makes the argument for its enduring worth much harder to make because repairs and upgrades are far cheaper than rebuilding something from a pile of debris. "The bottom line is: if you've already got it, and it's working, you can do an upgrade of the electronics and key systems and start doing your science," Beasley says. "That's always worth looking for. But if it collapses, and you have to rebuild it, that's a different discussion. You could be talking about two-orders-of-magnitude-different investment."

New projects could certainly use the money that might otherwise go into rebuilding Arecibo. But let the buyer beware: "The problem with the new, shiny things is that they can break down, they can take longer than you think, they can go overbudget, and the thing you end up with in the end isn't really the thing you wanted in the beginning," Mingarelli says.

"You could close a lot of telescopes and still not be able to pay for the operations of one of these new telescopes," Beasley says. When it comes to the old versus the new, there are no easy answers.

Aerial view of Arecibo's shattered radio dish, which was damaged beyond repair by the crash-landing of the observatory's 900-ton equipment platform after additional cable failures.

RICARDO ARDUENGO *GETTY IMAGES*

ARECIBO'S AUTOPSY

In a media briefing, Ralph Gaume, director of the NSF's astronomy division, seemed to say that the agency is treating the situation with the Arecibo telescope as firmly postmortem. Any decision to rebuild the radio dish or return the site to its natural state would be a "multiyear process that involves congressional appropriations and the assessment and needs of the scientific community," he said.

Already, though, others are applying the lessons of Arecibo to planning for the future. Francisco Córdova, director of the Arecibo Observatory, says that the dish's destruction shines a light on potential problems newer telescopes may encounter. Arecibo's saga, in which it was slowly exsanguinated of funds over time, should be a cautionary tale for other facilities. Nickel-and-diming a legacy observatory may help balance budgets, but the associated operational uncertainties and inefficiencies the practice introduces can be profoundly disruptive for actually doing scientific research—perversely reducing the benefits of keeping an aging facility's lights on in the first place.

One solution the NSF pursued—transferring ownership of Arecibo to private entities or consortiums to reduce the agency's responsibilities—offers "another way of doing things well," Córdova says. Auctioning aging sites close to their peak scientific performance years would give them the best chance at a second life. Such efforts, however, are not guaranteed to work: For years, NASA sought to "save" its aging Spitzer Space Telescope by handing it off to the private sector for a hefty but fair sum. Yet in the end, no deals were struck, and Spitzer was shut down in early 2020.

In any event, Arecibo's tragic decline suggests that slowly siphoning away funds from preexisting facilities to support new projects is treacherous and not at all guaranteed to lead to net positive outcomes. "I think in the view of many, the NSF has just not adequately funded the facility over the years," Bruck Syal says. "And that's apparent now. [The dish's collapse] is the consequence of underfunding an iconic observatory like that. You can't keep it going on a shoestring budget forever."

"The bottom line is: if you've already got it, and it's working, you can do an upgrade of the electronics and key systems and start doing your science."
—Tony Beasley

Money, however, cannot solve everything. In Arecibo's case, Córdova says, some of the facility's structural degradation was difficult, if not impossible, to see using nondestructive technology. That situation meant that even if a well-funded consortium had been managing the observatory and doing the same checks using the same maintenance technology, it would not have caught the fatal cable degradation either. Speaking for the current management team at the University of Central Florida, Córdova adds that the team "never at any point stopped performing maintenance tasks on the structure because of the lack of funding."

Like Córdova, Freire, who worked at Arecibo back when Cornell University managed the site, does not believe the collapse arose from direct neglect. "I think nature was especially unkind to the structure," he says, referring to recent earthquakes and 2017's Hurricane Maria. "I think this might have been the main reason why the strength of the cables was far below what was expected."

But declining funds certainly did not help. Although maintenance on Arecibo did not stop, it was triaged. "A lot of the money that [the observatory] had, spare money for maintenance, was then with tasks that were perceived to be more urgent," Freire says. In recent years corrosion from airborne salts had been a constant worry for the facility's managers. "People were not so worried about the cables," Freire adds.

If you are striving for a balance between reliable workhorses and novel projects, representation also matters. "I think it's easier to ignore or underfund facilities that are off the U.S. mainland" and hope that no one notices, Bruck Syal says. "The fact that Puerto Rico doesn't have senators, for example, to advocate for it more aggressively might have hurt the facility's funding."

Ultimately, though, the reason for the tension between the NSF's upkeep of old observatories and its plans for new ones lies in the funding it receives. That arrangement is "kind of insane, right?" the Planetary Society's Dreier says. "We're talking about fractional, single-digit millions that Arecibo had to fight to keep out of an annual U.S. budget of approximately $4.5 trillion. That's how squeezed our sciences are. All of our basic R&D—that includes the [National Institutes of Health], that includes NASA, that includes the NSF—we're still only talking about $80-ish billion a year, out of a $4.5-trillion budget." The situation strikes some as senseless: As others, such as China and Europe, seek scientific ascendancy on the international stage, Beasley says, his colleagues are asking, "Why are we just rolling over on this?"

"In astronomy, we are right at that moment, that sort of inflection point, where we have to make a very clear decision about world leadership and what the benefits to the U.S. are of being a world leader in a field like this," he says. "Where the money goes is a reflection of values." Considering the complicated saga of Arecibo, then, what Americans are really confronting is a fundamental question of what sort of country they wish the U.S. to be. SA