

The collapse of the Arecibo radio telescope

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The destruction of the Arecibo radio telescope, a scientific crime, is a direct consequence of years of neglect and underfunding. Far from being an unforeseeable disaster, it directly flows from decades of impoverishment of all activities, scientific, cultural, artistic, that do not most directly channel the riches of labor into the overflowing coffers of the ruling class.

The telescope, 305 meters in diameter and commissioned in 1963, was the world's largest single-dish instrument until the completion of a 500-meter dish in China in 2016, sharing its similar unusual design.

Instead of a large and massive movable structure consisting of a radio-reflecting dish and receiver at the dish's focus, Arecibo was built in a natural area of Puerto Rico in which the underlying limestone geology creates bowl-shaped depressions rather than valleys. The water outflow is through underlying river caves in the limestone. The bottom of one of these depressions was outfitted with panels comprising a spherical radio-reflecting dish, and an array of receivers and a powerful radar were suspended at a movable focus high above on a network of cables from masts atop the bowl's encircling ridges.

On August 10 of this year, after 15 years of increasingly tenuous funding, two changes in management and an ongoing transition to "pay-to-play" private partnership support, one of those cables snapped. Before the bureaucracy could even decide to approve, much less implement, temporary or permanent repairs, a main supporting cable from the same support mast snapped on November 7. At this point, without redundant support, the fate of the telescope was sealed: no safe access could be obtained to shore up the 900-ton suspended platform, and additional strand breaks began in an unstoppable cascade.

On December 1, the single remaining cable on the damaged side completely failed, dropping the platform 137 meters onto the dish and snapping numerous cables and support points throughout the mast system. Only ruins remain.

Arecibo has a distinguished scientific career behind it. Within months of commissioning on November 1, 1963, it managed the unprecedented act of bouncing radar off the innermost planet in the solar system, Mercury, and in so doing correctly measuring its rotation period of 59 days.

With the detection of the Crab Nebula pulsar in 1968, Arecibo established the existence of highly compact neutron stars, exotic objects formed in some stellar explosions by massive stars at the ends of their lives, that weigh more than our sun but span only 20 kilometers and spin rapidly, up to hundreds of times per second, emitting radio pulses as they do. Six years later, the radio telescope detected the first instance of two neutron stars orbiting one

another, a system where two star-like masses complete an orbit in only eight hours. This system provided the most exquisite test of Einstein's theory of General Relativity until the recent direct measurement of black hole mergers by the new technology of gravitational wave telescopes, and won the 1993 Nobel Prize in physics for the discoverers, Russell Hulse and Joseph Taylor.

In subsequent years, the instrument has imaged asteroids with radar (1989), made the first detection of planets outside the solar system, though in the decidedly exotic environment of a neutron star pulsar, not a regular star (1994), and detected possible ice in the shadowed craters of Mercury's polar regions (also 1994). It has also conducted extensive surveys of the sky, detecting 203 new neutron star pulsars and mapping the distribution and velocity of hydrogen and numerous other gaseous substances in the Milky Way, our own galaxy.

Arecibo also played a significant role in promoting astronomy among the general population. It famously broadcast a message about Earth and humanity to the globular cluster M13 in 1974 with the hope that another intelligent species would pick it up and respond in kind. It was written by Frank Drake in collaboration with others, including Carl Sagan, and helped to popularize radio astronomy and science in general during that decade.

The 1950s were heady times for a new horizon opening in astronomy, the use of radio waves to explore the universe. Only two decades earlier, in 1933, were radio signals discovered from outside the solar system, accidentally at that, as unexplained static on transatlantic radio links. While individual low-budget discoveries occurred in the following years, only in the 1950s did a systematic effort begin to plan and fund large radio observatories in the same way that revolutionized astronomy in visible light through its increasingly capable large telescopes.

But Arecibo bears only an indirect heritage to that lineage. It did not emerge from the birth of the National Radio Astronomy Observatories, in 1956. That federal research center was able to access \$850,000 in its early days to begin construction of a 91-meter radio dish that could only be steered north to south along the sky's meridian. That telescope, with a collecting area 11x smaller than Arecibo but still the largest in the world at completion, entered service the year before Arecibo.

Arecibo and its initial \$12.7 million budget, and millions more in upgrades throughout its first decade, was a project initially of the Air Force. Its primary mission was not to understand the astronomical universe, but the "universe" of reentering intercontinental ballistic missiles, and how to separate the real thing from decoys. For this, it was originally designed only to look straight up, and outfitted with a powerful radar system not only to

passively receive signals from the hot upper atmosphere region called the ionosphere and objects traveling through it, but also to probe them. Its chief task was to make such studies over a complete 11-year solar cycle, during which the changing magnetic field of the sun also changes the “climate” of the ionosphere.

The Air Force contracted with Cornell University to construct and manage the facility. This same period saw the birth of “Project Plowshare” in 1957 to sell “peaceful” uses of nuclear explosions, and for undoubtedly similar reasons, Arecibo’s design was reworked to make it steerable enough for astronomical observations, as the atmospheric and missile studies would occupy only a small fraction of its operations. No doubt the expertise attracted through participation of leading astronomers and other civilian experts also improved the “atmospheric” studies.

Only in 1970 and the end of its military research was responsibility transferred from the Air Force to the National Science Foundation. Cornell continued to manage the facility until 2011.

To further illuminate the relative priorities of science versus the Cold War, at the same time of Arecibo’s initial funding, the Navy became aware of the possibility of monitoring remote radio signals that bounced off the moon. In June 1958, groundbreaking took place in Sugar Grove, West Virginia, only 30 miles from the new civilian radio astronomy observatories, for a gigantic \$79 million radio telescope consisting of a fully steerable 183-meter dish weighing 22,000 tons, what would have been the largest land-based movable structure ever created. Its budget even invited the attention of Congress, which capped outlays at \$135 million in 1961. The following year, Secretary of Defense Robert McNamara canceled it, after \$42 million spent and a projected cost that had ballooned to \$230 million, as it became clear that radio surveillance satellites, a new capability of the space age, made moon-bounce surveillance obsolete.

The modern highly classified space-based radio telescopes, pointed downwards to monitor decidedly terrestrial concerns, are by some estimates potentially 100 meters or more in diameter. The cost of these telescopes is classified, but their Titan IV launches alone cost half a billion dollars each, and seven have been launched since 1995. Like the optical Hubble Space Telescope, whose optics were only novel for being constructed outside of a classified supply chain and tasked to look outwards, pure scientific studies are a distinct stepchild.

Radio astronomy evolves. The focus in recent decades has not been on single radio dishes, but radio arrays. Because the “sharpness” of an image depends on the size not only of the telescope generating it, but also the wavelength of the electromagnetic radiation used, a single radio telescope is a hundred thousand times more blurry than an optical telescope of the same size. Arecibo at its shortest operational wavelength provided images about as sharp as what the eye can see. At its longest wavelengths, it could barely see the moon as something other than a point.

Large radio arrays can deliver a sharpness that depends on the size of the entire network, which today effectively means the diameter of the earth itself. Through these advances, the black hole at the center of our own galaxy was recently imaged, the

equivalent of imaging a baseball on the moon.

But new technology does not always make the old obsolete. The recent Chinese version of Arecibo, FAST (Five Hundred Meter Aperture Spherical Telescope), is continuing the survey work of Arecibo, where the “blurry” beam is an advantage, if the unknown objects in it have signatures that can be pulled out of the radio signal. That they chose a large single dish telescope through which to innovate is also a reflection of American pressures to exclude China from international collaborations, including world-spanning radio arrays.

But FAST, while having Arecibo’s exquisite sensitivity and more, does not have the transmitter capability. There is no telescope operational on earth or planned to match the radar capabilities lost with Arecibo’s collapse.

The 91-meter dish in West Virginia also collapsed on November 15, 1988 after a structural failure and years of shoestring budgets. Other large-scale structural failures in the US, like the I-35W Mississippi River bridge in Minneapolis, which collapsed during evening rush hour on August 1, 2007, are testament to the increasing neglect to our infrastructure. So too is the hollowing out of our educational system a form of infrastructure collapse, a process greatly accelerated after the 2008 economic crisis, with the prospects after this year’s pandemic painful to imagine.

The operational costs of Arecibo, \$12 million annually at a bare minimum, are also the same costs to simply maintain and operate a single F-22 fighter. Replacing Arecibo from scratch, perhaps \$150 million by some estimates, would cost about the same as building that jet plane. The budget for one B-2 bomber would rebuild and maintain Arecibo for the better part of a century. The \$2.2 trillion CARES act, largely directed to the already super-rich, already begins to enter the sphere of numbers formerly reserved to astronomy alone.

In that light, one must see the painful choices made by the Astronomical Sciences Division of the National Science Foundation when it recommended a 60 percent cut to Arecibo in 2006, a product of decades of straitened circumstances, and which marked the beginning of the end for the great Arecibo radio telescope.



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