



# The Arecibo Ionospheric Observatory

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March 5, 2009

**Congressional Research Service**

7-5700

[www.crs.gov](http://www.crs.gov)

R40437

## Summary

The Arecibo Ionospheric Observatory is a radio and radar telescope located in Barrio Esperanza, Arecibo, Puerto Rico. The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, operated by Cornell University under a cooperative agreement with the National Science Foundation. In 2005-2006, NSF's Division of Astronomical Sciences (AST) conducted a Senior Review of its portfolio of facilities. Among other things, the Senior Review was to identify potential reinvestment in the highest priority existing programs in AST and restructure the operational efficiency of the existing facilities. The Review reported that the scientific value of the Arecibo was modest when compared to other existing and proposed projects and recommended decreasing the telescope's annual \$12.0 million budget to \$9.0 million in FY2009, and securing partnerships for the remaining necessary funding. If alternate funding sources or partnerships could not be obtained by 2011, the Review recommended dismantling the facility. It has been estimated that the cost of decommissioning Arecibo may exceed that of keeping it in operation. The issue before the 111<sup>th</sup> Congress is whether the decommissioning of Arecibo is more cost-effective than replacing it with newer, available technology. Congress may consider examining the balance between the demands of existing facilities and the investments in the next generation of large facilities.

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## Background

The Arecibo Ionospheric Observatory is a radio and radar telescope located on approximately 120 acres of federally-owned land in Barrio Esperanza, Arecibo, Puerto Rico.<sup>1</sup> The Arecibo Observatory is part of the National Astronomy and Ionosphere Center (NAIC),<sup>2</sup> operated by Cornell University under a cooperative agreement with the National Science Foundation (NSF).<sup>3</sup> Built in a natural depression in the jungles of Puerto Rico, Arecibo is the world's largest single-dish radio-wavelength reflector, measuring approximately 1,000 feet across and 167 feet deep. The 900-ton receiver platform is suspended 450 feet above the reflector dish. The 40,000 aluminum panels of the structure cover 20 acres. Arecibo can receive signals from 25 megahertz to 10 gigahertz. Transmitters include an S-band 2,380-megahertz radar system for solar studies and a 430-megahertz radar system for ionospheric studies. Arecibo can access approximately 40.0% of the sky and "has an unrivalled sensitivity due to its large size."<sup>4</sup> The fixed spherical telescope has the ability to predict and track the movement of potentially hazardous near-Earth objects.<sup>5</sup>

Construction of the Arecibo Observatory began in 1960 at the initial cost of \$9.7 million. The Defense Department's Advanced Research Projects Agency provided funding for the project, the Air Force administered it, and Cornell University managed the project for the Air Force. Arecibo was commissioned for service on November 1, 1963. Initially designed for radar studies of Earth's ionosphere, it was also found to be valuable for research in radio and radar astronomy. In 1970, ownership of Arecibo was transferred from the Department of Defense to the NSF's Division of Astronomical Sciences (AST),<sup>6</sup> with NSF subsequently taking responsibility for funding of the telescope. It was at this time that the NAIC was established at Cornell University to manage the facility.

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<sup>1</sup> The primary instrument on the grounds is the Arecibo Observatory. Also on the grounds are laser radar (lidar) systems used for atmospheric observations.

<sup>2</sup> The National Astronomy and Ionosphere Center (NAIC) is a visitor-oriented national research center focusing on radio and radar astronomy and atmospheric sciences. NAIC has operating status as an NSF Federally Funded Research and Development Center (FFRDC) since 1970. For discussion of an FFRDC please see National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 2005-07*, NSF09-300, Arlington, VA, November 2008, p. 358.

<sup>3</sup> The current cooperative agreement expires in 2010.

<sup>4</sup> National Science Foundation, *From the Ground Up: Balancing the NSF Astronomy Program*, Report of the National Science Foundation, Division of Astronomical Science Senior Review Committee, Arlington, VA, October 22, 2006, p. 42.

<sup>5</sup> For discussion of the near-Earth objects and the capabilities of Arecibo see for example House Committee on Science and Technology, Subcommittee on Space and Aeronautics, *Near-Earth Objects (NEOs)-Status of the Survey Program and Review of NASA's 2007 Report to Congress*, 109<sup>th</sup> Congress, 1<sup>st</sup> Sess. November 8, 2007.

<sup>6</sup> AST is in the Directorate for Mathematical and Physical Sciences.

**Figure 1. The Arecibo Radio/Radar Telescope**  
National Astronomy and Ionosphere Center, Arecibo, Puerto Rico



**Source:** <http://www.aerospace-technology.com/projects/Arecibo/Arecibo4.html>

The telescope has evolved and developed over its lifetime. In 1974, the first upgrade was completed, replacing the original wire mesh surface with aluminum panels. The upgrade totaled approximately \$8.0 million—approximately \$5.0 million from NSF and \$3.0 million from National Aeronautics and Space Administration (NASA). The upgrade enabled Arecibo to operate at 3 gigahertz. Also, planetary radar studies were expanded with the installation of a 420 kilowatt transmitter, operating at 2.4 gigahertz.

In 1997, the second upgrade of the facility was completed, with the installation of a Gregorian reflector system, suspended approximately 450 feet above the telescope's 1,000-foot dish and a 1-megawatt radar transmitter. This upgrade allowed the telescope to operate at up to 10 GHz, increasing the telescope's "sensitivity, frequency coverage, and agility, and enabl[ing] dual-beam incoherent scatter radar capability, providing new research opportunities."<sup>7</sup> The upgrade was undertaken by NSF and NASA, with support from Cornell University, at a cost of \$25.0 million—\$14.0 million from NSF and \$11.0 million from NASA.

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<sup>7</sup> "The Arecibo Observatory Celebrates 40 Years-A Timeline," [http://www.research.cornell.edu/vpr/cwc172-04/pdfs/naic\\_timeline.pdf](http://www.research.cornell.edu/vpr/cwc172-04/pdfs/naic_timeline.pdf).

## Research Conducted at Arecibo

Arecibo is recognized for its research in radio astronomy, solar system radar astronomy/planetary radar, and ionospheric observations/terrestrial aeronomy. It has been used for research in such diverse areas as interstellar gas, pulsars and fundamental physics, variations in Earth's ionosphere, galactic structure formation and evolution, planetary surfaces and moons, and the post-discovery characterization and orbital refinement of near-Earth asteroids. One of the first accomplishments of Arecibo was determining the correct rotation rate of Mercury, which was found to be 59 days instead of the previously estimated 88 days. Other Arecibo firsts include the first discovery of a binary pulsar, the first discovery of planets outside the solar system, and the first detailed three-dimensional mapping of how galaxies are distributed in the universe. In 1982, research conducted at Arecibo discovered a type of radio emission—hydroxyl megamaser—that has since been found to indicate a collision between two galaxies.

## Reports of the National Research Council

In 1997, the Board on Physics and Astronomy of the National Research Council (NRC), established the Astronomy and Astrophysics Survey Committee to assess the field of ground- and space-based astronomy and astrophysics for the decade 2000 to 2010. The committee was charged with recommending priorities for initiatives during that decade and to explore areas of development of new technologies. The report of the 2000 decadal survey, *Astronomy and Astrophysics in the New Millennium*,<sup>8</sup> made an effort to find the balance between long-term support for facility operations and research grants and priority for new technological opportunities and facilities. The Committee made recommendations relating to coordination of the astronomy and astrophysics programs of the NSF, NASA, and the Department of Energy Office of Science (DOE). The Committee also explored possibilities for international collaboration and private, state, and federal partnerships. The decadal survey recommended that NSF conduct competitive review of its astronomy facilities and organizations approximately every five years.

The next decadal survey, addressing the period 2010-2020, is to report in early 2010. This survey is to provide a comprehensive and robust review of strategic planning process. It is to explore interagency issues among NSF's AST, NASA's Astrophysics Division, and DOE's Office of Science, High Energy Physics. The committee for this survey, known as Astro2010, was directed to make its recommendations for funding levels for astronomical research based on a flat budget trajectory.<sup>9</sup>

Another report of the NRC, *Connecting Quarks with the Cosmos*,<sup>10</sup> proffered recommendations that paralleled those of the decadal survey. Both noted that AST should respond to emerging scientific opportunities and construct different operational models for future astronomy facilities and organizations.

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<sup>8</sup> National Research Council, *Astronomy and Astrophysics in the New Millennium*, 2001, 246 pp.

<sup>9</sup> The National Academies, "Astro2010: The Astronomy and Astrophysics Decadal Survey," <http://www7.nationalacademies.org/bpa/Astro2010.html>.

<sup>10</sup> The National Academies, National Research Council, *Connecting Quarks with the Cosmos, Eleven Science Questions for the New Century*, Washington, DC, National Academy Press, 2003, 205 pp.

The 2008 annual report of the federal Astronomy and Astrophysics Advisory Committee<sup>11</sup> mirrored many of the recommendations contained in the 2000 decadal survey and *Connecting Quarks with the Cosmos*. It stated that:

AST's focus must of necessity change to reflect the needs of these new, powerful and very expensive facilities. A robust program of support for the majority of our current facilities, combined with the operations funding needed for our new and immensely more powerful facilities... , mandate cuts in funding for some current facilities if we are to make a credible case for new funding!<sup>12</sup>

The report suggested that in order to bring long-term stability to Arecibo for the science community, alternative funding sources and partnerships should be explored with other institutions in Puerto Rico and possibly with support from NSF's Division of Atmospheric Sciences. It was suggested also that international partnerships should be explored. In a joint NSF-NASA response to the Committee, it was noted that although partnerships and joint projects can be problematic by increasing managerial complexity, they do offer the benefit of sharing responsibility and authority.<sup>13</sup>

## Report of NSF's Senior Review

In 2005-2006, NSF's Division of Astronomical Sciences conducted a Senior Review of its portfolio of facilities. This review resulted from a combination of factors—projections for federal spending on research and development, growth of the AST budget, the proposed directions of the astronomical research community, and the recommendations and analyses contained in the aforementioned reports on ground-and space-based facilities. The Senior Review was to, among other things, identify potential reinvestment in the highest priority existing programs in AST and to restructure the operational efficiency of the existing AST-operated facilities. The Senior Review examined the balance within the full portfolio of projects and recommended changes that would provide savings from existing programs to be redirected in support of new activities. The Senior Review stated that Arecibo continues to produce scientific results, but when budgets are limited, choices have to be made to explore new science opportunities and new capabilities. The Committee reported that the scientific value of the telescope was modest when compared to other existing and proposed projects funded primarily by the NSF. NSF has stated that: "Identifying potential cost savings in our current portfolio of projects and devising an acceptable implementation plan for realizing these savings will allow progress to be made on the next generation of Astronomical instruments and better position AST for future budget augmentation."<sup>14</sup>

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<sup>11</sup> The Astronomy and Astrophysics Advisory Committee was established under the National Science Foundation Authorization Act of 2002 (P.L. 107-368). The Committee's charter was updated in 2005 to include advising the DOE in addition to NSF and NASA.

<sup>12</sup> 2008 Annual Report, Astronomy and Astrophysics Advisory Committee, University of California, Santa Cruz, p.31. [http://www.nsf.gov/mps/ast/aaac/reports/annual/aaac\\_2008\\_report.pdf](http://www.nsf.gov/mps/ast/aaac/reports/annual/aaac_2008_report.pdf).

<sup>13</sup> Joint NSF-NASA Response, October 18, 2002 Report of the National Astronomy and Astrophysics Advisory Committee, p. 4. See also Cho, Adrian and Daniel Clery, "Astronomy Hits the Big time," *Science*, v. 323, January 16, 2009, pp. 332-335.

<sup>14</sup> [http://www.nsf.gov/mps/ast/seniorreview/q\\_and\\_al-07.pdf](http://www.nsf.gov/mps/ast/seniorreview/q_and_al-07.pdf).

The Senior Review determined that the approximately \$200.0 million astronomy budget was facing a deficit of \$30.0 million by 2010. The Senior Review recommended decreasing the Arecibo's annual \$12.0 million budget to \$9.0 in FY2009 and securing partnerships for the remaining necessary funding. It stated that if alternative funding sources or partnerships could not be obtained by 2011, the Observatory should be dismantled.<sup>15</sup> The Senior Review anticipated that by FY2010, the \$2.5 million savings resulting from the proposed changes would be recovered by the AST budget and be made available for other projects and activities. The recommendation from the Senior Review as it relates to Arecibo is as follows:

The [Senior Review] recognizes the significant and unique scientific contributions that the Arecibo Observatory has made to astronomy and astrophysics and it congratulates NAIC and Cornell on operating the facility so effectively.... However, the committee was not persuaded of the primacy of the science program beyond the end of the decade and found that the case for long term support at the present level was not as strong as that for other facilities. The [Senior Review] recommends a decrease in AST support for Arecibo to \$8 m (plus the \$2M from ATM) over the next three years. This should permit a reduction in the scientific and observing support staff and a discontinuation of the future instrumentation program without compromising the main science program.. The [Senior Review] recommends that NAIC plan either to close Arecibo or to operate it with a much smaller AST budget. This will require that NAIC seek sufficient external funding to continue to operate it fully. If Arecibo is kept operating beyond 2011, it is expected that this will only be a limited term extension, pending the deliberations of the next decadal survey.<sup>16</sup>

Supporters of Arecibo charge that the Senior Review made its recommendations based on anticipated flat budget forecasts. They contend that NSF's budget has been increasing over the years, and that should translate into additional funding for the AST and Arecibo in particular.<sup>17</sup>

There are some in the scientific community who believe that the NSF does not view solar system science as a high priority. In testimony before the House Subcommittee on Space and Aeronautics, Donald B. Campbell, professor, Cornell University, contended that the planetary/near-Earth objects radar research program at the Arecibo was in jeopardy as a result of the recommendations in the Senior Review.<sup>18</sup> Campbell charged that the Senior Review gave the planetary program scant attention in its report and failed to take into account the telescope's capabilities in detecting near-Earth objects. The Arecibo radar system has conducted approximately 65.0% of all radar observations characterizing near-Earth objects.

Others in the science community maintain that NASA should provide funding for the Observatory because it benefits greatly from its ability to track near-Earth objects. The NASA Authorization

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<sup>15</sup> There is the suggestion that the Square Kilometer Array (SKA), a new array of radio telescopes, could replace the capabilities of the Arecibo. The SKA is being planned by an international consortium. See National Science Foundation, *From the Ground Up: Balancing the NSF Astronomy Program*, pp. 63-64. In addition, China has started construction on a Five-hundred-meter Aperture Spherical Telescope (FAST) in Guizhou Province, China. With its anticipated completion in 2013-2014, FAST would be the world's largest radio telescope with an overall capacity 10 times larger than Arecibo. See "China Exclusive: China Starts Building World's Largest Radio Telescope," December 26, 2008, [http://news.xinhuanet.com/english/2008-12/26/content\\_10563849.htm](http://news.xinhuanet.com/english/2008-12/26/content_10563849.htm).

<sup>16</sup> National Science Foundation, *From the Ground Up: Balancing the NSF Astronomy Program*, p. 63.

<sup>17</sup> Weiss, Rick, "Radio Telescope and Its Budget Hang in the Balance," *The Washington Post*, September 9, 2007, p. A01.

<sup>18</sup> House Committee on Science and Technology, Subcommittee on Space and Aeronautics, 110<sup>th</sup> Cong., 1<sup>st</sup> Sess., November 8, 2007, Written testimony of Donald B. Campbell, Professor of Astronomy, Cornell University.



Act, 2005, directs NASA to, among other things, track and catalogue, and characterize all near-Earth objects.<sup>19</sup> NASA counters that NSF should be the supporter of the Observatory.<sup>20</sup> NASA contends that it is focused on space-based programs and not ground-based programs. The report of the Senior Review noted that:

NASA has been very clear that it does not regard the support of ground-based telescopes as part of its mandate although on those occasions when it has contributed in this manner, the results have usually been scientifically highly productive. There are good reasons now to revisit the working relationship between the two agencies. The relationship with DOE has a shorter history but is currently more stable.<sup>21</sup>

In response to the Senior Review recommendations, Cornell University said that it would terminate operations of the planetary radar in October 2007 in order to meet budget deadlines.<sup>22</sup> However, the University continued operation of the radar on a “less frequent schedule.” Cornell is also exploring its options for providing long-term support of the Arecibo with non-AST funding. The Senior Review proposed that the Arecibo and the NSF seek partners, including international partners, to share operation costs and to allow the telescope to remain as a competitive scientific and educational facility.<sup>23</sup> NSF has stated that a plan for operation of the facility must be developed by the spring of 2009, the anticipated time when NSF will be developing its FY2011 budget decisions about the long-term future of Arecibo.

There has been concern expressed about the cost of decommissioning the telescope. The cost of decommissioning could possibly exceed the cost of operating Arecibo for several years. Estimates range from \$170 million to \$200 million,<sup>24</sup> costs described by the Senior Review as “prohibitively large.”<sup>25</sup> The Senior Review recommended that NSF contract an engineering firm to conduct a cost analysis of decommissioning the facility. The study was to be released in November 2008, but has been delayed by budget planning activities. However, it is scheduled to be released in early 2009, simultaneously with the program solicitation for the NAIC management competition.<sup>26</sup>

## Funding

The FY2008 NSF budget for Arecibo is \$12.2 million, of which approximately \$10.5 million is from AST and \$1.7 million is from NSF’s Directorate for Geosciences, Division of Atmospheric

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<sup>19</sup> P.L. 109-155.

<sup>20</sup> Rivera-Lyles, Jeannette, “Huge Observatory Now Needs to Spot a Rescuer,” *Technology News*, chron.com April 5, 2008, <http://www.chron.com/disp/commnts.mpl/nation/5676855.html>.

NASA’s response is that it has the Deep Space Network 70 meter antenna at Goldstone to track NEOs. In addition, NASA anticipates that several telescopes are to be completed in the next five years that have the capabilities of tracking NEOs. The Large Synoptic Survey Telescope is expected to be completed in 2012.

<sup>21</sup> National Science Foundation, *From the Ground Up: Balancing the NSF Astronomy Program*, p. 30.

<sup>22</sup> NASA terminated support of the planetary radar in FY2006.

<sup>23</sup> It is both a research and teaching facility. Approximately 24% of the Arecibo users are graduate students.

<sup>24</sup> These estimates include dismantling the facility and restoring the land to its original state.

<sup>25</sup> Rivera-Lyles, Jeannette, “Huge Observatory Now Needs to Spot a Rescuer,” *Technology News*, Chron.com, April 5, 2008, *Ibid.*, p. 63.

<sup>26</sup> Personal communication with NSF’s Office of Legislative and Public Affairs, December 10, 2008.

Science (ATM). Arecibo will receive an additional \$60,000 in support of its Research Experiences for Undergraduate program. The FY2009 request for the NAIC was \$11.4 million, which includes \$9.6 million from the AST and \$1.8 million from the ATM. Congress has not yet completed action for FY2009 appropriations for NSF.

NSF has stated that a plan for operation of the facility must be developed by the spring of 2009, the anticipated time when NSF is developing its FY2011 budget-decision about the long-term future of Arecibo.

## Congressional Activity

Language in the FY2008 Omnibus Appropriations Act stated:

The Appropriations Committees express concern over the conclusion of the NSF's division of Astronomical Science Senior Review with regard to the Arecibo Observatory. The Committees believe that this Observatory continues to provide important scientific findings on issues of near-space objects, space weather, and global climate change, as well as numerous other research areas. The Committees believe that these endeavors will have scientific merit far beyond the end of this decade. As such, the Committees hope the Division of Astronomical Science will reconsider its conclusion regarding future funding for the Arecibo Observatory.<sup>27</sup>

In the 110<sup>th</sup> Congress, S. 2862, a bill to provide for NSF and NASA utilization of the Arecibo Observatory, was introduced on April 15, 2008. The bill would have provided for operation of Arecibo to continue. It would:

- (1) ensure that the facility is fully funded to continue
  - (A) its research on Earth's ionosphere, and
  - (B) its research in radio astronomy, and
  - (C) research on the solar system; and
- (2) coordinate with the Administrator of NASA to ensure that the capabilities of the Arecibo Observatory continue to be available for NASA in characterizing and mitigating near-Earth objects, and other research as needed.

A similar bill, H.R.3737, was introduced on October 3, 2007.

The 111<sup>th</sup> Congress may choose to consider increased funding for Arecibo. NASA has received a legislative mandate to observe and detect near-Earth objects. Considering the capabilities of Arecibo to characterize the physical properties of near-Earth objects, some say NASA could benefit from its continued support. In addition, preliminary estimates for dismantling Arecibo and restoring the land to its original state could exceed the cost of maintaining it for several years. It

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<sup>27</sup> P.L. 110-161, H.R. 2764, House Appropriations Committee Print, Consolidated Appropriations Act, 2008, Title III, Division B-Commerce, Justice, Science, and Related Agencies Appropriations Act, 2008, p.316. Signed into law on December 26, 2007.

is anticipated that continued operation of Arecibo will be assessed in the 2010-2020 decadal survey currently underway.

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