FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTERS (FFRDCS)

GREEN BANK OBSERVATORY (GBO) $10,830,000
+$1,930,000 / 21.7%

Green Bank Observatory Funding
(Dollars in Millions)

FY 2021 Actual	FY 2022 (TBD)	FY 2023 Request	Change over FY 2021 Actual Amount	Percent
$8.90	-	$10.83	$1.93	21.7%

Brief Description

GBO is a major NSF research facility and a FFRDC located in Green Bank, West Virginia. It is operated by Associated Universities, Inc. (AUI) under a cooperative agreement with NSF. GBO enables leading ground-based research at radio wavelengths by offering access to telescopes, facilities, and advanced instrumentation to the U.S. scientific community, and it conducts an active program of education and public outreach. GBO is also the administrative site of the 13,000-square-mile National Radio Quiet Zone, where radio transmissions are restricted by law. Having telescopes within this quiet zone allows detection of faint astronomical signals that would otherwise be overwhelmed by anthropogenic radio signals.

Scientific Purpose

The main scientific instrument at GBO is the 100-meter Robert C. Byrd Green Bank Telescope (GBT), which became fully operational in 2002. GBT is the world's largest fully steerable single-dish radio telescope, operating at frequencies from 0.2 GHz to 116 GHz. Its large sky coverage, very high sensitivity, and extensive suite of instruments make it a powerful and versatile telescope that continues to enable important advances in virtually all areas of modern astrophysics, including Solar System and planetary astronomy; star formation and evolution; interstellar physics and chemistry; pulsar studies of long-wavelength gravitational waves; physics of black holes, neutron stars, and other compact objects; and galaxy formation and evolution. GBT provides excellent response to point sources, such as pulsars, and as a filled aperture, it also offers very high sensitivity to faint extended emissions of the kind associated with comets, molecular clouds, and distortions of the cosmic microwave background. GBT is complementary to and synergistic with interferometric arrays, such as the Karl G. Jansky Very Large Array (VLA), the Very Long Baseline Array (VLBA), and the Atacama Large Millimeter/submillimeter Array (ALMA). It also plays a critical supporting role as a highly sensitive element of very long baseline interferometry, achieving the highest angular resolution, as well as a bistatic radar receiver for rapid and sensitive imaging of near-Earth objects and asteroids. GBT's focal plane is ideal for rapid, wide field imaging using multi-pixel cameras.

Status of the Facility

GBT observations have continued remotely throughout the COVID-19 pandemic period. Public activities, meetings, and conferences have been paused or migrated to remote formats since mid-March 2020. Observer training workshops and scientific community workshops are also

continuing remotely. A phased return to on-site work is occurring and being closely monitored; currently most of the staff are on site, with physical distancing, sanitization, and personal protective equipment measures in place. Education and public outreach activities, and associated revenues, have been impacted severely, due to the closing of the Green Bank Science Center and the lodging facilities for visitors.

GBO conducts regular inspections of and maintenance on numerous components of its telescopes and site infrastructure. The last full structural inspection of the GBT by an independent engineering firm was completed in 2021. That report identified key areas for future maintenance work and upgrades. Additional inspections are scheduled in 2024.

Meeting Intellectual Community Needs

Approximately 500 scientists use GBT each year for research that spans virtually every field of modern astrophysics. GBT is flexible and easy to use and can rapidly respond to new ideas from the scientific community. It is straightforward for a small group to build and install a new instrument on this world-class research facility. State-of-the-art instruments now under development in collaboration with university groups will keep GBT equipped with the latest technology. Graduate students using GBT gain vital hands-on experience with a major telescope, an increasingly rare opportunity and critical for their training.

In November 2021, the National Academies' report on the Decadal Survey of Astronomy and Astrophysics, "Pathways to Discovery (Astro2020),"[1] recommended ongoing support for three key capabilities: long term timing of pulsars, development of new instrumentation, and mitigation of radio-frequency interference. The GBT is already involved in these activities and is poised to play a key role in all three areas.

GBT is currently used for observations approximately 6,500 hours per year. Of these, approximately 4,500 hours are available as Open Skies, or NSF-sponsored observing time, and are allocated through community-based peer review. The "oversubscription rate", or the ratio of the Open Skies time requested to the time granted, has been in the range 2-3 since FY 2015. Non-open-skies time (about 2,000 hours) at GBT is provided to GBO partners (see Partnerships section below) who make significant financial contributions to facility operations.

GBO also conducts a variety of education and public outreach programs and activities that have impact regionally and across North America. The Green Bank Science Center enables these programs and activities with its auditorium, classrooms, and large exhibit hall, visited by nearly 50,000 people every year. Thousands of K-12 teachers and students participate in educational programs using the variety of radio telescopes available at GBO. Since the onset of the pandemic, much of GBO's education and public outreach programming has shifted online, including virtual visits and at-home educational activities, as well as biweekly Zoom webinars for its scientific community.

The scientific direction and operations of the Observatory are assessed through regular NSF reviews, input from various community workshops, and AUI governance and external advisory committee meetings. Development and upgrade efforts are driven by community needs and priorities, address

[1]www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020

certain key recommendations of the NSF external merit review panel that evaluated the most recent renewal proposal, and align with strategic initiatives such as the NSF Windows on the Universe Big Idea. Thus, GBO is poised to address community needs and enable important advances in astronomy in the coming years.

Governance Structure and Partnerships

NSF Governance Structure

Oversight from NSF is provided by a program officer in the Division of Astronomical Sciences (AST), who carries out continuing oversight and assessment for GBO by making use of detailed annual program plans, technical and financial reports, and annual reports submitted to NSF. The AST program officer attends AUI governance and advisory committee meetings. To address issues as they arise, NSF has an Integrated Project Team for GBO, which includes representatives from other NSF offices, such as the Office of the General Counsel, as well as the Division of Acquisition and Cooperative Support and the Large Facilities Office within BFA. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.

External Governance Structure

GBO is managed and operated through a cooperative agreement with AUI, a non-profit research management organization consisting of an Executive office overseen by a Board of Trustees, with input from several internal and external committees. AUI manages GBO through its own community-based oversight and users committees. The GBO Director reports directly to the AUI Vice President for Radio Astronomy.

Partnerships and Other Funding Sources

External contributions represent approximately 30-35 percent of the total operations budget of GBO. These contributions come mostly from non-federal partners, including Breakthrough Listen (BL),[2] the Gordon and Betty Moore Foundation,[3] and individual contracts for GBT observing time. The NSF-funded North American Nanohertz Observatory for Gravitational Waves (NANOGrav) Physics Frontiers Center also contributes to annual operations costs. Partnerships with BL and NANOGrav are anticipated to continue through FY 2024. Many of the GBO partnerships involve guaranteed allocations of observing time on the GBT in exchange for operations funding. Other partnership development efforts are continuing.

[2] www.breakthroughinitiatives.org/initiative/1

[3] www.moore.org/

Funding

Total Obligations for GBO
(Dollars in Millions)

	FY 2021	FY 2022	FY 2023	ESTIMATES[1]				
	Actual	(TBD)	Request	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028
Operations & Maintenance	$8.90	-	$9.12	$9.55	$9.55	$9.55	$9.55	$9.55
Special Projects[2]	-	-	$1.71	-	-	-	-	-
TOTAL	**$8.90**	**-**	**$10.83**	**$9.55**	**$9.55**	**$9.55**	**$9.55**	**$9.55**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2024.

[2] Reflects additional funding for research infrastructure and O&M costs, including additional costs for repairs and maintenance.

NSF conducted a community-based review of the AST portfolio in response to a recommendation of the 2010 National Academies of Science, Engineering and Medicine Decadal Survey of Astronomy and Astrophysics.[4] In 2012, that portfolio review recommended divestment of GBT in order to sustain balance in the AST program.[5] NSF subsequently undertook a full environmental review of options for the future of GBO, culminating in NSF's July 2019 Record of Decision (ROD)[6] to pursue continued GBO operations with reduced NSF funding and increased partner contributions. Following the ROD, NSF awarded a new cooperative agreement to AUI for GBO O&M for the five-year period FY 2020-FY 2024. While GBO's total annual O&M costs are projected to remain stable to ensure continued effective operation of the facility, NSF's share should decrease as new viable funding partnerships and collaborations are developed. The current funding picture will be examined within the context of the most recent Decadal Survey, Astro2020, which highlighted the importance of ongoing support for the GBT for key activities described above

The FY 2023 request encompasses support for direct telescope operations at GBO, including maintenance, infrastructure upgrades, and telescope management, as well as funds allocated for education and public outreach. This includes a GBO evaluation that is near completion, and includes replacement and fortification of the track and foundation, which are showing signs of degradation

Reviews

NSF conducts annual reviews of the program operating plan and reports, including external advice from community representatives. Recommendations from these annual reviews with external panelists are routinely used to inform GBO's operations planning and NSF's oversight thereof. Under the new cooperative agreement, annual reviews have been held in December 2020 and December 2021.

Renewal/Recompetition/Termination

NSF's current cooperative agreement with AUI for operations and management of GBO spans the five-year period October 1, 2019 – September 30, 2024. NSF plans to conduct a comprehensive review of GBO operations in the second half of the five-year reward to assess choices regarding renewal, competition, or divestment of the facility beyond FY 2024.

[4] www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics
[5] www.nsf.gov/mps/ast/portfolioreview/reports/ast_portfolio_review_report.pdf
[6] www.nsf.gov/mps/ast/env_impact_reviews/greenbank/greenbank_rod.jsp

Views showing the Green Bank Telescope in the Fall (left) as well as the unblocked aperture and fully steerable structure (right). *Credit: GBO/AUI.*