NATIONAL RADIO ASTRONOMY OBSERVATORY (NRAO) **$85,660,000**
+$2,650,000 / 3.2%

National Radio Astronomy Observatory Funding[1]
(Dollars in Millions)

FY 2018 Actual[2]	FY 2019 (TBD)	FY 2020 Request	Change over FY 2018 Actual Amount	Percent
$83.01	-	$85.66	$2.65	3.2%

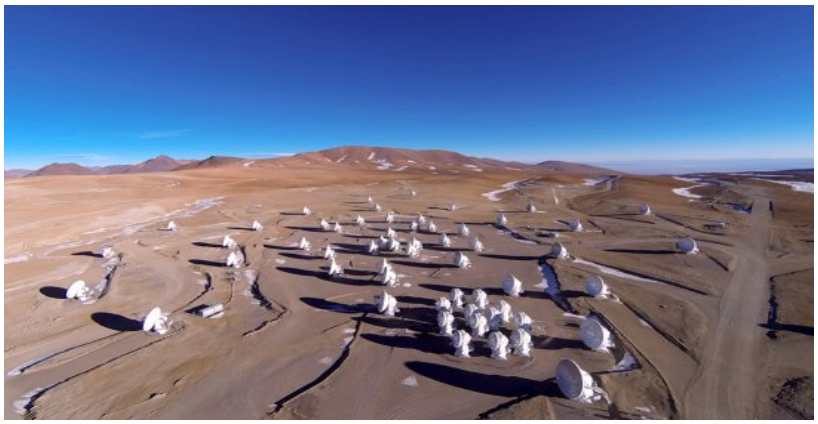
[1] This table aggregates funding requested for NRAO and ALMA base operations. FY 2020 also includes funding for the Very Long Baseline Array (VLBA).

[2] The FY 2018 Actual includes $3.50 million in additional FY 2018 one-time funding above the requested amount and $2.0 million in supplemental appropriation funding for hurricane repairs.

NRAO conceives, designs, builds, operates, and maintains state-of-the-art radio telescopes used by scientists from around the world. Operating synergistically with optical, infrared, x-ray, and gravitational wave telescopes, NRAO facilities enable discovery over a remarkably broad range of key problems in modern astrophysics that reach from within our solar system to the most distant galaxies in the universe. Using NRAO observing capabilities and data archives, scientists: carry out precision cosmological measurements; test fundamental physics; probe deep into the earliest, most intense, and optically obscured phases of planet, star, galaxy, and black hole formation; reveal the cool gas from which stars form; provide essential tools for studying magnetic fields and high-energy cosmic phenomena; and seek to detect the sources of gravitational waves.

As a Federally Funded Research and Development Center headquartered in Charlottesville, Virginia, NRAO operates the Karl G. Jansky Very Large Array (VLA) near Socorro, New Mexico; the Very Long Baseline Array (VLBA), with 10 sites throughout the continental United States, Hawaii, and the U.S. Virgin Islands; and is also the North American implementing organization for the international Atacama Large Millimeter/submillimeter Array (ALMA). These ground-based observing facilities for radio astronomy are available to any qualified researcher, regardless of affiliation or nationality, on the basis of scientific, merit-reviewed proposals. In addition to conducting NSF-funded astrophysical observations, the VLBA is used for fundamental support of the International Celestial Reference Frame, under an agreement with the United States Naval Observatory (USNO). NRAO facilities annually serve over 2,500 users worldwide; moreover, continued high demand for ALMA has resulted in the most proposals ever received for an astronomical facility in response to a single proposal call. NSF does not provide individual investigator awards targeted specifically for use of NRAO facilities, but many users are supported through NSF or NASA grants to pursue scientific programs that require use of NRAO facilities.

Including the ALMA operations staff located at NRAO, staff in FY 2020 will consist of 402 full-time equivalent positions (FTEs) in the operations and maintenance components, including: 71 in telescope operations, 47 in science support and research, 39 in development programs, 81 in computing and data management, 73 in administrative services, and 19 in education and public outreach. These numbers exclude staff at the partitioned Green Bank Observatory, managed and operated separately from NRAO, as well as 72 staff in the NRAO common cost pool that serve multiple observatories. In addition, the NRAO managing organization, Associated Universities, Inc. (AUI), employs local ALMA operations staff in Chile, currently about 250 FTEs.



ALMA is in science operations following the completion of construction in 2015. An international partnership between North America, Europe, and East Asia, ALMA provides orders-of-magnitude improvement in observing sensitivity and image quality over previous facilities. *Credit: NRAO/AUI.*

In September 2017, Hurricane Maria damaged the VLBA facility on St. Croix, Virgin Islands. Funding for observatory repairs was provided in the Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) totaling $16.30 million. Of the total amount provided, $2.0 million was identified for NRAO and obligated in FY 2018.

Total Obligations for NRAO

(Dollars in Millions)

	FY 2018 Actual	FY 2019 (TBD)	FY 2020 Request	ESTIMATES[1] FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
Operations & Maintenance[2]	$38.96	-	$38.40	$39.45	$40.53	$41.65	$39.79	$40.98
Telescope Operations	*10.98*	-	*10.99*	*11.28*	*11.60*	*11.91*	*11.38*	*11.72*
Development	*9.70*	-	*7.57*	*7.77*	*7.98*	*8.21*	*7.84*	*8.07*
Science Operations	*5.91*	-	*6.17*	*6.35*	*6.53*	*6.71*	*6.41*	*6.60*
Administrative Services	*9.46*	-	*10.49*	*10.77*	*11.06*	*11.37*	*10.86*	*11.19*
Directors Office	*2.16*	-	*2.42*	*2.49*	*2.55*	*2.62*	*2.51*	*2.58*
Education and Public Outreach	*0.75*	-	*0.76*	*0.79*	*0.81*	*0.83*	*0.80*	*0.82*
ALMA Operations	38.55	-	47.26	48.68	50.14	51.64	56.19	57.79
Facility Upgrades[3]	3.50	-	-	-	-	-	-	-
Hurricane-related Repairs[4]	2.00	-	-	-	-	-	-	-
Total	**$83.01**	**-**	**$85.66**	**$88.13**	**$90.67**	**$93.29**	**$95.98**	**$98.77**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in FY 2026.

[2] FY 2018 funding for VLBA, formerly the Long Baseline Observatory (LBO), was provided under a separate cooperative agreement and is shown in the Other AST Facilities narrative. Beginning October 1, 2018, operations funding for LBO was reintegrated into NRAO as the VLBA at $3.43 million per year.

[3] The FY 2018 Actual includes $3.50 million in additional FY 2018 one-time funding above the requested amount.

[4] Further Additional Supplemental Appropriations for Disaster Relief Requirements Act of 2018 (P.L. 115-123) provided NSF $16.30 million in no-year funding to repair radio observatory facilities damaged by hurricanes that occurred during 2017. Of the total amount provided, $2.0 million of the total amount was identified for NRAO and obligated in FY 2018.

Facility Upgrades: In FY 2018, NSF awarded $3.50 million for repair of tracks at the VLA (supporting critical maintenance) and for the provision of fiber optics for the VLBA, enhancing that facility's data transmission capability.

The total FY 2020 NRAO Budget Request includes ALMA operations ($47.26 million) and non-ALMA operations and maintenance ($38.40 million). Included in the non-ALMA funding is $3.43 million for the VLBA which was reintegrated into NRAO beginning October 1, 2018. FY 2018 funding for the VLBA, formerly Long Baseline Observatory (LBO), was provided under a separate cooperative agreement and is shown in the Other AST Facilities narrative.

Partnerships and Other Funding Sources: NRAO supplements NSF Division of Astronomical Sciences (AST) support with funding provided by other NSF sources, other federal agencies, and non-federal sources. In FY 2018, NRAO received approximately $100,000 from non-AST sources at NSF, $1.20 million from other federal agencies, and $1.50 million from U.S. universities, foreign scientific and technical institutes, and other non-federal and industrial sources. The development of new telescopes, instrumentation, and sensor techniques is conducted in partnership with relevant industries through competitive sub-awards to various large and small aerospace companies, radio antenna manufacturing firms, and specialized electronics and computer hardware and software companies. The LBO received $6.76 million from the USNO while it was part of Other AST Facilities, before it was reintegrated into NRAO at the beginning of FY 2019. For FY 2019, USNO provided $4.14 million in funding for the VLBA, and plans to provide $4.19 million for FY 2020.

Telescope Operations, $10.99 million: This encompasses support for direct telescope and array operations of the VLA including maintenance, infrastructure upgrades, and telescope management.

Development, $7.57 million: The FY 2020 Budget Request continues to support development programs including next generation electronics and detectors for radio astronomy, as well as planning and the development of technologies for a next-generation centimeter wavelength facility (next generation Very Large Array, or ngVLA).

Science Operations, $6.17 million: This includes telescope time allocation, staff research, science training and education, and science community outreach.

Administrative Services, $10.49 million: This includes internal common costs used to allocate common and management expenses across the total pool of observatory activity, such as business services, utilities, and other facility costs at the operating locations, observatory management, and the library.

Director's Office, $2.42 million: This supports the director's office and managing organization costs.

Education and Public Outreach, $760,000: NRAO supports a comprehensive outreach program that makes radio astronomy information available to the public.[24] With over 150 students involved per year, NRAO facilities are used by graduate students carrying out dissertation research and work experience programs and by undergraduates participating in the Research Experiences for Undergraduates program. NRAO also supports a visitor and education center and conducts active educational and public outreach programs. The VLA visitor center attracts over 20,000 public visitors each year.

ALMA Operations, $47.26 million: In FY 2015, NRAO completed construction of the international ALMA Observatory, funded through the MREFC account. Early operations funding for ALMA began in FY 2005 and ramped up to steady state operations in FY 2018. Operations funding supports a share of observatory operations in Chile, a technical development program, and the North American ALMA Science Center (NAASC). NRAO created the NAASC in 2006 to provide technical and scientific support for, and easy access by, the broad astronomical community that uses ALMA. The NAASC also organizes summer schools, workshops, and courses in techniques of millimeter and submillimeter astronomy.

Management and Oversight

- NSF Structure: In consultation with community representatives, an AST program officer carries out continuing oversight and assessment for NRAO and ALMA by making use of detailed annual program plans, long-range plans, quarterly technical and financial reports, and annual reports. This program officer participates in the international ALMA Board and attends AUI/NRAO governance and advisory

[24] https://public.nrao.edu/

committee meetings. To address issues as they arise, AST has a dedicated Integrated Project Team (IPT) which includes representatives from other NSF offices, such as the Office of General Counsel, OISE, and the Division of Acquisition and Cooperative Support and the Large Facilities Office in BFA. The MPS Facilities team, together with the NSF Chief Officer for Research Facilities, also provide high-level guidance, support, and oversight.

- External Structure: Management is through a cooperative agreement with AUI, which manages the observatory through its own community-based oversight and users committees. The NRAO director reports to the AUI president. Oversight of the international ALMA project is vested in the ALMA Board, which includes a member from NSF; coordination and management of the merged international efforts are the responsibility of the Joint ALMA Observatory whose staff includes an ALMA director. An international ALMA review committee advises the ALMA Board.
- Reviews: NSF conducts annual reviews of the NRAO Program Operating Plan and strategic planning documents, ALMA operations, and the AUI Management Report.

Renewal/Recompetition/Termination

Following a solicitation issued in FY 2014 (NSF 14-568), management and operation of NRAO, including ALMA, was competed and the NSB authorized a cooperative agreement with AUI for October 2016 through September 2026. Reintegration of the VLBA operations support into NRAO occurred in October 2018.