

## NATIONAL RADIO ASTRONOMY OBSERVATORY (NRAO)

<https://public.nrao.edu/>

### National Radio Astronomy Observatory Funding

(Dollars in Millions)

	FY 2023		Change over	
FY 2022	Estimate	FY 2024	FY 2023 Estimate Base	
Actual	Base	Request	Amount	Percent
\$102.72	\$93.66	\$98.35	\$4.69	5.0%

### Brief Description

NRAO is a Federally Funded Research and Development Center that conceives, designs, builds, operates, and maintains radio telescopes used to study all types of astronomical objects, from bodies in our solar system to objects in the distant universe. Operating synergistically with optical, infrared, and x-ray telescopes, NRAO's state-of-the-art, general-purpose facilities enable discovery over a broad range of key questions in modern astrophysics. NRAO operates the North American component of the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, the Karl G. Jansky Very Large Array (VLA) near Socorro, New Mexico, the Very Long Baseline Array (VLBA) throughout the continental United States, Hawaii, and the U.S. Virgin Islands, and the Central Development Laboratory (CDL) in Charlottesville, Virginia.

### Meeting Scientific Community Needs

Since 1956, NRAO has provided world-class radio telescope facilities for use by the U.S. and international scientific community. NRAO also provides both formal and informal programs in education and public outreach for teachers, students, the public, and the media.

NRAO's observing facilities for radio astronomy are available to researchers, regardless of affiliation or nationality, based on merit-reviewed scientific proposals. NRAO facilities annually serve over 2,500 users worldwide; moreover, continued high demand for ALMA has resulted in the most proposals ever received (1,836) for an astronomical facility in response to a single proposal call. NRAO is among the top three astronomical facilities worldwide for the highest publication numbers (937 in 2022) and over 810,00 total citations.

NRAO facilities continue to enable ground-breaking discoveries, from the detection of a massive flare from our nearest stellar neighbor to the detection of unusually massive galaxies and black holes in the very early universe. Using data from VLA sky surveys twenty years apart, astronomers were able to detect jets of relativistic charged particles from near supermassive black holes that had been launched during that interval, providing insight into how these enigmatic phenomena are created. Closer to Earth, ALMA showed that volcanoes are responsible for the sulfur dioxide gas in the atmosphere of Jupiter's moon, Io.

## *Major Facilities*

The National Academies of Sciences, Engineering, and Medicine Decadal Survey for Astronomy and Astrophysics (Astro2020)<sup>1</sup> identified time-domain astronomy and multi-messenger astrophysics (MMA) as components of one of the three scientific pillars for the next decade. NRAO facilities support crucial radio observations of MMA events by providing timely follow-up observations of transients and archival data supporting longer-term studies of those events. Astro2020 also identifies the next-generation Very Large Array (ngVLA) as an important component of the portfolio of future ground- and space-based facilities needed to achieve the ambitious scientific goals of the report. NRAO is continuing to lead development efforts for the potential ngVLA.

### **Status of the Facility**

#### Atacama Large Millimeter/submillimeter Array

ALMA is the world's preeminent facility for millimeter- and submillimeter-wave astronomy, enabling transformational research into the physics of the cold universe, regions that are optically dark but shine brightly in the millimeter/submillimeter portion of the electromagnetic spectrum. In late CY 2022, the Joint ALMA Operations center in Chile suffered a cyberattack that halted operations but did not result in any data loss. As of December 2022, operations have resumed with new policies, procedures, and reviews by international partners based on lessons learned. Additional security measures will be enacted pending further reviews.

#### Karl G. Jansky Very Large Array (VLA)

The VLA is one of the world's most sensitive and flexible instruments for centimeter-wavelength continuum and imaging spectroscopy. The VLA operates over a very large range of wavelengths (0.6 to 30 cm, plus narrow windows at 90 cm and 400 cm) using 27 separate 25-meter radio telescopes located in central New Mexico about 50 miles west of Socorro. The VLA is conducting an all-sky survey that will provide the astronomy community with archival data for many years to come and that will support multi-wavelength synoptic surveys using existing and future facilities, such as the Vera C. Rubin Observatory.

#### Very Long Baseline Array (VLBA)

The VLBA is the world's preeminent facility for high-precision astrometric studies and high-resolution imaging, comprising ten 25-meter diameter telescopes distributed across the U.S., from the U.S. Virgin Islands to Hawaii. The U.S. Naval Observatory (USNO) continues to rely on VLBA data for mission-critical measurements of Earth orientation, data necessary for accurate functioning of GPS and has recently provided funding to make the infrastructure more reliable.

#### Central Development Laboratory (CDL)

The CDL supports NRAO's existing facilities, and provides technology and expertise needed to build the next generation of radio astronomy instruments and facilities. Most recently the CDL has been supporting the development of powerful radar transmitters for the Green Bank Telescope, development of sensitive next-generation receivers for ALMA and potentially ngVLA, and an upgraded correlator for ALMA.

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<sup>1</sup> [www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020](http://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020)

## **Governance Structure and Partnerships**

### NSF Governance Structure

NSF oversight is led by a program officer in the MPS Division of Astronomical Sciences (AST), who works cooperatively with staff in the Office of Budget, Finance and Award Management (BFA), the Office of the General Counsel, and the Office of Legislative and Public Affairs. Within BFA, the Large Facilities Office provides advice and assists with agency oversight and assurance. The MPS facilities team and the Chief Officer for Research Facilities also provide high-level guidance, support, and oversight.

### External Governance Structure

NRAO is managed and operated through a cooperative agreement with Associated Universities Inc. (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 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. The AST Division Director and NRAO program officer participate in the international ALMA Board and attend governance and advisory committee meetings for NRAO and its managing organization, AUI. An international review committee advises the ALMA Board.

### Partnerships and Other Funding Sources

NRAO supplements NSF/AST support with funding provided by other NSF sources, other federal agencies, and non-federal 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. USNO provides approximately 50 percent of the funding for the VLBA.



View of the Very Large Array. Credit: NRAO/AUI/NSF.

ALMA is supported by an international partnership, comprising the United States and its partners Canada and Taiwan ("North America" or NA), the European Southern Observatory (ESO), and Japan and its partners Taiwan and South Korea (East Asia (EA)). NA and ESO are equal (37.5 percent) partners and EA contributes 25 percent. Canada contributes approximately 2.72 percent of operations (i.e., 7.25 percent of the 37.5 percent NA share). Taiwan contributed about 4 percent of NA construction costs but contributes operations funding through the EA partnership.

## Major Facilities

### Funding

Total Obligations for NRAO								
(Dollars in Millions)								
	FY 2022 Actual	FY 2023		ESTIMATES <sup>1</sup>				
		Estimate Base	FY 2024 Request	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029
<b>NRAO<sup>2</sup></b>	<b><u>\$52.09</u></b>	<b><u>\$43.03</u></b>	<b><u>\$43.59</u></b>	<b><u>\$44.37</u></b>	<b><u>\$45.59</u></b>	<b><u>\$45.59</u></b>	<b><u>\$45.59</u></b>	<b><u>\$45.59</u></b>
<i>Operations &amp; Maintenance</i>	40.53	40.53	40.53	44.37	45.59	45.59	45.59	45.59
<i>Special Projects<sup>3,4</sup></i>	11.56	2.50	3.06	-	-	-	-	-
<b>ALMA Operations</b>	<b><u>50.63</u></b>	<b><u>50.63</u></b>	<b><u>54.76</u></b>	<b><u>56.96</u></b>	<b><u>59.24</u></b>	<b><u>59.24</u></b>	<b><u>59.24</u></b>	<b><u>59.24</u></b>
<i>Operations &amp; Maintenance</i>	50.63	50.63	50.63	56.96	59.24	59.24	59.24	59.24
<i>Special Projects<sup>3,4</sup></i>	-	-	4.13	-	-	-	-	-
<b>TOTAL</b>	<b><u>\$102.72</u></b>	<b><u>\$93.66</u></b>	<b><u>\$98.35</u></b>	<b><u>\$101.33</u></b>	<b><u>\$104.83</u></b>	<b><u>\$104.83</u></b>	<b><u>\$104.83</u></b>	<b><u>\$104.83</u></b>

<sup>1</sup> Outyear estimates are for planning purposes only. The current cooperative agreement ends September 30, 2026.

<sup>2</sup> Operations funding for NSF's contribution to VLBA is included in the NRAO total at \$3.43 million per year.

<sup>3</sup> Special Projects reflects funding for repairs and maintenance beyond regular O&M, as well as extraordinary inflationary impacts on O&M. NRAO Special Projects also includes funding for the ngVLA program office.

<sup>4</sup> Funding in FY 2023 and FY 2024 does not include potential additional funding that may be provided by MPS' Office of Strategic Initiatives (formerly Office of Multidisciplinary Activities) for deferred maintenance projects.

The FY 2024 Request funds NRAO and the U.S. share of ALMA O&M costs, including ongoing support for education and public outreach programs as well as development programs, such as planning for ngVLA. In FY 2022, funding was provided to NRAO in support of the ngVLA program office (covering efforts across both FY 2022 and FY 2023). The FY 2024 request also includes additional funding under special projects for maintenance and upgrade costs, including structural repairs of buildings in New Mexico, replacement of cryogenic cold head spares, and vehicle renewals. Continued funding for the ngVLA program office is under review and, if funded, will be added as a supplement. Additional funding for deferred maintenance may be provided by MPS' Office of Strategic Initiatives.

### Reviews and Reports

NSF conducts annual reviews of the NRAO Program Operating Plan and strategic planning documents, ALMA operations, and the AUI Management Report. Recommendations from these annual reviews, by external panelists are routinely used to inform NRAO's operations planning and NSF's oversight of the facility. A comprehensive management review was conducted in December 2021 by an external panel of experts.

### Renewal/Recompetition/Disposition

Following a solicitation issued in FY 2014, the O&M of NRAO, including VLA, North American contributions to ALMA, and associated development laboratories, administration, and management functions, was competed and the National Science Board (NSB) authorized a 10-year award to AUI for the period October 1, 2016 – September 30, 2026. NSF will assess the options regarding renewal, competition, or disposition of the facilities operated by NRAO beyond FY 2026, in accordance with NSF policy.