

**NSF'S NATIONAL OPTICAL-INFRARED ASTRONOMY  
RESEARCH LABORATORY (NOIRLAB)**

**\$70,900,000  
+\$10,580,000 / 17.5%**

**NSF's National OIR Astronomy  
Research Laboratory Funding<sup>1</sup>**  
(Dollars in Millions)

FY 2021 Actual	FY 2022 (TBD)	FY 2023 Request	Change over FY 2021 Actual	
			Amount	Percent
\$60.32	-	\$70.90	\$10.58	17.5%

<sup>1</sup> Funding includes the base operations for Gemini and Rubin Observatory.

**Brief Description**

NOIRLab integrates into a single center Vera C. Rubin Observatory<sup>1</sup> operations (excluding the Rubin Observatory construction project), the International Gemini Observatory, and the programs and activities that were previously associated with NSF's National Optical Astronomy Observatory (NOAO). The components of the former NOAO—the Kitt Peak National Observatory (KPNO) and Cerro Tololo Inter-American Observatory (CTIO), now collectively known as the Mid-Scale Observatories (MSO), as well as the Community Science and Data Center (CSDC) in Tucson, Arizona—have been subsumed into NOIRLab as of October 1, 2019. NSF's NOIRLab is a strategic priority for the MPS Division of Astronomical Sciences (AST) to facilitate U.S. leadership in optical-infrared (OIR) astronomy, and in the process to optimize scientific synergies. NOIRLab promotes efficient operations among NSF-funded nighttime OIR assets and will provide a cornerstone for future NSF investment in the next generation of OIR facilities.

**Scientific Purpose**

As a Federally Funded Research and Development Center (FFRDC), NSF's NOIRLab has a crucial role in U.S. astronomy: its purpose is to coordinate and integrate the observational, technical, and data-management capabilities across all NOIRLab programs and to develop and sustain domestic and international partnerships with a view to advancing OIR astronomy for the entire U.S. community. NOIRLab's mission is to enable breakthrough discoveries in ground-based optical and infrared astronomy and astrophysics.

NOIRLab will be the foundational hub of U.S. ground based OIR astronomy in the era of Rubin Observatory, multi-messenger astrophysics (MMA), and data intensive science. NOIRLab will also contribute to NSF's implementation of recommendations from the recently released *Pathways to Discovery in Astronomy and Astrophysics for the 2020s* Decadal Survey (Astro2020)<sup>2</sup>. NOIRLab enables the U.S. research community to pursue a broad range of modern astrophysical challenges, from studying rapidly moving small bodies within the Solar System, to characterizing the most distant galaxies in the early universe and indirectly observing dark matter and dark energy. A brief overview of NOIRLab's scientific programs and component observatories is given below.

<sup>1</sup> Prior to the passage of the Vera C. Rubin Observatory Designation Act (P.L. 116-97), the project was known as the Large Synoptic Survey Telescope.

<sup>2</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)

Vera C. Rubin Observatory

Since 2014, NSF, in partnership with the Department of Energy (DOE), has been constructing Vera C. Rubin Observatory, an 8.4-meter wide-field optical survey telescope located near Gemini-South in Chile. With its 3.2-billion-pixel camera and 10-square degree field of view, Rubin Observatory will rapidly survey the southern sky with a cadence enabling repeat observation of each survey field approximately twice weekly and will produce a long-lived data set of unprecedented utility. Once complete, it will be the U.S. flagship ground-based OIR observatory, producing the deepest, widest-field image of the sky ever and issuing alerts for changing and transient objects within 60 seconds of their discovery. For more information on the construction project, see the MREFC section of this Research Infrastructure Theme within the NFS-Wide Investments chapter.

International Gemini Observatory

Over the last two decades, NSF has been a leading partner in operations of the two 8.1-meter Gemini telescopes, Gemini-North and Gemini-South, located on Maunakea in Hawai‘i at an altitude of 4,200 meters and on the 2,700-meter summit of Cerro Pachón in Chile, respectively. Technological advances incorporated into the design of the twin Gemini telescopes optimize their imaging capabilities and infrared performance as well as their ability to quickly switch instruments in response to changing atmospheric conditions. Gemini’s flexible observing modes and new instrumentation also make it ideal for reacting rapidly to opportunities that arise in the new era of MMA. NOIRLab is developing software and hardware aimed at enhancing Gemini’s ability to respond to transient and MMA phenomena discovered by NSF facilities such as Rubin Observatory, the Laser Interferometer Gravitational-Wave Observatory (LIGO), and the IceCube Neutrino Observatory.

Mid-Scale Observatories (MSO)

NOIRLab’s 4-meter class telescopes at KPNO in Arizona and CTIO in Chile (see table below) have been a critical resource for research in OIR astronomy for several decades. These telescopes have been revitalized in recent years through the development of new instruments and observing modes.

<b>Primary Telescopes Comprising the Mid-Scale Observatories Program</b>				
	<b>WIYN</b>	<b>Mayall</b>	<b>Blanco</b>	<b>SOAR</b>
<b>Location</b>	KPNO, Arizona	KPNO, Arizona	CTIO, Chile	CTIO, Chile
<b>Diameter</b>	3.5-m	4.0-m	4.0-m	4.1-m
<b>Commissioned</b>	1994	1970	1974	2005
<b>Primary Uses</b>	Exoplanet research with NEID <sup>3</sup> and general PI-led astronomy, in partnership with National Aeronautics and Space Administration (NASA)	Survey science with Dark Energy Spectroscopic Instrument (DESI) <sup>4</sup> , in partnership with DOE	General PI-led astronomy with an emphasis on survey projects with Dark Energy Camera (DECam).	General PI-led astronomy with an emphasis on time domain astronomy follow-up programs

<sup>3</sup> Refers to the NASA-NSF Exoplanet Observational Research (NN-EXPLORE) Exoplanet Investigations with Doppler spectroscopy (NEID) instrument, which was commissioned in mid-2021.

<sup>4</sup> The instrument was commissioned in May 2021 and the DESI five-year survey began shortly thereafter.

## Major Facilities

### Community Science & Data Center (CSDC)

On behalf of the U.S. astronomy community, the CSDC in Tucson develops strategies for archival data management and is building the capacity to serve as the national center for ground based OIR data archiving and utilization. CSDC has also taken a leading role in the brokering of time-domain alerts from Rubin Observatory through its Arizona-NOIRLab Temporal Analysis and Response to Events System and Astronomical Event Observatory Network (AEON) collaborations with the University of Arizona, the Gemini Observatory, the Las Cumbres Observatory,<sup>5</sup> and the Zwicky Transient Facility.<sup>6</sup>

### Education and Public Outreach

NOIRLab supports U.S. educational goals by promoting the public understanding of science and by providing education and training opportunities at all levels. The observatories introduce undergraduate students to scientific research by providing stimulating environments for basic astronomical research and related technologies through internship programs. NOIRLab maintains a diverse education program that includes teacher training programs based in Tucson, Arizona and La Serena, Chile, week-long school visit programs in Hawaii and Chile (Gemini's *Journey Through the Universe* program in Hawai'i has been running for almost two decades), visitor centers at Kitt Peak and Cerro Tololo, and a web-based information portal. With supplementary support from NSF, NOIRLab is also converting the recently retired McMath-Pierce Solar Telescope on Kitt Peak into a new, self-supporting astronomy visualization and presentation center with a focus on MMA. The center, to be known as the Windows on the Universe Center for Astronomy Outreach, will include a Science on a Sphere visualization system, along with interactive exhibits and an astronomy classroom.

### **Status of the Facility**

NOIRLab facilities have been significantly impacted by the COVID-19 pandemic. CTIO, KPNO, and Gemini-South suspended operations from March 16 through late October 2020, when a phased restart of operations became possible as infection rates fell. Gemini-North operations were suspended only until mid-May, after which science observations were able to resume, since COVID infection rates were relatively low in Hawai'i. Since that time, operations have continued unabated at all NOIRLab sites, albeit with reduced on-site support and delays to some non-essential maintenance work. Remote observing is possible at almost all NOIRLab facilities, and some instrument teams have been able to work at the sites. The observatories have been remarkably productive given travel restrictions and the limitations set by safe workforce practices. After some COVID-related delays, two major new instruments at Kitt Peak, NEID and DESI, were successfully commissioned in mid-2021 and both have begun their respective survey projects. The new Gemini facility instrument GHOST has, in the meantime, been safely delivered to the telescope in Chile and the instrument team expects to begin commissioning in mid-2022.

### **Meeting Intellectual Community Needs**

Developing closer ties among the U.S. OIR ground-based facilities has been a recommendation of numerous National Academies of Sciences, Engineering, and Medicine (National Academies) studies and other advisory reports, including the 2010 Decadal Survey of Astronomy and Astrophysics,<sup>7</sup> the

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<sup>5</sup> [www.lco.global/](http://www.lco.global/)

<sup>6</sup> [www.ztf.caltech.edu/](http://www.ztf.caltech.edu/)

<sup>7</sup> [www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics](http://www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics)

2012 AST Portfolio Review,<sup>8</sup> and the 2015 National Academies study on the OIR system.<sup>9</sup> Coordination among components of the U.S. OIR system has continued to be a theme in more recent community assessments. The creation of NSF's NOIRLab is responsive to this guidance.

In 2018, the Astronomy and Astrophysics Advisory Committee (AAAC), which advises NSF, NASA, and DOE on synergistic activities in astronomy, set up a subcommittee to consider the evolving roles of Gemini, the Blanco telescope, and the SOAR telescope in the era of Rubin Observatory and MMA. The AAAC subcommittee recognized the strategic importance of all three telescopes (Gemini, Blanco, and SOAR) in Rubin Observatory follow-up, time-domain astronomy, and MMA in the coming decade. This advice has driven NSF's and NOIRLab's activities at these telescopes; NSF funded the development of a new adaptive optics system for Gemini-North in FY 2018 and FY 2019 as part of the Gemini in the Era of Multi-Messenger Astronomy project, and both SOAR and Blanco are being incorporated into the AEON network for the purposes of time domain astronomy (TDA) and MMA follow-up.

Many of the activities and initiatives being led by NOIRLab support the recommendations in the Astro2020 released in November 2021. The report identifies "New Messengers and New Physics" as one of three scientific pillars for the upcoming decade, highlighting the importance of TDA and MMA observations. NOIRLab is already busy developing tools, services and instrumentation in support of TDA and MMA (ANTARES and AEON), and with NSF supplemental support is re-commissioning two instruments on Blanco and SOAR specifically for TDA and MMA follow-up. Astro2020 recommends U.S. involvement in future thirty-meter class Extremely Large Telescopes (ELTs) provided that various funding, site selection, management, governance, and public access conditions are met; development of a U.S. ELT Program Office at NOIRLab is already underway in support of potential NSF involvement in one or more ELT projects. The report also encourages maximizing science by developing databases and software tools for use with archival data from all ground-based OIR telescopes; NOIRLab's CSDC provides these services for existing NSF-funded facilities and is considering the possibilities of expanding services to other observatories.

NOIRLab's facilities, telescopes, and data systems are open to all qualified astronomers regardless of institutional affiliation. NOIRLab provides services to approximately 1200 scientists annually, 800 of whom are based in the United States. Doctoral dissertation students and non-thesis graduate students from U.S. institutions use the facilities for a broad range of research projects. NOIRLab currently employs approximately 500 people in Arizona, Hawaii, and Chile, including engineers, technicians, support scientists, administrative support staff, postdoctoral fellows, and interns. As NSF builds toward Rubin Observatory operating at full capacity starting in mid-2024, the need for new staff at NOIRLab to support operations is expected to steadily increase in the forthcoming years.

## **Governance Structure and Partnerships**

### NSF Governance Structure

In consultation with community representatives, four AST Program Officers, working as a team, carry out continuing oversight and assessment of NOIRLab and its component programs, Rubin Observatory operations, Gemini, MSO, and CSDC. The team makes use of regular detailed reporting: annual program operating plans; long-range plans; quarterly finance, technical, risk and milestone

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<sup>8</sup> [www.nsf.gov/mps/ast/ast\\_portfolio\\_review.jsp](http://www.nsf.gov/mps/ast/ast_portfolio_review.jsp)

<sup>9</sup> [www.nap.edu/catalog/21722/optimizing-the-us-ground-based-optical-and-infrared-astronomy-system](http://www.nap.edu/catalog/21722/optimizing-the-us-ground-based-optical-and-infrared-astronomy-system)

## Major Facilities

reports; and retrospective annual performance and management reports. A set of pre-defined Key Performance Indicators has been established to measure performance; these are defined in a Performance Evaluation and Measurement Plan which is reviewed and updated annually. To address issues as they arise, AST also leads an Integrated Program Team (IPT) for NOIRLab, which includes representatives from other NSF offices, including the Office of the General Counsel, BFA's Division of Acquisition and Cooperative Support, and BFA's Large Facilities Office. AST leadership, the MPS Facilities Team and the NSF Chief Officer for Research Facilities also provide high-level guidance, support, and oversight.

### External Governance Structure

NOIRLab is managed for NSF by the Association of Universities for Research in Astronomy, Inc. (AURA), which comprises 47 U.S. institutions and three international affiliates and is overseen by the AURA Board of Directors. All NOIRLab activities associated with Rubin Observatory operations, Gemini, MSO, and CSDC are currently managed by AURA through cooperative agreements with NSF. AURA and the NOIRLab Director receive management advice from AURA's NOIRLab Management Oversight Council, which meets three times a year and is composed of members of the broad scientific and management communities. MSO and Gemini also have Users' Committees, comprising community scientists, to advise the respective observatory directors on all aspects of the user experience at each corresponding facility.

- *Vera C. Rubin Observatory Governance Structure:* The operation of this new observatory includes a management board with members from the NSF managing organization and DOE lead laboratory, AURA and the SLAC National Accelerator Laboratory, respectively. The board approves new observing modes, capabilities, and on-line services as needed to ensure that the facility and its data products meet community expectations for Rubin Observatory's key 10-year survey initiative.
- *International Gemini Observatory Governance Structure:* Gemini Observatory is governed by the Gemini Board, the roles and responsibilities of which are codified in the International Gemini Agreement. This board meets at least twice a year and acts as the primary forum for interactions and decisions among the participants in the International Gemini Agreement; it ensures that Gemini is managed and operated in accordance with the Agreement, and it is the body with overall budgetary and policy control over the observatory. NSF serves as the Executive Agency for the partnership, carrying out the project on their behalf. An AST Program Officer holds a seat on the Gemini Board and acts as the chair of the Gemini Finance Committee.

### Partnerships and Other Funding Sources

NOIRLab and its component programs support several important national and international partnerships on behalf of NSF:

- Operations of the Gemini Observatory are supported by the Gemini international partnership, which includes NSF, the National Research Council (NRC) of Canada, the Agencia Nacional de Investigación y Desarrollo (ANID) of Chile, the Ministério da Ciência Tecnologia, Inovações e Comunicações (MCTIC) of Brazil, the Ministro de Ciencia, Tecnología e Innovación Productiva (MINCYT) of Argentina, and the Korea Astronomy and Space Science Institute (KASI) of South Korea. These six agencies are signatories to the International Gemini Agreement, which the partnership recently renewed for another six years (2022-2027).
- The SOAR telescope is supported by MCTIC of Brazil, NOIRLab, the University of North Carolina Chapel Hill, and Michigan State University; a new five-year SOAR agreement was signed in 2020.
- The WIYN telescope is supported by a consortium comprising the University of Wisconsin, Indiana University, and NOIRLab; the University of Missouri, Purdue University, University of California

Irvine, and Penn State University are operational partners. NSF’s continued participation is built around a partnership with NASA, which is providing NEID, a state-of-the-art instrument for extrasolar planet studies under the NN-EXPLORE program.

- Key agreements between NSF and DOE have supported not only the construction of Rubin Observatory, but also the recently completed Dark Energy Survey at the Blanco telescope and the construction and future operations of DESI on the Mayall telescope. DOE assumed full operations funding of the Mayall telescope in FY 2019.
- Many U.S. universities support their own astronomical facilities at the KPNO and CTIO sites with reimbursed services provided by NOIRLab. NOIRLab receives approximately \$12 million each year from partnerships (WIYN, Mayall and SOAR), for reimbursed services provided to tenant observatories at KPNO and CTIO, from the Kitt Peak Visitors Center, and from grants from other federal agencies.
- Construction and subsequent development of NOIRLab’s telescopes and their instrumentation has involved many industrial entities in several countries, with areas of specialization that included large and complex optical systems, engineering, electronics, electro-mechanical systems, and computing.

## Funding

NSF funding for NOIRLab includes support for Rubin Observatory pre-operations, Gemini Observatory operations and development, and MSO and CSDC operations along with associated special projects. Awards for NOIRLab component programs are organized under one overarching cooperative agreement with AURA.

**Total Obligations for NOIRLab**  
(Dollars in Millions)

	FY 2021 Actual	FY 2022 (TBD)	FY 2023 Request	ESTIMATES <sup>1</sup>				
				FY 2024	FY 2025	FY 2026	FY 2027	FY 2028
Vera C. Rubin Observatory Operations	\$6.09	-	\$20.30	\$33.80	\$36.09	\$36.34	\$35.71	35.71
Gemini Observatory O&M <sup>2</sup>	24.27	-	24.61	23.67	23.67	23.67	23.67	23.67
Mid-Scale Observatories & CSDC	29.95	-	25.99	21.13	21.13	21.13	21.13	21.13
<i>Operations &amp; Maintenance</i>	20.51	-	21.13	21.13	21.13	21.13	21.13	21.13
<i>Special Projects</i> <sup>3</sup>	9.44	-	4.86	-	-	-	-	-
<b>Total</b>	<b>\$60.31</b>	<b>-</b>	<b>\$70.90</b>	<b>\$78.60</b>	<b>\$80.89</b>	<b>\$81.14</b>	<b>\$80.51</b>	<b>80.51</b>

<sup>1</sup> Outyear funding estimates are for planning purposes only. A new NOIRLab-wide cooperative agreement is expected for the period FY 2023 through FY 2027.

<sup>2</sup> FY 2023 request contains \$1.63 million for additional research infrastructure and O&M, including costs for repairs and maintenance.

<sup>3</sup> Special projects funding contains support for the Windows on the Universe Center for Astronomy Outreach, ongoing activities at the WIYN telescope, and potential future participation in the U.S. Extremely Large Telescope program, as well as research infrastructure including additional costs for repairs and maintenance.

## Major Facilities



The colorful band of the Milky Way is poised above the 8.1-meter Gemini South telescope of NSF's NOIRLab in this arresting image, which depicts bright patches of stars threaded through with winding lanes of dust. The Galactic Center hangs directly above the telescope, framing one of the most powerful astronomical observatories in the southern hemisphere. *Credit: Gemini Observatory/NSF's National Optical-Infrared Astronomy Research Laboratory/AURA/Kwon O Chul.*

Rubin Observatory pre-operations funding began in FY 2018 to support the ramp-up of activities associated with observatory operations; information on plans for full operations of Rubin Observatory (in partnership with DOE) can be found in the Rubin Observatory MREFC construction narrative. The FY 2023 Request for Gemini Observatory covers NSF's partnership share of O&M costs as well as an additional contribution to Gemini's Instrument Development Fund (IDF; partners contribute on a best-efforts basis). The FY 2023 Request for MSO and CSDC supports all NOIRLab Directorate-level activities, O&M of KPNO and CTIO not otherwise funded by other national or international entities or partners, user support services, data archiving, and software development at CSDC. Special projects include continued operational support of the NN-EXPLORE exoplanet program at WIYN, the operations of the Windows on the Universe Center for Astronomy Outreach, and development of next-generation OIR telescope instrumentation and software as well as planning for a potential U.S. Extremely Large Telescope Program. Funding for special projects also includes additional deferred maintenance projects, upgrades necessary for the continued effective operations of the facility, such as replacement of observatory dome mechanisms, removal of possible asbestos-containing materials and updates to water systems. The execution of projects will be prioritized based on the outcome of ongoing facility condition .

## Reviews

NSF has, in the past, conducted annual reviews of program operating plans, progress reports, and strategic planning documents for NOIRLab's component observatories, and now continues to do so for the entire NOIRLab enterprise. Quarterly reports outlining progress against milestones and Key Performance Indicators are reviewed by NSF's NOIRLab IPT. Within the last three years, detailed communications, staffing, risk management and change management plans that describe the transition to NOIRLab have also been reviewed, either internally by the NOIRLab IPT, or by external panels of experts. In February 2021, NSF conducted its first NOIRLab-wide review of performance and program operating plans with support from an external panel of experts in program management, observatory operations, and astronomy. Audits and reviews of NOIRLab's annual budgets, indirect cost rates, overhead rates, and accounting systems are conducted annually by BFA.

## **Renewal/Recompetition/Termination**

The latest recompetition of the O&M awards for MSO/CSDC and Gemini separately concluded in 2015, resulting in awards through the ends of FY 2020 and CY 2022, respectively. A renewal of funding for MSO, CSDC, and the NOIRLab Directorate for a further two years (FY 2021-FY 2022), authorized by the NSB in July 2020, has allowed NSF to synchronize the award periods for all existing programmatic components of NOIRLab, which also includes Rubin Observatory pre-operations. In February 2022, NSF reviewed a five-year proposal for the renewal of all NOIRLab programs (MSO, CSDC, Gemini and Rubin Observatory operations) for the period FY 2023-FY 2027.<sup>10</sup> The next opportunity to begin a competition of NOIRLab as an integrated organization would then be around FY 2025. Currently there are no plans for divestment of any NOIRLab facilities, although evaluation of the future of current MSO facilities will necessarily be part of any future proposal.

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<sup>10</sup> The Gemini operations award would begin at the start of CY 2023, after the end of the current award.