

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

**\$54,440,000
-\$3,490,000 / 6.0%**

NSF's National OIR Astronomy Research Laboratory Funding¹
(Dollars in Millions)

FY 2020	FY 2021	FY 2022	Change over	
			FY 2021 Estimate	
Actual	Estimate	Request	Amount	Percent
\$57.86	\$57.93	\$54.44	-\$3.49	-6.0%

¹Funding includes the base operations for Gemini and Rubin

Brief Description

Launched at the start of FY 2020, NSF’s National Optical-Infrared Astronomy Research Laboratory integrates into a single center Vera C. Rubin Observatory¹ 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—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. It will promote 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-oriented 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 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.

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

¹ 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.

issuing alerts for changing and transient objects within 60 seconds of their discovery. For more information on the construction project, see the MREFC 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 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.

Primary Telescopes Comprising the Mid-Scale Observatories Program				
	WIYN	Mayall	Blanco	SOAR
Location	KPNO, Arizona	KPNO, Arizona	CTIO, Chile	CTIO, Chile
Diameter	3.5-m	4.0-m	4.0-m	4.1-m
Commissioned	1994	1970	1974	2005
Primary Uses	Exoplanet research with NEID ² and general PI-led astronomy, in partnership with National Aeronautics and Space Administration (NASA)	Survey science with Dark Energy Spectroscopic Instrument (DESI), ³ in partnership with DOE	General PI-led astronomy with an emphasis on PI-led survey projects with Dark Energy Camera (DECam), in partnership with DOE	General PI-led astronomy with an emphasis on time domain astronomy follow-up programs

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-NOAO Temporal Analysis and Response to Events System and Astronomical Event Observatory Network collaborations with the University of Arizona, the Gemini Observatory, the Las Cumbres Observatory⁴, and the Zwicky Transient Facility⁵.

Education and Public Outreach

NOIRLab supports U.S. educational goals by promoting the public understanding of science and by

² Refers to the NASA-NSF Exoplanet Observational Research (NN-EXPLORE) Exoplanet Investigations with Doppler spectroscopy (NEID) instrument, currently undergoing final testing and commissioning.

³ DESI is currently undergoing final testing and commissioning.

⁴ www.lco.global/

⁵ www.ztf.caltech.edu/

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 is now in its 16th year), 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 and a GeoDome Digital Planetarium, along with interactive exhibits and an astronomy classroom.

Status of the Facility

In 2020 and 2021, NOIRLab facilities have been 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 Hawaii. Throughout the shutdown periods, telescopes and instruments were placed in a safe state, and only a skeleton crew remained on site and at the base facilities in La Serena, Chile; Hilo, Hawai'i; and Tucson, Arizona. Commissioning and characterization of NEID and DESI were halted at KPNO, though work has since resumed with support from local staff. Both instruments are expected to begin their respective five-year survey programs in mid-2021. The Kitt Peak Visitor Center was closed in March 2020 and is likely to remain so through at least mid-2021. No known major technical issues resulted from the shutdown at any of the NOIRLab sites. Most operations staff were able to work effectively from home.

Meeting Intellectual Community Needs

Developing closer ties between 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,⁶ the 2012 AST Portfolio Review,⁷ and the 2015 National Academies study on the OIR system.⁸ 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 sub-committee 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 AEON was used to commission queue based observing at SOAR in FY 2019.

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

⁶ www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics

⁷ www.nsf.gov/mps/ast/ast_portfolio_review.jsp

⁸ www.nap.edu/catalog/21722/optimizing-the-us-ground-based-optical-and-infrared-astronomy-system

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 430 people in Arizona, Hawaii, and Chile, including engineers, technicians, support scientists, administrative support staff, postdoctoral fellows, and interns. As NSF builds towards Rubin Observatory operating at full capacity, the need for new staff at NOIRLab to support operations is expected to steadily increase in the forthcoming years as the need for staff on the Rubin Observatory construction project decreases.

Governance Structure and Partnerships

NSF Governance Structure

In consultation with community representatives, three 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 reports; and retrospective annual performance and management reports. A set of pre-defined Key Performance Indicators have been established to measure performance; these are defined in a Performance Evaluation and Measurement Plan. 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 General Counsel, the Division of Acquisition and Cooperative Support, Office of Budget, Finance, and Award Management, and the Large Facilities Office. The 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 agreement 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, comprised of 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 GFC.

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

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(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 is working toward renewing before the end of 2021, when the current agreement expires.

- The SOAR telescope is supported by MCTIC of Brazil, NOIRLab, the University of North Carolina Chapel Hill, and Michigan State University; a new 5-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 typically receives approximately \$11 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 2020	FY 2021	FY 2022	ESTIMATES ¹				
	Actual	Estimate	Request	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027
Vera C. Rubin Observatory Operations	\$0.01	\$5.00	\$5.20	\$19.98	\$33.80	\$36.09	\$36.34	\$35.71
Gemini Observatory O&M	22.31	22.98	22.98	23.67	23.67	23.67	23.67	23.67
Mid-Scale Observatories & CSDC	33.54	29.95	26.26	22.55	21.13	21.13	21.13	21.13
<i>Operations & Maintenance</i>	19.91	20.51	21.13	21.13	21.13	21.13	21.13	21.13
<i>Special Projects</i> ²	13.63	9.44	5.13	1.42	-	-	-	-
NOIRLab Transition ³	2.00	-	-	-	-	-	-	-
Total	\$57.86	\$57.93	\$54.44	\$66.20	\$78.60	\$80.89	\$81.14	\$80.51

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

² Special projects funding supports the Windows on the Universe Center for Astronomy Outreach, ongoing activities at the WIYN telescope, as well as potential future participation in the U.S. Extremely Large Telescope program.

³ Transition activities associated with the creation of NOIRLab were funded in FY 2019 and FY 2020.



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 narrative. The FY 2022 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 2022 Request for MSO and CSDC supports all NOIRLab Directorate-level activities, including 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 development of the Windows on the Universe Center for Astronomy Outreach, and development of next-generation OIR telescope technologies as well as planning for a potential U.S. Extremely Large Telescope Program.

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 progress 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.

Renewal/Recompetition/Termination

The latest recompetition of the O&M awards for both MSO/CSDC and Gemini concluded in 2015, resulting in awards concluding at 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 the existing programmatic components of NOIRLab, which also includes Rubin Observatory pre-operations. In 2022, NSF expects to review linked five-year proposals for the renewal of all NOIRLab programs (MSO, CSDC, Gemini and

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Rubin Observatory operations) for the period FY 2023-FY 2027.⁹ The next opportunity to begin a competition of NOIRLab as an integrated organization would then be mid-decade. 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.

⁹ The Gemini operations award would begin at the start of CY 2023, after the end of the current award.