

**NSF'S NATIONAL OPTICAL-INFRARED ASTRONOMY  
RESEARCH LABORATORY**

**\$48,120,000**  
**-\$15,690,000 / -24.6%**

**NSF's National OIR Astronomy Research Laboratory Funding<sup>1</sup>**

(Dollars in Millions)

FY 2019 Actual <sup>2</sup>	FY 2020 (TBD)	FY 2021 Request	Change over FY 2019 Actual	
			Amount	Percent
\$63.81	-	\$48.12	-\$15.69	-24.6%

<sup>1</sup> Established in early FY 2020, this lab encompasses operations of the mid-scale observatories and Community Science & Data Center, which formerly comprised NOAO, together with operations of the Gemini Observatory and the Vera C. Rubin Observatory.

<sup>2</sup> Includes \$12.99 million in additional funding for Gemini special projects and \$5.73 million for continuity of funding into FY 2020.

At the start of FY 2020, NSF launched NSF's National Optical-Infrared Astronomy Research Laboratory (henceforth "the Lab"), a Federally Funded Research and Development Center (FFRDC) that will be the foundational hub of U.S. ground-based, optical-infrared (OIR) astronomy in the era of the Vera C. Rubin Observatory, multi-messenger astrophysics (MMA), data intensive science, and Extremely Large Telescopes (ELTs). The Lab integrates into a single center the programs and activities that have previously been associated with the National Optical Astronomy Observatory (NOAO), the Gemini Observatory, and the Vera C. Rubin Observatory operations (the Lab does not encompass the Rubin Observatory construction project).<sup>1</sup>

The Lab 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. The Lab is a strategic priority for the MPS Division of Astronomical Sciences (AST) to facilitate U.S. leadership in OIR astronomy. The Lab will optimize scientific synergies, promote efficient operations among NSF-funded night-time OIR assets, and provide a cornerstone for future NSF investment in the next generation of OIR facilities. The Lab's telescopes will also be used to further NSF's Big Idea, "Windows on the Universe: The Era of Multi-Messenger Astrophysics," through their participation in MMA research, providing a more complete understanding of the nature of matter and energy and helping answer some of the most fundamental questions in contemporary science.

The Lab's facilities, telescopes, and data systems are open to all qualified astronomers regardless of institutional affiliation. It 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. The Lab currently employs 430 people in Arizona, Hawai'i, and Chile, including engineers, technicians, support scientists, administrative support staff, postdoctoral fellows and interns. As NSF builds towards the Vera C. Rubin Observatory operating at full capacity, the need for new staff at the Lab to support operations is expected to steadily increase in the forthcoming years.

Lab telescopes continue to make ground-breaking discoveries in all areas of astronomy. Observations from Gemini have been used to determine the location of a repeating Fast Radio Burst (FRB) in a nearby galaxy, making it the closest known example to Earth and only the second repeating FRB to have its location

<sup>1</sup> See the MREFC chapter for information on the Vera C. Rubin Observatory construction project.

pinpointed. FRBs are sudden rapid explosions of energy from space that typically last only a few milliseconds and can only be found with radio telescopes. Optical telescopes like Gemini can subsequently be used to identify and characterize the host galaxy, hopefully shedding some light on the possible source of these remarkable objects.

Using Gemini and the Lab's Mayall Telescope at Kitt Peak, astronomers have uncovered two historic events in which the Andromeda Galaxy underwent major changes to its structure. The motions of 77 clusters of stars around the bright disk of the galaxy have been measured and associated with two distinct populations, a young group associated with stellar streams, and an older, more randomly distributed group. The two populations both orbit the Andromeda Galaxy, but their orbital axes are nearly perpendicular to each other. These data shed light not only on the formation and evolution of the Andromeda Galaxy, but on our own Milky Way Galaxy as well.

## **Overview of NSF's National OIR Astronomy Research Laboratory Programs and Activities**

### Gemini Observatory

Over the last two decades, NSF has been a leading partner in operations of the two 8.1-meter Gemini telescopes, 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. 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 swap 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. The Lab is developing software and hardware aimed at enhancing Gemini's ability to respond to transient and MMA phenomena discovered by NSF facilities such as the Vera C. Rubin Observatory, the Laser Interferometer Gravitational-Wave Observatory (LIGO), and the IceCube Neutrino Observatory. NSF also 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 (GEMMA) project.

### Vera C. Rubin Observatory

Since 2014, NSF, in partnership with the Department of Energy (DOE), has been constructing the Vera C. Rubin Observatory (formerly known as the Large Synoptic Survey Telescope), 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, the Vera C. 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 sky image ever and issuing alerts for changing and transient objects within 60 seconds of their discovery. Commencement of the initial 10-year survey is planned for FY 2023. NSF funding of activities associated with operations planning and preparation began in FY 2019. For more information on the construction project, see the MREFC chapter.

### Mid-Scale Observatories (MSO)

The Lab's 4-meter class telescopes at Kitt Peak National Observatory (KPNO) in Arizona and Cerro Tololo Inter-American Observatory (CTIO) in Chile (see table below), formerly operated by NOAO, have been a critical resource for research in OIR astronomy for several decades. KPNO and CTIO, now collectively known as the Mid-Scale Observatories, have been revitalized in recent years through the development of new instruments and observing modes. The Dark Energy Camera (DECam) on the Blanco telescope recently completed the very productive Dark Energy Survey and is now being used for other frontier scientific surveys. The NASA-NSF Exoplanet Observational Research (NN-EXPLORE) program's Doppler spectroscopy instrument (NEID) and the Dark Energy Spectroscopic Instrument (DESI), at the WIYN and Mayall telescopes respectively, will be commissioned in FY 2020, providing powerful new capabilities in exoplanet research and cosmology. The SOUTHERN Astronomical Research (SOAR) telescope,

while continuing to serve its diverse, international community, is developing its role as an important mid-sized facility for follow-up of transients identified by the Vera C. Rubin Observatory as well as time-domain astronomy in general over the coming decade.

<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	Cerro Tololo, Chile	Cerro Pachón, 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 and general PI-led astronomy	Dark Energy spectroscopic survey science with DESI	General PI-led astronomy with an emphasis on PI-led survey projects with DECam	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 lead role in the brokering of time-domain alerts from the Vera C. Rubin Observatory through its Arizona-NOAO Temporal Analysis and Response to Events System (ANTARES) and Astronomical Event Observatory Network (AEON) collaborations with the University of Arizona, the Gemini Observatory, the Las Cumbres Observatory, and the Zwicky Transient Facility. In FY 2019, AEON was used to commission queue-based observing at SOAR.

Lab Partnerships

The Lab and its components support several important national and international partnerships on behalf of NSF.

- The Gemini Observatory is managed on behalf of the Gemini international partnership which includes NSF, the National Research Council (NRC) of Canada, the Comisión Nacional de Investigación Científica y Tecnológica (CONICYT) of Chile, the Ministério da Ciência, Tecnologia, Inovações e Comunicações (MCTIC) of Brazil, the Ministerio de Ciencia, Tecnología e Innovación Productiva (MCTIP) of Argentina, and the Korea Astronomy and Space Science Institute (KASI) of South Korea. These six agencies are signatories to the Gemini International 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, NSF’s National OIR Astronomy Research Laboratory, the University of North Carolina Chapel Hill, and Michigan State University; a new SOAR agreement will be signed in late FY 2020.
- The WIYN telescope is owned and operated by a consortium comprising the University of Wisconsin, Indiana University, NSF’s National OIR Astronomy Research Laboratory, the University of Missouri, and Purdue University. NSF’s continued participation is built around a partnership with the National Aeronautics and Space Administration (NASA), which has funded a state-of-the-art instrument for extrasolar planet studies under the NN-EXPLORE program mentioned above.
- Key agreements between NSF and DOE have supported not only the construction of the Vera C. 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. 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 the Lab. The Lab typically receives approximately \$11 million each

## Major Multi-User Research Facilities

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 the Lab’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.

### Education and Public Outreach

The Lab 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. The Lab maintains a diverse education program that includes teacher training programs based in Tucson, Arizona and La Serena, Chile, week-long school visit programs in Hawai’i and Chile (Gemini’s *Journey Through the Universe* program in Hawai’i is now in its 16<sup>th</sup> year), visitor centers at Kitt Peak and Cerro Tololo, and a web-based information portal. With supplementary support from NSF, the Lab 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 (WoUCAO), will include a Science On a Sphere (SOS) visualization system and a GeoDome Digital Planetarium, along with interactive exhibits and an astronomy classroom.

#### Total Obligations for NSF’s National OIR Astronomy Research Laboratory

(Dollars in Millions)

	FY 2019	FY 2020	FY 2021	ESTIMATES <sup>1</sup>				
	Actual	(TBD)	Request	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026
Mid-Scale Observatories & CSDC	\$26.66	-	\$22.23	\$22.10	\$21.93	\$20.51	\$20.51	\$20.51
<i>Operations &amp; Maintenance</i> <sup>2</sup>	25.48	-	20.51	20.51	20.51	20.51	20.51	20.51
<i>Special Projects</i> <sup>3</sup>	1.18	-	1.72	1.59	1.42	-	-	-
Gemini Observatory	34.65	-	20.89	23.67	23.67	23.67	23.67	23.67
<i>Operations &amp; Maintenance</i>	21.66	-	20.89	23.67	23.67	23.67	23.67	23.67
<i>Facility Upgrades</i> <sup>4</sup>	12.99	-	-	-	-	-	-	-
Vera C. Rubin Observatory	-	-	5.00	14.32	26.85	29.64	30.93	28.62
<i>Operations</i> <sup>5</sup>	-	-	-	-	-	-	-	-
<i>Lab Transition</i> <sup>6</sup>	2.50	-	-	-	-	-	-	-
<b>Total</b>	<b>\$63.81</b>	<b>-</b>	<b>\$48.12</b>	<b>\$60.09</b>	<b>\$72.45</b>	<b>\$73.82</b>	<b>\$75.11</b>	<b>\$72.80</b>

<sup>1</sup> Outyear funding estimates are for planning purposes only.

<sup>2</sup> Reflects O&M funding for the Mid-Scale Observatories (including KPNO and CTIO) and the CSDC in Tucson, which formerly comprised the National Optical Astronomy Observatory through the end of FY 2019. Included in the FY 2019 total is \$5.73 million for continuity of funding into FY 2020 and approximately \$412,000 in supplemental funding for U.S. Extremely Large Telescope

<sup>3</sup> Includes funding for the WIYN telescope and the Windows on the Universe Center for Astronomy Outreach (WoUCAO); both cooperative agreements end in FY 2023. NSF support for the Mayall concluded in FY 2018 and operations are now fully funded by DOE. Excludes \$3.32 million of FY 2019 and FY 2020 design and development costs for WoUCAO obligated in FY 2018.

<sup>4</sup> Reflects \$12.99 million in additional funding to enhance Gemini’s adaptive optics system, software capabilities, and public information and outreach activities in the era of multi-messenger astronomy.

<sup>5</sup> A new cooperative agreement for O&M of the Vera C. Rubin Observatory for FY 2022 to FY 2026 is anticipated in FY 2021; outyear funding represents preliminary estimates. Excluded is \$11.10 million in FY 2019 - FY 2021 pre-operations ramp up costs obligated in FY 2018. The funding amounts shown represent NSF support only and amount to about 50 percent of the total operations cost. Other Support from DOE and non-federal contributors provides the balance.

<sup>6</sup> NSF transition activities associated with the creation of the Lab are funded in FY 2019 and FY 2020.

For information on continuity of operations funding, see the opening narrative of this chapter.

## **Management and Oversight**

### MSO and CSDC O&M

MSO and CSDC base funding supports all Lab directorate-level activities and the administrative offices in Tucson and La Serena, together with operations and maintenance of the astronomical facilities and infrastructure at KPNO and CTIO, user support services, data archiving, and software development activities at CSDC.

### Special Projects

In FY 2021 special projects include \$1.14 million for continuing operational support of the NN-EXPLORE program on the WIYN 3.5-m Telescope on Kitt Peak, and \$580,000 toward the development of the WoUCAO.

### Gemini Operations, O&M

NSF is currently a partner in the Gemini Observatory. The FY 2021 Request provides funding for facility operations and maintenance costs that will maintain this partner share (the other international participants intend to contribute a further \$10.08 million in FY 2021 for operations).

### Vera C. Rubin Observatory Operations

NSF made an initial award of \$11.10 million in FY 2018 to cover expected pre-operations costs through FY 2021. Due to changes in the Observatory's operations model,<sup>2</sup> additional pre-operations funding of \$5.0 million is now anticipated for FY 2021 to support the ramp-up of activities associated with observatory operations.

The Lab is managed for NSF by the Association of Universities for Research in Astronomy, Inc. (AURA), which is comprised of 47 U.S. institutions and three international affiliates.

- **NSF Structure:** In consultation with community representatives, three AST Program Officers, working as a team, carry out continuing oversight and assessment of the Lab and its component programs, MSO, CSDC, Gemini, and Vera C. Rubin Observatory operations, by making use of detailed annual program plans, long-range plans, quarterly finance and technical reports, and retrospective annual 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 the Lab, which includes representatives from AST as well as other NSF offices, including the Office of General Counsel, the Division of Acquisition and Cooperative Support, and the Large Facilities Office. The MPS facilities team and the NSF Chief Officer for Research Facilities also provide high-level guidance, support, and oversight.
- **Gemini Governance Structure:** The Gemini Observatory is governed by the Gemini Board, the roles and responsibilities of which are codified in the Gemini International Agreement. This board meets at least twice a year and acts as the primary forum for interactions and decisions among the participants in the Gemini Agreement; it ensures that Gemini is managed and operated in accordance with the Agreement and is the body with overall budgetary and policy control over the observatory. The Gemini Board has two standing subcommittees, the Gemini Finance Committee (GFC) and the Gemini Science and Technology Advisory Committee (STAC), which provide support and input to the Board. 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.
- **Vera C. Rubin Observatory Governance Structure:** The operation of this new observatory includes a management board with members from the NSF and DOE managing organizations, 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

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<sup>2</sup> See the MREFC chapter for more information on Vera C. Rubin Observatory operations planning.

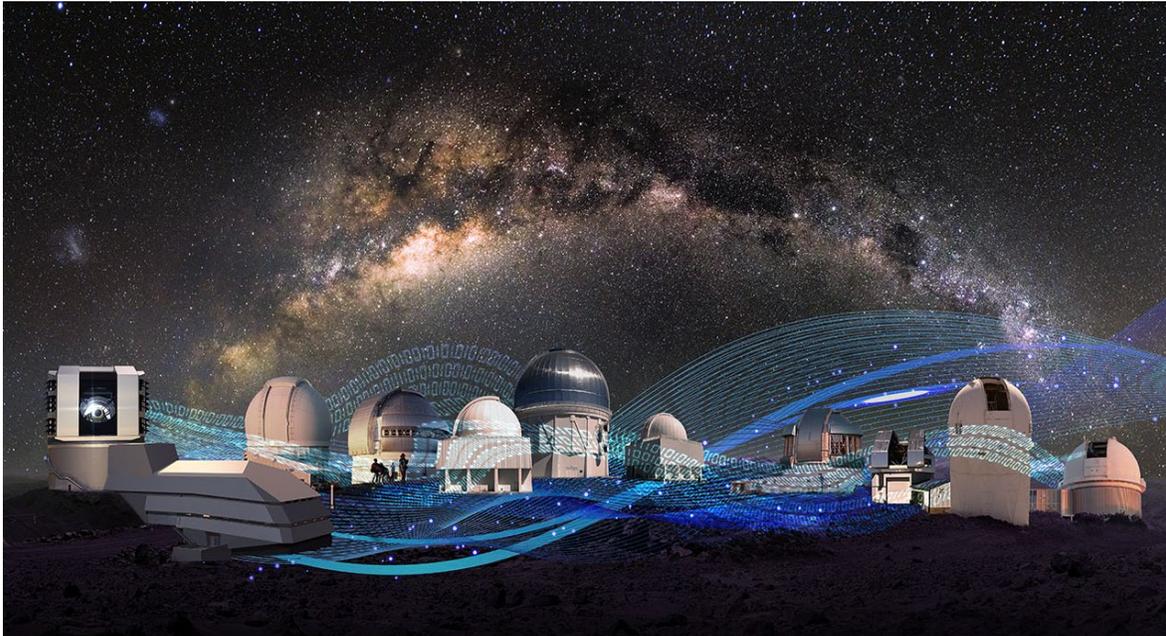
## Major Multi-User Research Facilities

community expectations for the Vera C. Rubin Observatory's key 10-year survey initiative.

- **Managing Organization and External Oversight:** All Lab activities associated with MSO, CSDC, Gemini, and Vera C. Rubin Observatory operations are currently managed by AURA through cooperative agreement with NSF. AURA receives management advice from a Lab-wide oversight council which meets three times a year and is composed of members of its scientific and management communities. MSO and Gemini also use Users' Committees, comprised of community scientists, to advise the observatory directors on all aspects of the user experience at each corresponding facility.
- **Reviews:** NSF has in the past conducted annual reviews of program operating plans, progress reports, and strategic planning documents, and will continue to do so for the entire Lab enterprise in the future. Within the last 24 months, detailed communications, staffing, risk management and change management plans that describe the transition to the Lab have been reviewed either internally by the Lab IPT, or by external panels of experts.

## Renewal/Recompetition/Termination

NSF is planning for a recompetition/renewal decision for the Lab in FY 2023. This requires the synchronization of the agreements that fund all Lab activities (Gemini, MSO, CSDC and Vera C. Rubin Observatory operations), expected to be accomplished over the period FY 2021-FY 2023.



A montage showing the telescope facilities that have become part of NSF's National Optical-Infrared Astronomy Research Laboratory. From left: the Vera C. Rubin Observatory (artist's impression), SOAR, Gemini-South, CTIO 1.5-m, Blanco, CTIO 0.9-m, Gemini-North, WIYN, Mayall, and the KPNO 2.1-m. Credit: NSF's National Optical-Infrared Astronomy Research Laboratory/AURA/NSF/P. Marenfeld.