

NATIONAL SOLAR OBSERVATORY (NSO)

\$27,740,000
+\$3,550,000 / 14.7%

National Solar Observatory Funding¹ (Dollars in Millions)

FY 2021 Actual	FY 2022 TBD	FY 2023 Request	Change over FY 2021 Actual	
			Amount	Percent
\$24.19	-	\$27.74	\$3.55	14.7%

¹ Includes operations for NSO and DKIST.

Brief Description

As a Federally Funded Research and Development Center, NSO is NSF's central institution for support of ground-based solar astronomy in the United States. Headquartered on the campus of the University of Colorado, Boulder, NSO provides leadership to the global solar astronomy community through operations of NSF's Daniel K. Inouye Solar Telescope (DKIST). DKIST is the largest and most advanced solar telescope on the planet, poised to answer fundamental questions in solar physics by providing transformative improvements over current ground-based facilities.

NSO also operates the NSO Integrated Synoptic Program (NISP), which consists of the Global Oscillations Network Group (GONG) facility and the Synoptic Long-term Investigations of the Sun (SOLIS) telescope. GONG is a coordinated worldwide network of six telescopes specifically designed to study solar oscillations and, more recently, to provide critical data products for the prediction of space weather. NSO routinely provides detailed synoptic solar data from NISP for use by individual researchers and other government agencies through the NSO Digital Library.

Scientific Purpose

The mission of NSO is to advance our knowledge of the Sun, both as an astronomical object and as the dominant external influence on the Earth, by providing forefront observational capabilities to the scientific research community. NSO operates a diverse fleet of ground-based optical and infrared solar telescopes and auxiliary instrumentation, allowing solar physicists to probe all aspects of the Sun, from the deep solar interior to the photosphere and chromosphere, and out to the outer corona and its interface with the interplanetary medium.

NSF's flagship solar telescope, DKIST, enables the study of magnetic phenomena in the solar photosphere, chromosphere, and corona. Determining the role of magnetic fields in the outer regions of the Sun is crucial to understanding the solar dynamo, solar variability, and solar activity, including flares and coronal mass ejections and their impact on planets. Solar activity can affect life on Earth through phenomena generally described as space weather and may impact the terrestrial climate.

Other NSO assets also provide data to space weather researchers in their efforts to understand solar eruptions and their effect upon the Earth, and to apply that knowledge to the protection of satellites, astronauts, land-based power systems, and Earth's climate. GONG operations are a critical element of operational space weather prediction and provide data enabling refinement of forecasting models for solar activity.

Status of the Facility

Although delayed due to impacts of the COVID-19 pandemic, construction of DKIST at the summit of Haleakalā on Maui, Hawai'i, was completed in November 2021. The DKIST operations commissioning phase (OCP) began in December of the same year. Science observations from the first peer-reviewed proposal cycle will be made through the first half of CY 2022, including the possibility of one or more coordinated observing campaigns with other observatories. The second call for observing proposals is expected in the latter half of CY 2022. Throughout 2022, there will also be considerable time for the development, testing and verification of instrument configurations and combinations on the telescope. The anticipated start of steady-state observations is FY 2023. The DKIST Data Center is in Boulder, Colorado at the NSO headquarters where the observational data will be curated and made publicly available after an initial proprietary period.

NSO has been in the process of transitioning away from its two primary user facilities at Kitt Peak, Arizona and Sacramento Peak, New Mexico, which began operations in 1962 and 1969, respectively. Although these two sites were once the best ground-based facilities available to the U.S. solar research community on a peer-reviewed proposal basis, there are currently better ground-based facilities both inside and outside the United States. As part of the transition, NSO is currently providing site infrastructure support at the Sunspot Solar Observatory (formerly Sacramento Peak Observatory) to New Mexico State University (NMSU), which is responsible for the science operations of the Dunn Solar Telescope, while also performing site cleanup activities. As of January 2019, NSO has vacated its site at the Kitt Peak National Observatory (KPNO), and the remaining building there (the McMath-Pierce Solar Telescope) is currently being converted into an astronomy outreach center to be operated by NSF's National Optical-Infrared Astronomy Research Laboratory (NOIRLab). NISP's SOLIS telescope was removed from KPNO and is being relocated to Big Bear, California, which is an existing site for solar astronomy and the location of one of NSO's GONG stations. Construction of a new SOLIS telescope enclosure began on June 28, 2021. The relocation was delayed due to COVID-19 but is now expected to be complete early in 2022.

Due to COVID-19, on March 17, 2020, all work-related travel for NSO staff ceased, and the observatory initiated 100 percent telework at all NSO sites to comply with stay-at-home orders issued by the governors of Colorado, New Mexico, and Hawaii. In late October 2020, NSO headquarters in Boulder, Colorado began operating under Phase 1 of their operations restart plan. Phase 1 includes telework for non-essential employees. Only essential workers are allowed on site with safety measures in place. In early July 2021, NSO headquarters began operating in Phase 2 of their operations restart plan. Phase 2 includes most staff on telework with some non-essential, high-priority activities allowed on site. On-site activities must be scheduled, and the number of people allowed on-site is limited.

DKIST construction was completed in a modified Phase 1. The Operations Commissioning Phase has begun with observatory staff following established COVID safety guidelines and protocols. The GONG facility is operational. GONG sites are operated remotely and were minimally impacted by COVID-19 shutdowns. Sunspot Solar Observatory is operational under a similar Phase 1 status.

Meeting Intellectual Community Needs

NSO data, including NISP data, are made available to the user community via the Virtual Solar Observatory. DKIST data will be made available via the DKIST Data Center located at NSO's Boulder

headquarters. The relevance of DKIST's science drivers was reaffirmed by the National Academy of Sciences, Engineering, and Medicine's 2010 Astronomy and Astrophysics Decadal Survey: *New Worlds, New Horizons in Astronomy and Astrophysics*¹ as well as the 2012 Solar and Space Physics Decadal Survey: *A Science for a Technological Society*.² Both reports identified the completion of DKIST as a priority for the solar research community. More recently, the National Academies released the report from its 2020 Decadal Survey for Astronomy and Astrophysics entitled: *Pathways to Discovery in Astronomy and Astrophysics for the 2020s*.³ In the report, the committee noted the importance of both global observations of our Sun, such as those provided by NSO's GONG facility, as well as detailed observations such as those enabled by DKIST, which, it stated, "will revolutionize observations of the Sun's atmosphere."

Governance Structure and Partnerships

NSF Governance Structure

NSF oversight of NSO and DKIST is handled by program officers in the MPS Division of Astronomical Sciences (AST). The program officers work cooperatively with staff from MPS, the Office of the General Counsel, and the Office of Legislative and Public Affairs. Within BFA, the Large Facilities Office provides advice to program staff and assists with agency oversight and assurance. Representatives from some of the above NSF offices comprise the NSO Integrated Program Team, which meets on a semi-annual basis to discuss outstanding program issues. The MPS Facilities team and the NSF Chief Officer for Research Facilities also provide high-level guidance, support, and oversight.

External Governance Structure

NSO is managed by the Association of Universities for Research in Astronomy Inc. (AURA), which comprises 47 U.S. member institutions and three international affiliate members. The NSO director reports to the president of AURA, who is the principal investigator on the current cooperative agreement with NSF. AURA receives management advice from its Solar Observatory Council, composed of members of its scientific and management communities. NSO relies upon a User's Committee for the purposes of self-evaluation and prioritization. The Users Committee, composed of scientists with considerable experience with the observatory, reviews for the NSO director all aspects of NSO that affect user experiences. NSF program officers for NSO have frequent (at least weekly) discussions and interactions with NSO management, especially the NSO Director. In addition to NSF reviews of the project, the program officers attend the semi-annual meetings of the Solar Observatory Council and the periodic Users Committee meetings as *ex officio* observers. The program officers conduct periodic site visits to NSO facilities and attend community science meetings to keep abreast of the latest happenings in the solar community.

Partnerships and Other Funding Sources

NSO partners include the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), industrial entities, and universities and institutes that collaborate with NSO on solar instrumentation development. NOAA contributes approximately \$1 million per year to GONG operations under an interagency agreement with NSF. NMSU operates the Dunn Solar Telescope at Sunspot Solar Observatory through a consortium of universities, while

¹ www.nap.edu/catalog/12951/new-worlds-new-horizons-in-astronomy-and-astrophysics

² www.nap.edu/catalog/13060/solar-and-space-physics-a-science-for-a-technological-society

³ www.nap.edu/catalog/26141/pathways-to-discovery-in-astronomy-and-astrophysics-for-the-2020s

Major Facilities

NSO continues to maintain the site infrastructure. NSO has partnered with Big Bear Solar Observatory to operate the SOLIS facility once it is installed in Big Bear, California.

Funding

NSF identified a total planning budget of roughly \$202 million for NSO O&M over the 10-year term of the current NSO cooperative agreement, June 1, 2015 – September 30, 2024. This includes DKIST operations but does not include the cost of DKIST construction. This also does not include the costs associated with the transition of former NSO facilities on Sacramento Peak and Kitt Peak. The budget projections for FY 2022 and beyond have been slightly increased from prior projections based upon NSO’s comprehensive midterm review (see Reviews section), which identified additional budget needs over the remainder of the current award period.

Total Obligations for NSO

(Dollars in Millions)

	FY 2021	FY 2022	FY 2023	ESTIMATES ¹				
	Actual	(TBD)	Request	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028
NSO	\$4.65	-	\$7.06	\$6.24	\$6.24	\$6.24	\$6.24	\$6.24
<i>Operations and Maintenance</i>	4.65	-	5.88	6.24	6.24	6.24	6.24	6.24
<i>Special Projects</i> ²	-	-	1.18	-	-	-	-	-
DKIST Operations ³	\$19.54	-	\$20.68	21.30	21.30	21.30	21.30	21.30
<i>Operations and Maintenance</i>	19.54	-	19.58	21.30	21.30	21.30	21.30	21.30
<i>Special Projects</i> ⁴	-	-	1.10	-	-	-	-	-
Total	\$24.19	-	\$27.74	\$27.54	\$27.54	\$27.54	\$27.54	\$27.54

¹ Outyear funding estimates are for planning purposes only. The current cooperative agreement ends September 2024.

² Includes research infrastructure funding for transition activities at Sacramento Peak Observatory.

³ FY 2021 Actual includes \$2.0 million to another awardee for cultural mitigation activities as agreed to during the compliance

⁴ Reflects additional funding for research infrastructure to optimize community access.

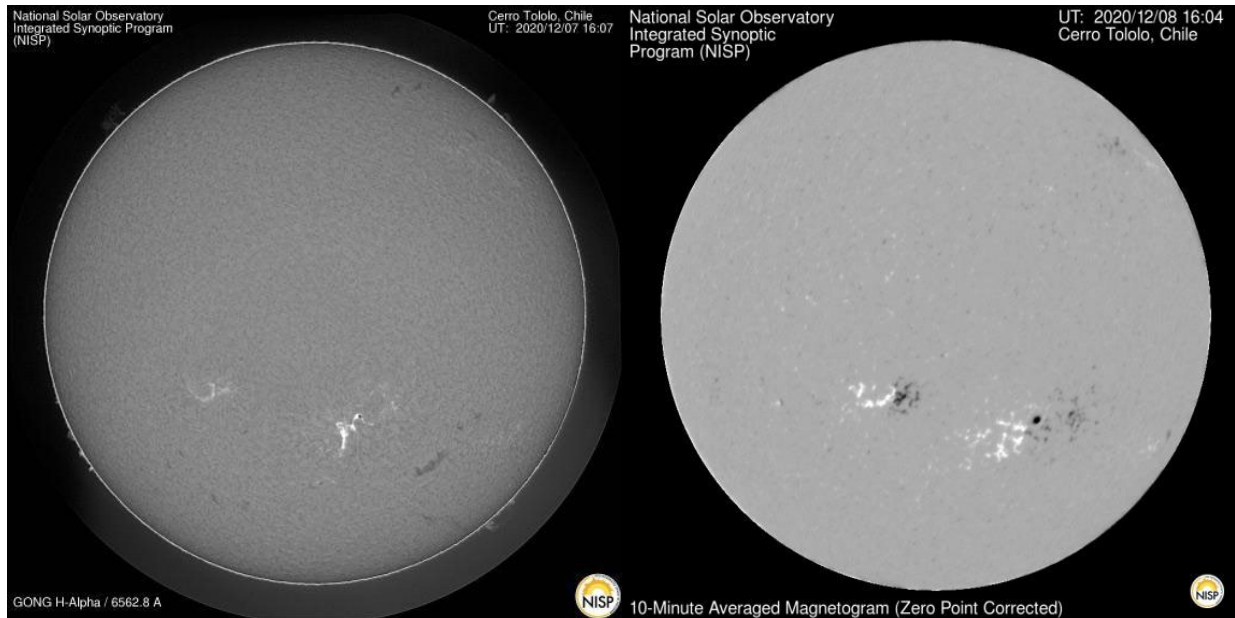
The total NSF obligations for NSO include additional funding for work performed under the operations award, including a supplement for about \$300,000 per year since FY 2018 to maintain the infrastructure at Sacramento Peak in collaboration with NMSU. Combined with additional funding from the state of New Mexico, these supplemental funds have ensured that the Dunn Solar Telescope and associated instrumentation remain available for continued research.

Reviews

- NSF conducts regular reviews of NSO’s Annual Progress Report and Program Plan (APRPP). A review of the current (FY 2020-FY 2021) APRPP was held virtually on April 8, 2021.
- In July 2019, a comprehensive midterm review of NSO’s midterm progress report and long-range plan for the second five years of the cooperative agreement was conducted. The results of this external review were presented to the NSB in February 2020.
- DKIST passed its final construction review in July 2021. The external panel was charged by NSF to examine project management and performance; cultural and environmental compliance; safety and security; and final project acceptance. The panel’s report highlighted the excellent work done by the construction team in completing construction under the challenging conditions imposed by COVID-19.

Renewal/Recompetition/Termination

The National Science Board approved the renewal of the NSO/DKIST cooperative agreement in August 2014. The renewed award for management and operations of NSO began June 1, 2015 and will run through September 30, 2024. NSF plans to conduct a comprehensive assessment of NSO operations in mid-2022 to review the options regarding renewal, competition, or divestment of the facility beyond FY 2024, in accordance with NSF policy. The NSF-NSO-NMSU partnership has resulted in partial operation of the Dunn Solar Telescope and the Visitor Center at NSO's Sacramento Peak Observatory in Sunspot, New Mexico as part of the divestment of operations costs of that facility. The effectiveness of this partnership, as well as potential costs of site restoration, will be evaluated in the assessment planned for 2022.



Sample images produced by the GONG facility. Sample H α image (left) and 10-minute average longitudinal magnetogram (right) from Cerro Tololo GONG station on 8 December 2020. Images show a two-ribbon flare (X-ray class C7.4) in the new solar cycle (Cycle 25) active region AR 12790. *Credit: NSF/AURA/NSO/NISP.*