

DANIEL K. INOUE SOLAR TELESCOPE (DKIST)

\$16,130,000

The FY 2019 Budget Request for NSF’s Daniel K. Inouye Solar Telescope is \$16.13 million. This represents the final year in an 11-year funding profile within a National Science Board approved not-to-exceed total project cost of \$344.13 million. Completion of construction atop Haleakalā on Maui, Hawai‘i is planned for no later than June 2020.

When completed, DKIST will be the world's most powerful solar observatory, poised to answer fundamental questions in solar physics by providing transformative improvements over current ground-based facilities. DKIST will enable 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. Solar activity can affect civil life on Earth through phenomena generally described as space weather, and may impact the terrestrial climate. The relevance of DKIST’s science drivers was reaffirmed by the National Academy of Sciences 2010 Astronomy and Astrophysics Decadal Survey: *New Worlds, New Horizons*¹ as well as the 2012 Solar and Space Physics Decadal Survey: *A Science for a Technological Society*.² DKIST will play an important role in enhancing the “fundamental understanding of space weather and its drivers,” an objective called out in the National Space Weather Strategy and associated *National Space Weather Action Plan*³ both of which were released by the National Science and Technology Council on October 29, 2015.

Appropriated and Requested MREFC Funds for the Daniel K. Inouye Solar Telescope

(Dollars in Millions)

	Prior Years	FY 2014 Actual	FY 2015 Actual	FY 2016 Actual	FY 2017 Actual	FY 2018 Request	FY 2019 Request	Total Project Cost
MREFC Approp.	\$60.00	\$36.88	\$25.12	\$20.00	\$20.00	\$20.00	\$16.13	\$198.13
ARRA MREFC Appropriation	146.00	-	-	-	-	-	-	146.00
Total	\$206.00	\$36.88	\$25.12	\$20.00	\$20.00	\$20.00	\$16.13	\$344.13

Baseline History

Beginning in 2001, NSF provided funds to the National Solar Observatory (NSO) for an eight-year design and development program for DKIST and its initial complement of instruments through the Division of Astronomical Sciences (AST) in the Directorate for Mathematical and Physical Sciences (MPS) and through the Division of Atmospheric and Geospace Sciences (AGS) in the Directorate for Geosciences (GEO). The current design, cost, schedule, and risk were scrutinized in an NSF-conducted Preliminary Design Review in October-November 2006.

The original total project cost to NSF, \$297.93 million, was set after a Final Design Review (FDR) in May 2009, which determined that the project was fully prepared to begin construction. The National Science Board (NSB) approved an award for this amount at the NSF Director’s discretion, contingent upon completion of compliance with relevant environmental and cultural/historic statutes. In FY 2009, \$153.0 million was appropriated to initiate construction. Funding was provided through a combination of the MREFC account (\$7.0 million) and the American Recovery and Reinvestment Act (ARRA) account (\$146.0 million). Given the timing of the receipt of budget authority and the complexity of project

¹ www.nap.edu/catalog.php?record_id=12951

² www.nap.edu/search/?term=13060&x=0&y=0

³ www.hSDL.org/?view&did=789864

contracting, the entire \$153.0 million was carried over from FY 2009 and obligated in FY 2010. The environmental compliance requirements were completed on November 20, 2009, and the NSF Director signed the Record of Decision authorizing construction on December 3, 2009. The Hawai‘i Board on Land and Natural Resources (BLNR) approved the project’s application for a Conservation District Use Permit (CDUP) on December 1, 2010. The Hawai‘i BLNR approved a Habitat Conservation Plan, designed to protect and rehabilitate habitats of the endangered Hawai‘ian petrel and Hawai‘ian goose that could potentially be affected by the construction of DKIST. The U.S. Fish and Wildlife Service completed a formal consultation regarding the endangered Hawai‘ian petrel in 2011. A contested case challenge to the 2010 CDUP issuance delayed site construction until the BLNR ruled in favor of the DKIST project and issued a new CDUP November 2012. Full access to the site atop Haleakalā followed shortly thereafter. Site preparation and excavation began November 30, 2012.



The DKIST telescope enclosure and Support and Operations building at the site on Haleakala, Maui, HI. Credit: Dave Boboltz, NSF.

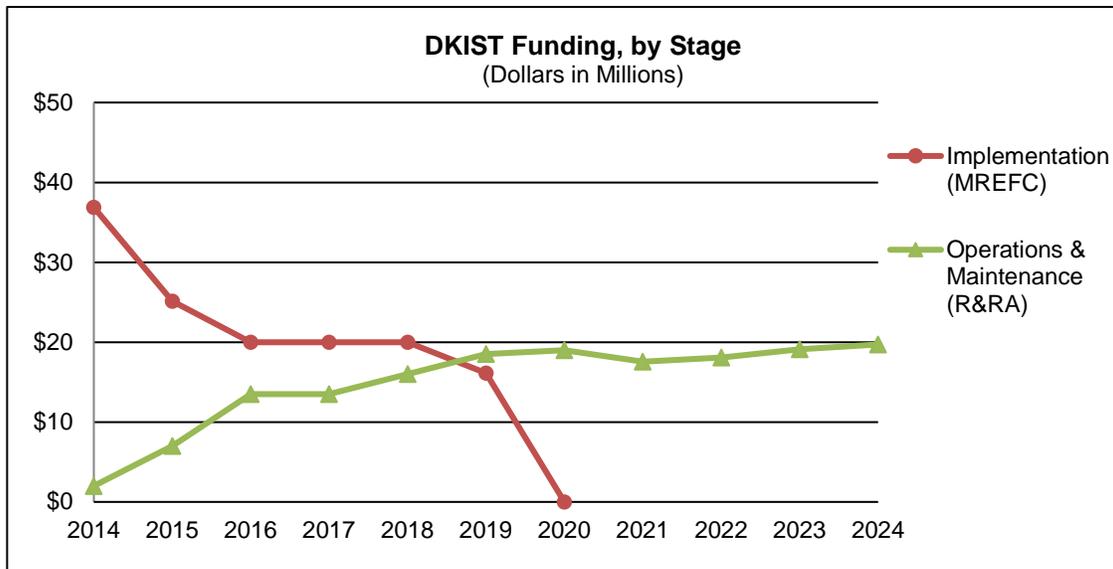
The unexpected length of the delay associated with the environmental compliance process led to a reassessment of the project schedule and total project cost in 2012. An external panel of experts reviewed the revised baseline and increased the total project cost by approximately \$46.20 million. The NSB also subsequently considered and approved a revised total project cost of \$344.13 million at their August 2013 meeting.

Total Funding Requirements for DKIST
(Dollars in Millions)

	Prior Years ¹	FY 2017 Actual	FY 2018 Request	FY 2019 Request	ESTIMATES				
					FY 2020	FY 2021	FY 2022	FY 2023	FY 2024
<i>R&RA:</i>									
Concept & Development	\$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance ²	13.50	13.50	16.00	18.50	19.01	17.54	18.08	19.13	19.71
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA	\$37.01	\$13.50	\$16.00	\$18.50	\$19.01	\$17.54	\$18.08	\$19.13	\$19.71
<i>MREFC:</i>									
Implementation	142.00	20.00	20.00	16.13	-	-	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC	\$288.00	\$20.00	\$20.00	\$16.13	-	-	-	-	-
TOTAL REQUIREMENTS	\$325.01	\$33.50	\$36.00	\$34.63	\$19.01	\$17.54	\$18.08	\$19.13	\$19.71

¹ Concept & Development funding and Implementation funding are cumulative of all prior years; Operations & Maintenance funding reflects prior year actual obligations only.

² Of the total Operations & Maintenance funding, \$2.0 million per year for FY 2011 through FY 2020 is for cultural mitigation activities as agreed to during the compliance process.



The DKIST project is a collaboration of scientists and engineers at more than 20 U.S. and international organizations. Other partners include the Air Force Office of Scientific Research and international groups in Germany, the United Kingdom, and Italy. Some partnership activities include:

- The U.S. Air Force replaced the aluminizing chamber at their Advanced Electro-Optical System telescope on Maui and sized it to accommodate the DKIST primary mirror. An Interagency Agreement for use of the Mirror Coating Facility (MCF) was signed by NSF and the U.S. Air Force in FY 2017. This eliminates the need to build a dedicated aluminizing chamber for DKIST.
- Kiepenheuer-Institut für Sonnenphysik (KIS; Freiburg, Germany) is constructing a narrow-band first-light instrument named the Visible Tunable Filter (VTF) as an in-kind contribution.
- Queens University Belfast (Northern Ireland) is leading a consortium of institutions from the United Kingdom that will supply high-speed visible cameras to feed the DKIST instruments.

Discussions of other possible contributions for second-generation instruments, algorithm development, coordinated observations, and student exchange are ongoing.

Management and Oversight

- **NSF Structure:** NSF oversight is handled by a program officer in AST working cooperatively with staff from MPS, 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 (LFO) provides advice to program staff and assists with agency oversight and assurance. Representatives from the above NSF offices comprise the DKIST Integrated Project Team (IPT), which meets on a quarterly basis to discuss outstanding project issues.
- **External Structure:** NSO conducts the construction project. NSF funds NSO operations and maintenance (O&M) and DKIST design and construction via separate Cooperative Support Agreements (CSAs) beneath an overarching Cooperative Agreement (CA) with the managing organization, the Association of Universities for Research in Astronomy, Inc. (AURA). The DKIST CSA for construction runs through the end of FY 2019, and will be extended to cover the FY 2020 completion date. In 2015, the NSO CA and O&M CSA were renewed through the end of FY 2024. This period covers the DKIST construction phase and the achievement of sustainable operations of the completed facility. The DKIST director is a senior NSO scientist who was a leader in the development of the science case and an expert in the field of solar adaptive optics, a critical technology for DKIST. The project manager has experience in large telescope development, having served as lead telescope

engineer for the Gemini Telescopes project. Several councils and working groups give input from the solar and space physics communities.

Reviews

- Management, Cost, and Schedule reviews: DKIST scope, schedule, budget estimate, and risk-adjusted total project cost were scrutinized and validated at the Preliminary Design and Final Design Reviews.
- Earned Value Management (EVM) System Review: LFO and AST conducted a review of the DKIST project's EVM system, September 20-22, 2016. The external reviewers verified the project's EVM system and conducted interviews with project management and individual cost account managers to validate the input estimates/data into the system. The evaluation team found that the EVM System has been effectively implemented and is being used to provide reliable project management information. The NSF formally accepted the project's EVM System in a notification dated February 22, 2017.
- Software Quality Assurance (SQA) Assessment: LFO engaged a contractor to perform an assessment of the DKIST project's processes and procedures for producing the software systems to be delivered at DKIST first light. The SQA assessment consisted of a document desk review followed by videoconference conducted July 10, 2017. The final report was received by NSF on October 3, 2017. The Executive Summary from the report states: "The results of the SQA assessment found that the processes and procedures employed by the project are reasonable to produce quality software." The report findings and recommendations have been relayed to AURA, NSO and the DKIST Project.
- Independent Risk Assessment (IRA): LFO engaged a contractor to perform an independent assessment of the project's remaining risks as DKIST enters the critical integration, testing and commissioning (IT&C) stage of construction. The IRA consisted of a document desk review followed by an in-person meeting on September 21, 2017. The final report was received by NSF on December 11, 2017. The final report transmittal memo from the contractor states: "We are pleased to report that the DKIST project has a mature risk management program that is well-positioned entering the Integration, Testing, and Commissioning (IT&C) phase. We found no critical areas that require corrective action."
- Programmatic Review: A comprehensive programmatic review of the DKIST MREFC construction project took place September 19-21, 2017 in Boulder, CO. This external programmatic review focused on the IT&C phase of construction. The final report was received by NSF on October 27, 2017. The Executive Summary from the report states: "The Panel found that the project is performing exceptionally well", and that "the Project is on track to complete the project within the project deadline and budget, and that the Project's science goals are attainable."

Project Status

The DKIST project continues to make progress on construction at the summit of Haleakalā on Maui, HI, while remaining in compliance with all local, state, and federal environmental and cultural requirements. The project continues to consult with various stakeholders on a regular basis including the Hawai'i Department of Land and Natural Resources, the Hawai'i Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, the Federal Aviation Administration, the National Park Service, and Native Hawai'ian cultural practitioners.

Construction highlights:

- The project continues to work on interior fit and finish items for the enclosure (dome) and the support and operations building.
- Work continues on the critical facility thermal systems.
- In FY 2017 the primary mirror (M1) and the M1 cell assembly were transported to Maui from Arizona and Belgium, respectively. The M1 and the M1 cell assembly were successfully transported to the summit of Haleakalā. In FY 2018 the M1 will be coated at the MCF and installed in the telescope support structure.
- The Coudé rotator platform assembly inside the enclosure is completed. Site acceptance testing was

Major Research Equipment and Facilities Construction

completed and the project is resolving punch-list items.

- Assembly of the Telescope Mount will be completed in FY 2018.
- Fabrication of the DKIST first-light instruments is continuing through FY 2018.

In FY 2019 the installation of the telescope structure and mechanical controls will be completed. By the end of FY 2019 the integration, testing, and commissioning of the M1 and the facility class instruments will be well underway.

Cost and Schedule

The original baseline not-to-exceed, risk-adjusted cost was established following FDR. As noted above, a revised project baseline review was held in October 2012; NSB approved the new baseline in August 2013. Total project cost of \$344.13 million is derived from ARRA (\$146.0 million) and annual appropriations in the MREFC account (\$198.13 million). A Monte Carlo analysis of the risk-adjusted project end date at the time of the project re-baseline indicated June 10, 2020 at an 80 percent Confidence Level for successful completion. The project is currently on track for a FY 2020 end date.

Risks

Project management control, interface control, and change controls are in place. The project also maintains a risk register that is reviewed and updated on a monthly basis.

Technical: The majority of the remaining technical risk is very low as a result of the long design and development phase, with the exception of one first-light instrument: the VTF mentioned above. The cooperative support agreement between NSF and AURA identifies four facility-class instruments (not including the VTF) to be delivered by the DKIST project at the end of the MREFC construction phase. The project is on track to deliver those four instruments. The VTF is a fifth instrument and is an in-kind contribution from the German Kiepenheuer-Institut für Sonnenphysik (KIS) being designed and developed through a Memorandum of Understanding (MOU) between AURA and KIS; therefore, the fabrication risks for this instrument remain with the German institute. KIS is currently on track to deliver a single-etalon version of the instrument to DKIST. The DKIST project and AURA continue to work with KIS to ensure that the instrument is delivered on schedule and on budget.



The Telescope Mount as of July 2017, showing two recently-completed Nasmyth platforms left and right of the main structure. Credit: P. Jeffers NSO/DKIST.

Environmental and Cultural Compliance: AST, NSF's Office of the General Counsel, and the DKIST project have carefully worked through the applicable statutes, and a cultural monitor has been retained during construction. All required permits are in place and semi-annual consultations with a Native Hawai'ian working group continue. The two outstanding legal appeals with the potential to impact project construction were resolved in favor of the DKIST project. On October 6, 2016, the Hawai'i Supreme Court ruled against the appellant in the two cases and upheld both the DKIST project's conservation district use permit (CDUP) and the University of Hawai'i Haleakalā Observatory Management Plan. These decisions substantially reduced the risks to DKIST construction due to permitting issues.

Environmental Health and Safety: NSO has a well-developed safety program engendered in the DKIST project. The DKIST project has developed a site safety plan and conducted a thorough construction readiness review in 2011 and conducts annual safety reviews.

Operations Costs

DKIST operations are funded through R&RA. In FY 2019, the budget request of \$18.50 million includes \$16.50 million for DKIST operations and \$2.0 million for cultural mitigation activities as agreed to during the compliance process.