

DANIEL K. INOUE SOLAR TELESCOPE (DKIST)**\$0**

No funding is requested in FY 2020 for construction of NSF’s Daniel K. Inouye Solar Telescope. FY 2019 represented the final year in an 11-year funding profile within an NSB 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. This narrative provides an update on the project’s status.

Appropriated and Requested MREFC Funds for the Daniel K. Inouye Solar Telescope
(Dollars in Millions)

	Prior Years	FY 2015 Actual	FY 2016 Actual	FY 2017 Actual	FY 2018 Actual	FY 2019 Estimate	FY 2020 Request ¹	Total Project Cost
MREFC Approp.	\$96.88	\$25.12	\$20.00	\$20.00	\$20.00	\$16.13	-	\$198.13
ARRA MREFC Appropriation	146.00	-	-	-	-	-	-	146.00
Total	\$242.88	\$25.12	\$20.00	\$20.00	\$20.00	\$16.13	-	\$344.13

¹ FY 2019 was the final year for MREFC funding for DKIST construction. The Project is currently on track to complete construction in 2020 within the Total Project Cost cap.

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 Academies of Sciences, Engineering, and Medicine 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: *Solar and Space Physics: 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 in October 2015. An update to the National Space Weather Strategy and Action Plan has been developed through the Space Weather Operations, Research, and Mitigation Working Group of the National Science and Technology Council and was informed by community input received through the Federal Register (83 FR 17526). This update, currently undergoing committee review within the Office of Science and Technology Policy, reaffirms a fundamental research objective that includes “Understanding the underlying physical processes of the Sun that drive space weather events...”

Baseline History

Beginning in 2001, NSF provided funds to the National Solar Observatory (NSO) for an eight-year development and design program for DKIST and its initial complement of instruments through the Division of Astronomical Sciences (AST) in MPS and through the Division of Atmospheric and Geospace Sciences in 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

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.hSDL.org/?view&did=789864

Major Research Equipment and Facilities Construction

2009, which determined that the project was fully prepared to begin construction. 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 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 in December 2009. The Hawai‘i Board on Land and Natural Resources (BLNR) approved the project’s application for a Conservation District Use Permit (CDUP) in December 2010. 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 in November 2012.



The DKIST telescope enclosure and Support and Operations building at the site on Haleakalā, Maui, HI. Credit: David 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 recommended increasing the total project cost by approximately \$46.20 million. The NSB subsequently considered and approved a revised total project cost of \$344.13 million at its August 2013 meeting.

Total Funding Requirements for DKIST

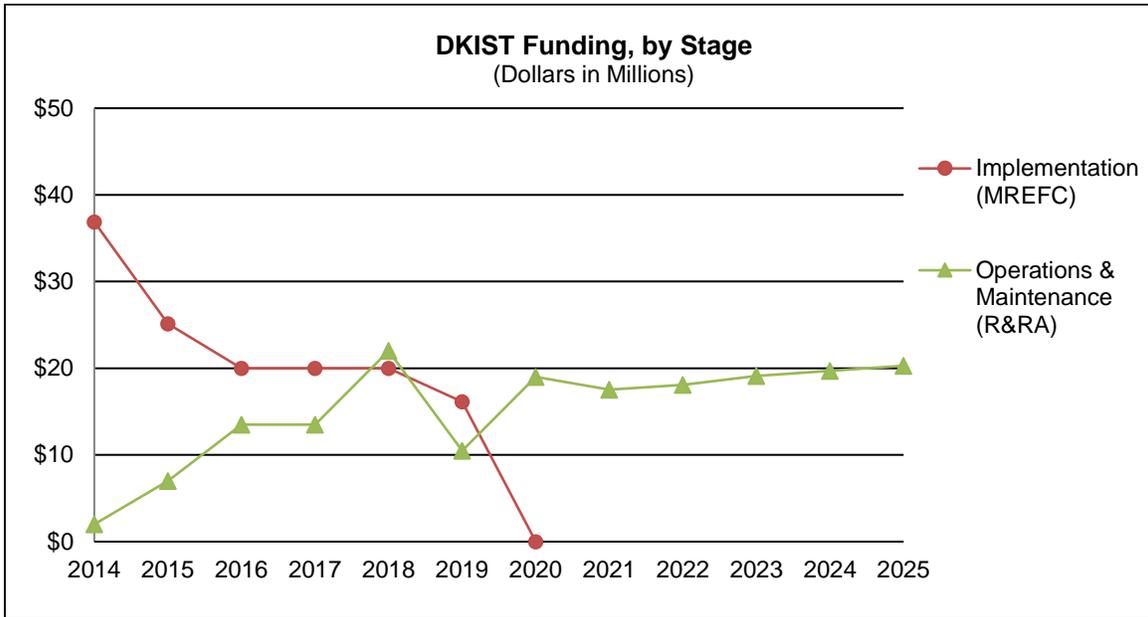
(Dollars in Millions)

	Prior Years	FY 2018 Actual ¹	FY 2019 Estimate	FY 2020 Request	ESTIMATES				
					FY 2021	FY 2022	FY 2023	FY 2024	FY 2025
<i>R&RA:</i>									
Development & Design	\$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance ²		24.00	10.50	19.01	17.54	18.08	19.13	19.71	20.30
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA	\$23.51	\$24.00	\$10.50	\$19.01	\$17.54	\$18.08	\$19.13	\$19.71	\$20.30
<i>MREFC:</i>									
Implementation ³	162.00	20.00	16.13	-	-	-	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC	\$308.00	\$20.00	\$16.13	-	-	-	-	-	-
TOTAL REQUIREMENTS	\$331.51	\$44.00	\$26.63	\$19.01	\$17.54	\$18.08	\$19.13	\$19.71	\$20.30

¹ FY 2018 obligations included \$8.0 million to fund part of the FY 2019 costs.

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.

³ Includes \$3.46 million carried forward into FY 2019.



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 (USAF) 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 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 (OGC), 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, 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 expires June 30, 2020. 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.
- Independent Risk Assessment (IRA): LFO engaged a contractor to perform an independent assessment of the project's remaining risks as DKIST entered 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 in September 2017. The final report was received by NSF in December 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."
- Government Accountability Office (GAO) Study: Based on congressional interest (Senate Report 114-289), the GAO assessed "NSF Major Projects", which included the DKIST construction project. The GAO final report was issued in June 2018. The GAO characterized the DKIST Project as one of two NSF projects that have experienced both cost and schedule increases. As described above, the cost and schedule increases were due to 30 months of unavoidable permitting delays, which resulted in the 2013 re-baseline of the project.
- Programmatic Review: A comprehensive external programmatic review of the DKIST MREFC construction project is scheduled for April 2019 in Boulder, CO. In addition to an assessment of the project's status against the Project Execution Plan, the review will focus on project close-out and criteria for acceptance.
- Earned Value Management (EVM) System Surveillance: In conjunction with the programmatic review described above, a one-day surveillance of the project's EVM system will be conducted in April 2019. This surveillance will provide an updated assessment of the project's previously validated EVM system.

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:

- A Level 1 milestone was achieved in FY 2018 with the completion of the Telescope Mount Assembly (TMA).
- In FY 2018 the primary (M1) mirror and the M1 Cell Assembly were successfully transported to Maui. The M1 commissioning blank and the M1 were both successfully coated at the USAF MCF. The M1 Cell Assembly successfully underwent site acceptance testing. The M1 commissioning blank was installed in the TMA to test the full range of motion under the mirror load. The M1 was installed in the Cell Assembly and the entire package installed on the TMA for initial alignment.
- In early FY 2019, DKIST achieved its first images of star light and completed its first pointing model using a temporary Nighttime Acquisition Telescope mounted at the telescope prime focus.
- In FY 2019, the project will continue to implement the critical IT&C phase of construction.
- Fabrication of the first of the DKIST instruments, the visible broadband imager (VBI), will be completed and the VBI delivered in FY 2019.

- In FY 2019 the project is expected to achieve another Level 1 milestone, i.e., first-light on the sun with the VBI instrument.

In FY 2020 the project will continue to work through the final stages of IT&C and the integration of all first-light instruments. By Q4 of FY 2020, it is expected that DKIST will have achieved its final Level 1 milestone—Start of Operations.

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 2020 at an 80 percent confidence level for successful completion. The project is currently on track for a FY 2020 end date.⁴

Risks

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



A view looking upward through the telescope enclosure entrance aperture during the first evening of on-sky tracking and pointing tests of DKIST. Credit: Shawn Granen, DKIST/NSO.

Technical: Most of the remaining technical risks are relatively low because of the long development and design phase. The CSA between NSF and AURA identifies four facility-class instruments 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 KIS being designed and developed through a Memorandum of Understanding between AURA and KIS; therefore, the risks for this instrument remain with the German institute. KIS is currently on track to deliver the VTF instrument to DKIST prior to the start of operations.

Environmental and Cultural Compliance: AST, NSF's OGC, 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. Following the November 2012 issuance of the CDUP as mentioned in the Baseline History section above, several challenges to both the CDUP and the University of Hawai`i's Haleakalā Observatory (HO) management plan made their way through the State court system. In October 2016, the Hawai`i Supreme Court ruled against the appellant in both cases, upholding both the project's CDUP and the HO management plan. Remaining environmental and cultural compliance risks are low since the project continues to be in compliance with all requirements as defined in the Biological Opinion (BO),⁵ the Habitat Conservation Plan (HCP),⁶ and the Programmatic Agreement.

⁴ At the time of writing in February 2019, commercial power to Haleakala has been off-line for several weeks, possibly to extend up to two months, due to severe storm damage in Maui, Hawai`i. This could cause a minor delay in project completion.

⁵ At the time of this writing, February 2019, compliance obligations contained within the U.S. Fish and Wildlife Service's (USFWS') BO have been met and closed out via a letter to NSF from the USFWS.

⁶ At the time of this writing, February 2019, NSF is scheduled to appear before the Endangered Species Recovery Committee in March 2019 seeking a recommendation to close out compliance obligations as listed in the State of Hawai`i Division of Forestry and Wildlife HCP.

Major Research Equipment and Facilities Construction

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 conducts annual external safety reviews. In addition, safety updates are provided to NSF by the project on a monthly basis and DKIST project safety is one of the topics covered in the annual external program reviews.

Operations Costs

DKIST operations are funded through R&RA. In FY 2020, the projected budget of \$19.01 million includes \$17.01 million for DKIST operations and \$2.0 million for cultural mitigation activities as agreed to during the compliance process. This will be the final year of the 10-year award for cultural mitigation activities.