

DANIEL K. INOUE SOLAR TELESCOPE

\$20,000,000

The FY 2018 Budget Request for NSF’s Daniel K. Inouye Solar Telescope (DKIST) is \$20.0 million. This represents the 10th year in an 11-year funding profile, with an estimated total project cost of \$344.13 million. Completion of construction atop Haleakala on Maui, Hawaii 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 have impact on 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, 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 Estimate	FY 2018 Request	FY 2019 Estimate	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, DKIST	\$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 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 contracting, the entire \$153.0 million was carried over from FY 2009 and obligated in FY 2010.

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

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

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 Hawaii Board on Land and Natural Resources (BLNR) approved the project’s application for a Conservation District Use Permit (CDUP) on December 1, 2010. The Hawaii BLNR approved a Habitat Conservation Plan, designed to protect and rehabilitate habitats of the endangered Hawaiian petrel and Hawaiian 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 Hawaiian 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 Haleakala followed shortly thereafter. Site preparation and excavation began November 30, 2012.

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.

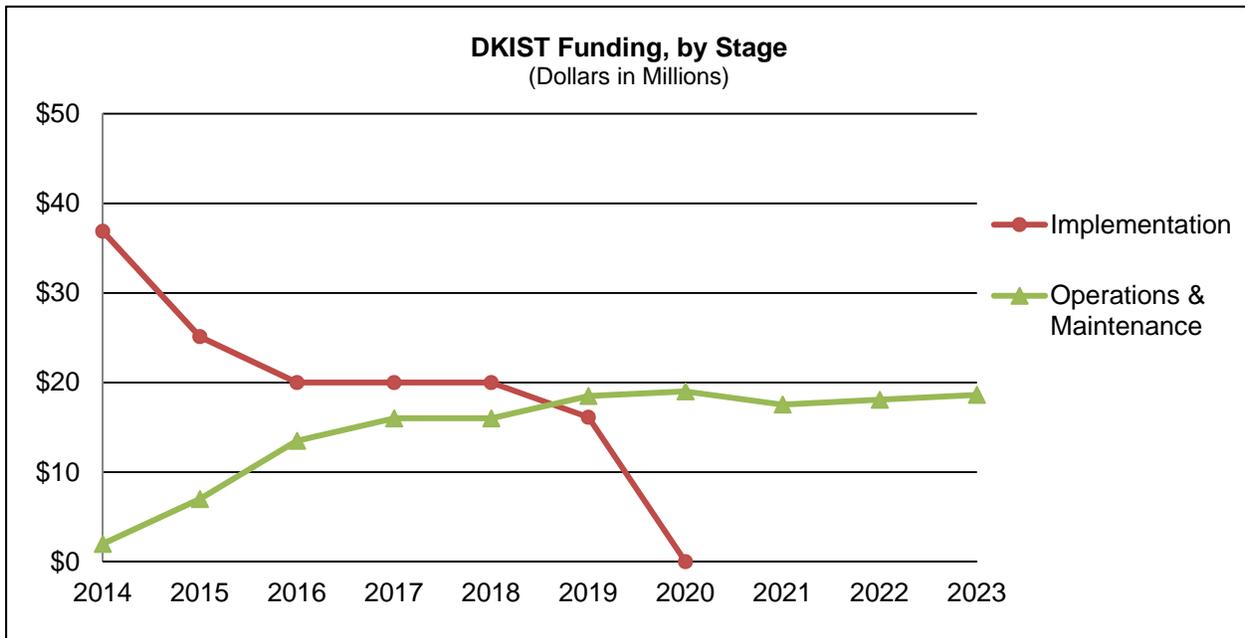
Total Funding Requirements for DKIST

(Dollars in Millions)

	Prior Years ¹	FY 2016 Actual	FY 2017 Estimate	FY 2018 Request	ESTIMATES				
					FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
<i>R&RA:</i>									
Concept & Development	\$20.41	-	-	-	-	-	-	-	-
Operations & Maintenance ²	7.00	13.50	16.00	16.00	18.50	19.01	17.54	18.08	18.62
ARRA	3.10	-	-	-	-	-	-	-	-
Subtotal, R&RA	\$30.51	\$13.50	\$16.00	\$16.00	\$18.50	\$19.01	\$17.54	\$18.08	\$18.62
<i>MREFC:</i>									
Implementation	122.00	20.00	20.00	20.00	16.13	-	-	-	-
ARRA	146.00	-	-	-	-	-	-	-	-
Subtotal, MREFC	\$268.00	\$20.00	\$20.00	\$20.00	\$16.13	-	-	-	-
TOTAL REQUIREMENTS	\$298.51	\$33.50	\$36.00	\$36.00	\$34.63	\$19.01	\$17.54	\$18.08	\$18.62

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 activities to be performed through partnerships are:

- 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. This eliminates the need to build a new 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).
- Queens University Belfast (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:** Oversight from NSF 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 General Counsel, and the Office of Legislative and Public Affairs. Within BFA the Large Facilities Office (BFA/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:** The construction project is conducted by NSO. 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 Association of Universities for Research in Astronomy, Inc. (AURA). The CSA for DKIST construction runs through the end of FY 2019. The NSO CA and O&M CSA were renewed for a period of ten years 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 the DKIST. The project manager has experience in several NSF-funded large projects including the Atacama Large Millimeter/submillimeter Array and the Expanded Very Large Array. Several councils and working groups provide 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.
- Business Systems Review (BSR): NSF conducted a BSR covering AURA, NSO, and the DKIST project December 2015 – March 2016. Findings and recommendations from NSF’s final report were conveyed to AURA on April 1, 2016, and AURA continues to resolve issues and implement recommendations from the report.
- Contingency Assessment: BFA/LFO and MPS/AST conducted a detailed assessment of the DKIST budget and schedule contingency, February 2016 – July 2016. The assessment found that management of contingency is in compliance with current NSF guidelines and requirements. The remaining project budget and schedule contingency appear to be adequate based on accepted industry standards at an 80 percent confidence level for an on-budget and on-time completion. Findings and recommendations from the final NSF report were conveyed to AURA on August 5, 2016. AURA continues to implement recommendations from the report, while NSF tracks its progress.
- Earned Value Management (EVM) System Review: BFA/LFO and MPS/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 (CAMs) to validate the input estimates/data into the system. The evaluation team found that the EVMS has been effectively implemented and is being used to provide reliable project management information. The NSF formally accepted the project’s EVMS in a notification dated Feb. 22, 2017.
- Software Quality Assurance (SQA) Assessment: BFA/LFO has 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 will consist of a document desk review followed by an in-person meeting in June 2017.
- Independent Risk Assessment (IRA): BFA/LFO has 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 will consist of a document desk review followed by an in-person meeting in September 2017.
- Programmatic Review: A comprehensive programmatic review of the DKIST MREFC construction project will be conducted in Q4 of FY 2017. This external programmatic review will focus on the IT&C phase of construction.

Project Status

The DKIST project continues to make progress on construction at the summit of Haleakala 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 Hawaiian Department of Land and Natural Resources, the Hawaiian Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, the Federal Aviation Administration, the National Park Service, and Native Hawaiian cultural practitioners.

Construction highlights:

- The project continues to work on interior fit and finish items for the enclosure (dome) and the support and operations (S&O) building.
- Work continues on the critical facility thermal systems (FTS) despite some staffing challenges.
- The Coudé rotator platform assembly inside the enclosure is completed. The Coudé rotator platform is undergoing site acceptance testing expected to be completed in Q3 of FY 2017.

Major Research Equipment and Facilities Construction

- Assembly of the telescope mount assembly (TMA) continues through FY 2017 into Q2 of FY 2018 (see picture).
- Fabrication of the DKIST first-light instruments continues through FY 2017.

In FY 2018 installation of the TMA will be completed, and commissioning and acceptance testing of the TMA underway. The installation of the telescope structure and mechanical controls will have begun. By the end of FY 2018 the installation of the M1 main mirror will be underway and the alignment of the mirror with the laser metrology system begun. The first of the five first-light instruments, the visible broadband imager (VBI), will be delivered to the site, assembled and will begin initial checkout.



Installation of the saddle sections of the DKIST telescope mount assembly (TMA), March 2017. Credit: P. Jeffers, DKIST.

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 (CL) for successful completion. The project is currently on track for a late 2019 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 described above. This instrument is an in-kind contribution from the German Kiepenheuer-Institut für Sonnenphysik (KIS) being designed and developed through an MOU between AURA and KIS, and therefore the fabrication risks for this instrument remain with the German institute. The VTF recently achieved a technical milestone regarding the precision of the optics. KIS is currently on track to deliver a de-scoped (single etalon) version of the instrument by DKIST first light. The DKIST project and the managing organization, AURA, continue to actively manage the situation. It should be noted that the cooperative support agreement between the 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 currently on track to deliver those four instruments.

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 Hawaiian 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 Hawaiian 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 Hawaii's Haleakala Observatory Management Plan. These decisions substantially reduce 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.

DKIST Operations Costs

DKIST operations are funded through the Research and Related Activities account (R&RA). (See the NSO narrative in the Facilities chapter for more information.) In FY 2018, the request of \$16.0 million includes \$14.0 million for the continuing ramp of DKIST operations and \$2.0 million for cultural mitigation activities as discussed below.

The need for a Remote Operations Building (ROB) facility located on Maui was identified in the early stages of DKIST development. In FY 2015, the managing organization (AURA) demonstrated to NSF that construction of a dedicated ROB would result in significant savings to the federal government, compared to leasing space over the planned 45-year lifetime of DKIST. Thus, operations costs of DKIST for FY 2018 and beyond have been reduced by \$500,000 annually as compared to the FY 2016 NSF Budget Request to Congress. In FY 2019, the estimated steady-state operations and maintenance cost will be \$16.50 million, exclusive of the \$2.0 million for cultural mitigation activities described below. DKIST will become the flagship telescope for the solar community, rendering some current facilities obsolete.

As noted above, cultural mitigation commitments were made pursuant to terms of DKIST environmental and cultural compliance as described in the final environmental impact study and the subsequent Record of Decision and the Programmatic Agreement. These include \$2.0 million of R&RA funding annually for 10 years (FY 2011 – FY 2020) for programs on Maui, supporting science, technology, engineering, and mathematics education and workforce development with an emphasis on Native Hawaiian students. A ten-year award to develop and administer these programs was made to University of Hawaii, Maui College in September 2011.



The DKIST telescope enclosure and Support and Operations building at the site on Haleakala, Maui, HI, March 2017. *Credit: D. Boboltz, NSF.*