Update: The Daniel K. Inouye Solar Telescope (DKIST)

Dave Boboltz (Program Director, NSO/DKIST)
Astronomy and Astrophysics Advisory Committee meeting
Sept. 27, 2017
The Sun: Our most important astronomical object!

• The Sun is a laboratory for Stellar Astrophysics  
  – Because of its proximity it can be resolved and studied like no other star

• The Sun drives the Space Weather that impacts Earth  
  – Earth-Sun interactions can shed light on exo-planet systems

• The Sun is a laboratory for Plasma Physics  
  – magnetic fields & fusion experiments
DKIST and Space Weather

• Oct. 2016 Executive Order continues NSWS/NSWAP efforts

• “The Director of the National Science Foundation (NSF) shall support fundamental research linked to societal needs for space weather information through investments and partnerships, as appropriate.”

• DKIST will help us understand the fundamental physics that drive Space Weather.
Simulation vs. Observation

• Current understanding is, to a large extent, driven by simulations
• Data are accepted/dismissed based on whether or not they fit the model

MHD Simulation
Grid size = 16 km = 0.02"

0.76m DST
Res = 132 km

Courtesy M. Rempel, HAO
The DKIST Telescope

- 4.2-m, off-axis Gregorian (all reflective), alt-az mount
- Integrated adaptive optics
- Enclosure with thermal control and dust mitigation
- Wavelength sensitivity from 0.3 - 28 microns (near-UV to infrared)
- Field of view: 2 - 5 arcmin
- Angular resolution: <0.03 arcsec (20km at the solar surface)
- Polarization accuracy: $10^{-4}$ of intensity

DKIST will be the world’s flagship facility for ground-based solar physics.
DKIST Site Atop Haleakala, Maui, HI

MaunaKea

MaunaLoa

DKIST at completion
DKIST Chronology

- Design and Development Study 2001
- Preliminary Design Review October 2006
- Final Design Review established the project baseline May 2009
- Awards totaling $298M authorized (NSB-09-57) August 6, 2009
- Federal environmental compliance completed December 2, 2009
- Construction funding (ARRA & MREFC) awarded January 2010
- Anticipated access to Haleakala site pending June 2010
- CDUP Issued by BLNR December 2, 2010
- CDUP challenged by Kilakila o Haleakala December 3, 2010
- Contested case hearing July 2011
- BLNR issues final decision affirming the CDUP November 9, 2012
- Final access to site granted November 30, 2012

30 month delay relative to original baseline – June 2010 to December 2012

- Re-baseline $344.12 authorized (NSB-13-42) August 16, 2013
Final Hawaiian Supreme Court Ruling: Oct. 6, 2016

Hawaii Supreme Court Affirms Maui Solar Telescope Permit

By JENNIFER SINCO KELLEHER, ASSOCIATED PRESS
HONOLULU — Oct. 6, 2016, 11:44 PM ET

Hawaii Supreme Court upholds telescope construction on Haleakala

The ruling denies a challenge to the construction of the Daniel K. Inouye Solar Telescope on a Maui mountain.

State Supreme Court upholds telescope permit

LEE IMADA
Managing Editor
leeimada@maisnews.com

The Hawaii Supreme Court upheld a state permit for the construction of the Daniel K. Inouye Solar Telescope atop Haleakala. This photo was taken of the $340-million telescope was taken in June. The Maui News / MATTHEW THAYER photo
DKIST in the NSF Facility Lifecycle

- **Initial Development**
  - MREFC Panel Review

- **Conceptual Design**
  - Conceptual Design Review (CDR)

- **Preliminary Design**
  - Preliminary Design Review (PDR)

- **Final Design**
  - Final Design Review (FDR)

- **Construction**
  - Operations Review

- **Operations**
  - Termination Review

**NSB Approved**

**We Are Here**

**Program Funds (Research & Related Activity, R&RA)**

R&RA funds also support scientific research

**MREFC**

Major Research Equipment and Facilities Construction (separate appropriation)

Astronomical Sciences
DKIST Construction Funding (MREFC)

- DKIST Re-baselined Total Project Cost = $344.13M
- FY 2017 MREFC $20M approved by NSB
  - $18.3M awarded (April 2017)
  - $1.7M (33% of contingency amount) withheld for future allocation
Total projected through FY 2024 = $201.84M

FY 2017 O&M awarded = $17.5M
  - NSO base = $6M
  - DKIST ops = $11.5M

Projected NSO Funding Profile

<table>
<thead>
<tr>
<th>Year</th>
<th>NSO Base</th>
<th>DKIST Ops. w/ ROB</th>
<th>Total, NSO</th>
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<tbody>
<tr>
<td>FY 2014</td>
<td>$8.0</td>
<td>$0.0</td>
<td>$8.00</td>
</tr>
<tr>
<td>FY 2015</td>
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<td>$13.00</td>
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<td>FY 2017</td>
<td>$6.0</td>
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<td>FY 2018</td>
<td>$5.0</td>
<td>$14.0</td>
<td>$19.00</td>
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<tr>
<td>FY 2019</td>
<td>$4.0</td>
<td>$16.5</td>
<td>$20.50</td>
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<tr>
<td>FY 2020</td>
<td>$4.12</td>
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<td>FY 2021</td>
<td>$4.24</td>
<td>$17.5</td>
<td>$21.78</td>
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<td>FY 2022</td>
<td>$4.37</td>
<td>$18.1</td>
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<td>FY 2023</td>
<td>$4.50</td>
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<tr>
<td>FY 2024</td>
<td>$4.64</td>
<td>$19.18</td>
<td>$23.81</td>
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</table>
DKIST Summary Schedule

Off-Site Design/Development
(Enclosure, TMA, Optical Systems, Instrument Systems, High Level Software)

Site Work: Excavation
Concrete, Steel Erection

Enclosure SAT & Testing

Facility Thermal Systems Installation

Telescope Mount Assembly
SAT & Testing

Instrument System
Fabrication & Lab Test (WFC, VBI)

Optics, Instrument
Integration & Commissioning

Site Closeout

8.3 Months Float

Start of Construction Project

Start of Site Construction

We Are Here

Current IPS
End of Construction

CSA End of Construction
(from MC 80%)
DKIST Cost and Schedule Status (July 31, 2017)

• Project **78%** complete

• **Budget**
  – NSF Funding to date = **$306.3M** ($146M ARRA)
  – Actuals + Commitments = **$263.0M**
  – Budget Contingency = **$25.9M** (36.8% of remaining estimate to complete)
    - Appropriate considering remaining risks.

• **Schedule**
  – 80% MC CL end date = **June 10, 2020**
  – Current IPS end date = **Oct. 30, 2019**
  – Schedule Contingency = **7.3 months**
Current Construction Site
DKIST Cutaway View
Telescope Mount Progress: Mar. – Sept., 2017
M1 Mirror polishing completed Dec. 2015
M1 Transport to Summit: August 2, 2017

Success!!!
Last extra-wide load
**Astronomical Sciences**

**Instruments**

**ViSP**
- Visible Spectropolarimeter
- Being Built by: the High Altitude Observatory (HAO)

**VBI**
- Visible Broadband Imager
- Being Built by: the National Solar Observatory (NSO)

**Cryo-NIRSP**
- Cryogenic Near-infrared Spectropolarimeter
- Being Built by: University of Hawaii

**VTF**
- Visible Tunable Filter
- Being Built by: KIS, Germany

**DL-NIRSP**
- Diffraction Limited Near-infrared Spectropolarimeter
- Being Built by: University of Hawaii
NSF oversight since last PEP review

- Recent/ongoing reviews
  - Software Quality Assurance (LFO-led; contractor)
  - PEP and Construction Status (AST-led; external panel)
  - Independent Risk Assessment (LFO-led; contractor)
Community: DKIST CSP Workshops

- NSO issued RFP for topical Critical Science Plan workshops
- 12 workshop proposals received
- Total number of workshops approved: 9
- Total number of scientists in approved proposals: 165
- Expected number of science use cases: 99
- All workshops open to community participation
- Website: http://www.nso.edu/cspw.php

<table>
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<tr>
<th>Workshop</th>
<th>Topic</th>
<th>Location(s)</th>
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<tbody>
<tr>
<td>IfA (some CfA)</td>
<td>Corona</td>
<td>Pukalani, Maui, HI</td>
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<tr>
<td>NMSU+UK</td>
<td>Connectivity (waves)</td>
<td>Las Cruces, NM/Newcastle, UK</td>
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<tr>
<td>SO/SPP</td>
<td>SO/SPP</td>
<td>JHU/APL (Laurel, MD)</td>
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<tr>
<td>UAH+Tokyo</td>
<td>Reconnection</td>
<td>Huntsville, AL/Tokyo, Japan</td>
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<tr>
<td>KIS (some CSUN)</td>
<td>MHD and Dynamo Processes</td>
<td>Freiburg, Germany</td>
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<tr>
<td>Rice</td>
<td>Flares</td>
<td>Houston, TX</td>
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<td>Catholic U</td>
<td>Connectivity</td>
<td>Washington, DC</td>
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<tr>
<td>NSO/CU Boulder</td>
<td>Synoptic</td>
<td>Boulder, CO</td>
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<tr>
<td>Montana State</td>
<td>Special</td>
<td>Bozeman, MT</td>
</tr>
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The 2017 Eclipse: A Public Outreach Opportunity to Promote DKIST
Variances

DKIST Schedule Variance & Cost Variance

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<tr>
<th>Month</th>
<th>Schedule Variance $K</th>
<th>Cost Variance $K</th>
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<tbody>
<tr>
<td>Aug-16</td>
<td>$(8,811)</td>
<td>$3,113</td>
</tr>
<tr>
<td>Sep-16</td>
<td>$(9,110)</td>
<td>$2,489</td>
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<tr>
<td>Oct-16</td>
<td>$(9,346)</td>
<td>$3,396</td>
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<tr>
<td>Nov-16</td>
<td>$(8,896)</td>
<td>$3,968</td>
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<tr>
<td>Dec-16</td>
<td>$(9,782)</td>
<td>$4,465</td>
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<tr>
<td>Jan-17</td>
<td>$(8,965)</td>
<td>$5,026</td>
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<tr>
<td>Feb-17</td>
<td>$(10,702)</td>
<td>$4,648</td>
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<td>Mar-17</td>
<td>$(10,469)</td>
<td>$4,050</td>
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<td>Apr-17</td>
<td>$(9,739)</td>
<td>$4,781</td>
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<tr>
<td>May-17</td>
<td>$(9,067)</td>
<td>$5,341</td>
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<td>Jun-17</td>
<td>$(9,174)</td>
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<tr>
<td>Jul-17</td>
<td>$(9,506)</td>
<td>$4,286</td>
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DKIST Schedule Variance and Cost Variance %

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<thead>
<tr>
<th>Month</th>
<th>CV%</th>
<th>SV%</th>
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<tbody>
<tr>
<td>Jul-16</td>
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<td>Nov-16</td>
<td>1.7%</td>
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<td>Dec-16</td>
<td>1.9%</td>
<td>-4.1%</td>
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<td>Jan-17</td>
<td>2.2%</td>
<td>-3.7%</td>
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<td>Feb-17</td>
<td>2.0%</td>
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<td>Mar-17</td>
<td>1.7%</td>
<td>-4.2%</td>
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<tr>
<td>Apr-17</td>
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<td>May-17</td>
<td>2.2%</td>
<td>-3.6%</td>
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<tr>
<td>Jun-17</td>
<td>1.8%</td>
<td>-3.6%</td>
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<tr>
<td>Jul-17</td>
<td>1.7%</td>
<td>-3.7%</td>
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DKIST Critical Path CY 2018 - 2019

The diagram shows a detailed project schedule with critical paths for the DKIST project. It includes milestones and dependencies for various tasks, spanning from September 2018 to 2019. The schedule is divided into quarterly and monthly intervals with specific tasks listed for each period. The diagram indicates key activities such as commissioning, integration, and testing phases, ensuring that project milestones are met on time. The critical path highlights the sequence of tasks that determine the project's completion time.
Coudé Rotator Platform

- Completed site acceptance testing (SAT) July, 2017
M1 Journey Tucson, AZ – Maui, HI via San Diego, CA, May 8–26, 2017
VTF: Excellent progress with key technology

- Etalon plates manufactured by Zygo Corp.
- Manufactured LIGO mirrors
- Sub-nm tolerances

Average of the 3 measurements with tilt removed over 250mm diameter aperture.

0.542nm RMS  4.895nm PV
**Multi-Conjugate Adaptive Optics (MCAO)**

- MCAO under development at Big Bear Solar Observatory (BBSO)
- Uses 3 deformable mirrors to compensate for turbulence at 3 different heights in the atmosphere
- NSO personnel leading the effort
- NSF funded through AST-ATI award
- **Pathfinder for DKIST next-generation AO system**
AST No-deadline SPG Pilot Program

- SPG split from AAG; started October 2016
- Individual investigator research into solar and planetary astronomy including exo-planets
- 21 solar projects (35 proposals) received to date
- Solar Panel in May
  - 4 projects funded
DKIST Remote Office Building (ROB)

- Located in Pukalani, Maui, HI next to UH-IfA
- NSF approved the purchase of land by AURA (July 31, 2015)
- AURA closed on the land purchase (Aug. 21, 2015)
- Final EA and Finding of No Sig. Impact (FONSI) (Apr. 6, 2016)
- AURA issued RFP to build the ROB (June 30, 2016)
- Bids received (Sept. 6, 2016)
- Project’s Selection approved by NSF (Dec. 2, 2016)
  - Contractor Arisumi Bros.
  - $8.321M
- Construction schedule:
  - Site prep (Feb. 2017)
  - Approx. 15 months to complete
ROB Ceremony: March 3, 2017
ROB Construction Progress

09/28/2017 AAAC Meeting