Building the control system to operate the Cryogenic Near Infrared Spectropolarimeter instrument for the Daniel K. Inouye Solar Telescope

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Image credit: NSO/AURA/NSF
DKIST is the world’s largest ground-based solar telescope. Under construction at Haleakala Observatory in Maui. Operates in near-infrared (IR). Will have 5 first light instruments.
Introduction: Cryo-NIRSP

• Under construction at the Institute for Astronomy at the University of Hawaii.

• Scientific aims:
  – Study the solar coronal magnetic field at near- to thermal- IR wavelengths over a large field of view.
  – Measure the full polarization state (Stokes IQUV) of spectral lines.
  – Will be able to study different solar phenomenon.
The Instrument

- **Cryogenic Near Infrared SpectroPolarimeter**
- Near- to thermal-IR SpectroPolarimeter (SP) and Context Imager (CI).
- Critical optics are cryogenically cooled.
- Two IR cameras (1 for SP, 1 for CI).
  - Use Non-Destructive Readouts (NDRs)
  - Support 3 readout modes:
    - Fast up-the-ramp
    - Slow up-the-ramp
    - Line-by-line
The Instrument

• Delta Tau Power PMAC is used to move mechanisms and support real-time motion.

• Uses a polarizing modulator (to measure the Stokes angles), which supports 3 different modes:
  – Stepped
  – Continuous
  – Constant position

• Time Reference And Distribution System (TRADS) used for timing and synchronization.
The Software: Requirements

- Operational modes: CI, SP or CI+SP.
- Two primary task types: calibration & observes. Within these there are:
  - several calibration tasks (e.g. dark, gain, alignment, focus).
  - observe tasks.
- 3 different camera modes.
- 3 different modulator modes.
- A variety of different scanning patterns and configurations.
- Multiple wavelength filters and slit options.
The Software: Common Services Framework

- Built within the DKIST software framework using the Common Services model.
- Provides:
  - deployment
  - communication (notification, logging, connection & alarm services)
  - persistence support
  - application support
  - additional tools
- Uses a Container/Component Model
The Software: Structure

GUI

- Create a new Instrument Program (IP).
- Saves information to a DataSet Parameter (DSP).

Instrument Controller

- IP is submitted to the Instrument Controller (IC).
- This instigates the Instrument Sequencer (IS).
- The IS runs the IP by calling Jython scripts that call out to Java classes.

Instrument Sequencer

- IS manages the forwarding of instructions to the Mechanism Controller (MC), Polarizing Modulator Controller (PMC), Time Base Controller (TBC), and Detector Controller (DC).

TBC
- Camera Software System (CSS)
- TRADS
- TRADS

DC
- Camera Software System (CSS)
- CI
- SP

MC
- Power PMAC
- Mechanisms

PMC
- Modulator
Main Panel
-> IP Control
GUI: IP Control

- Instrument Program Control:
  - select task
  - observation mode
  - create a DSP
GUI : IP Control

General Settings

CryoNIRSP Operation Mode
- Spectrograph only
- Pickoff Mirror
- Pellicle
- Open

Misc. Parameters
- SP cold mask: On
- Feed relay Attenuation filter: Open
- FM2 Defocused delta:

Calibration Lamp
- Continuum (ThAr)
- IR

Wavelength
- Filter: He I, Fe XIII
- Wavelength: 1.080
- Order: 52
- Dispersion: 2.3874457016432...

Context Imager Filter
- Wheel 1:
- Wheel 2:

Save to Sequence
Reset to Default
Cancel Edits
**GUI: IP Control**

<table>
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<tr>
<th>General Settings</th>
<th>Camera/Modulator Settings</th>
<th>Scanning Settings</th>
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<tr>
<td>Primary field scanning</td>
<td>FOV</td>
<td></td>
</tr>
<tr>
<td>Secondary field scanning</td>
<td>None</td>
<td></td>
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**Spectrograph FOV Scanning**

- **Slit**: 52
- **Length**: 120"
- **Width on the Sun**: 0.15"

- **Pattern**: Raster
- **FOV**: Inner, Full, Restricted
  - **1st Direction**: Horizontal
  - **Step size (arcsec)**: 59
  - **Num. scan positions**: 3
  - **2nd Direction**: None
  - **Step size (arcsec)**: 0
  - **Num. scan positions**: 0

- **Restricted FOV center position**
  - (arcsec): width, height
  - Scanning overlap in spatial direction: 0.00%

**Buttons**: Save to Sequence, Reset to Default, Cancel Edits
Running An Observation: The Setup Phase

- Mechanisms are moved to their defined positions by the Mechanism Controller.

- Camera/CSS set-up:
  - Creation of Data Acquisition Trees (DATs) – a structure to define when a camera should expose.
  - A DAT contains:
    - Camera configurations – parameters needed for the camera hardware.
    - Execution Blocks (EBs) – contains the timings.
• Primarily calculated within the tiers of an EB to define:
  – number of times to execute each tier.
  – the time that a single execution of a tier should take (a time slice).

• Must consider:
  – camera setup parameters.
  – synchronization with the spinning modulator.
  – synchronization with moving mechanisms if performing a scan (real-time motion).
Timing : Example

- Exposure time
- Camera setup/reset times
- Modulator move time
- Mechanism move time

SP execBlock:
- eb_rootSP.35734.4
  - eb_secondSPScanV.35734.6 x 2 time sliced for 16.0646s repeatedly.
  - eb_firstSPScanH.35734.5 x 2 time sliced for 8.03232s repeatedly.
  - cc_cn_sp_100.0ms@1.1204728610604464Hz.35734.3 x 8 time sliced for 0.89248s repeatedly.
Running an observation: Execute phase

- Involves submitting the configurations to the mechanisms/cameras:
  - real-time motion program is submitted to the MC.
  - global start time is calculated and submitted.
  - modulator configuration is submitted with rate, wait time, number of states, starting state etc.
  - submit to cameras the time to begin executing the DATs.
Conclusions

• The Cryo-NIRSP control and data processing system has been developed in line with the DKIST CSF to facilitate the complex design and operation of the instrument.

• Handles different observing modes, tasks, camera modes, scanning operations and modulator configurations.

• Combined with the data processing software it provides a full end-to-end solution allowing Cryo-NIRSP to function to its optimum ability.