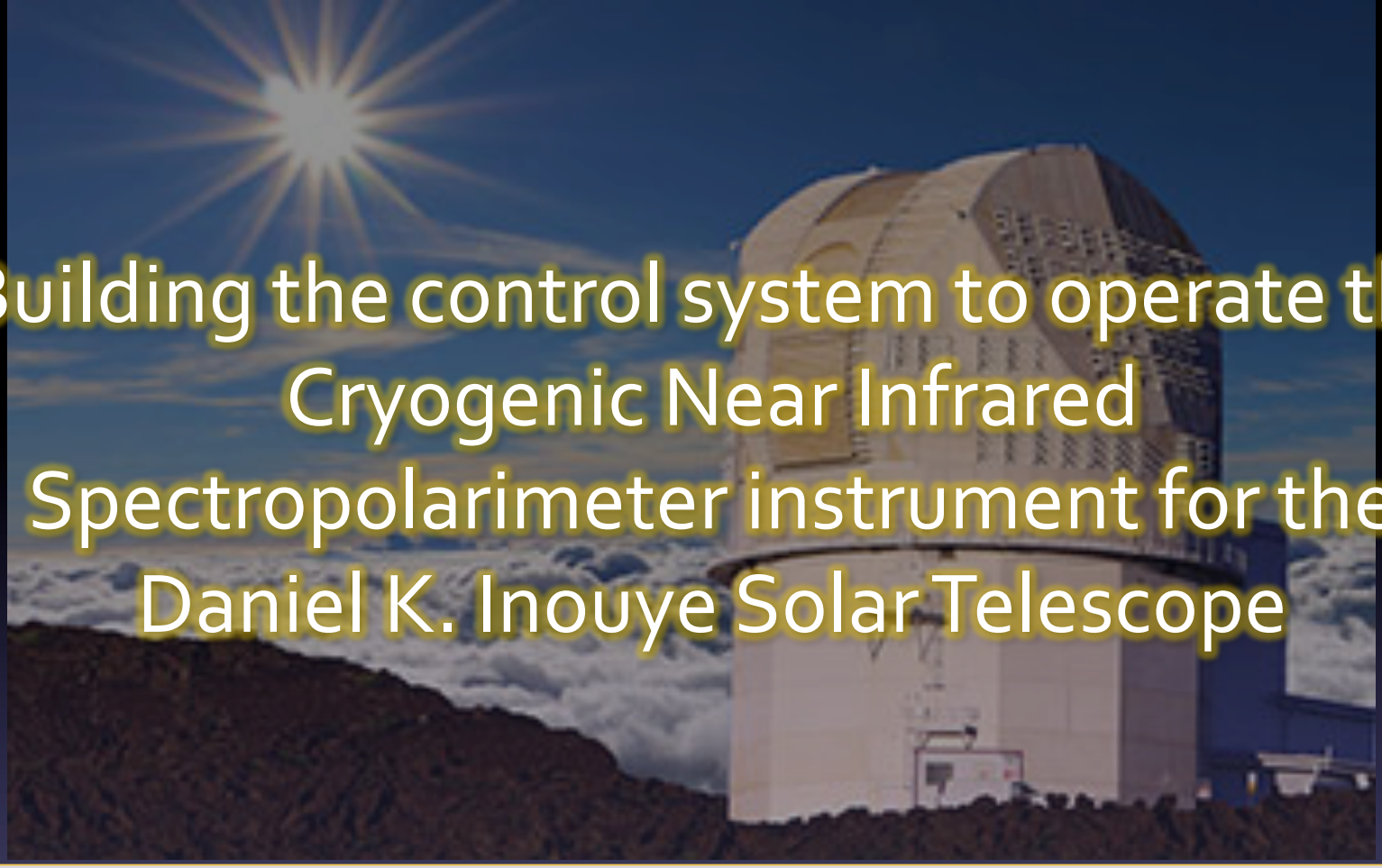

Building the control system to operate the Cryogenic Near Infrared Spectropolarimeter instrument for the Daniel K. Inouye Solar Telescope

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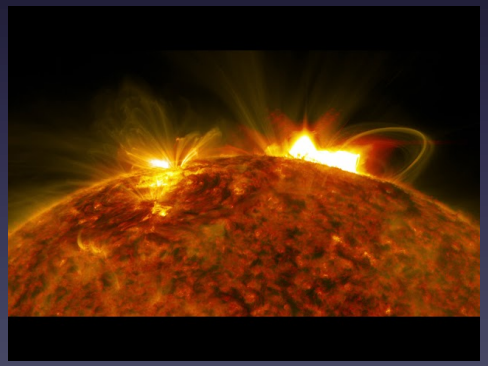
Introduction : DKIST

- 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

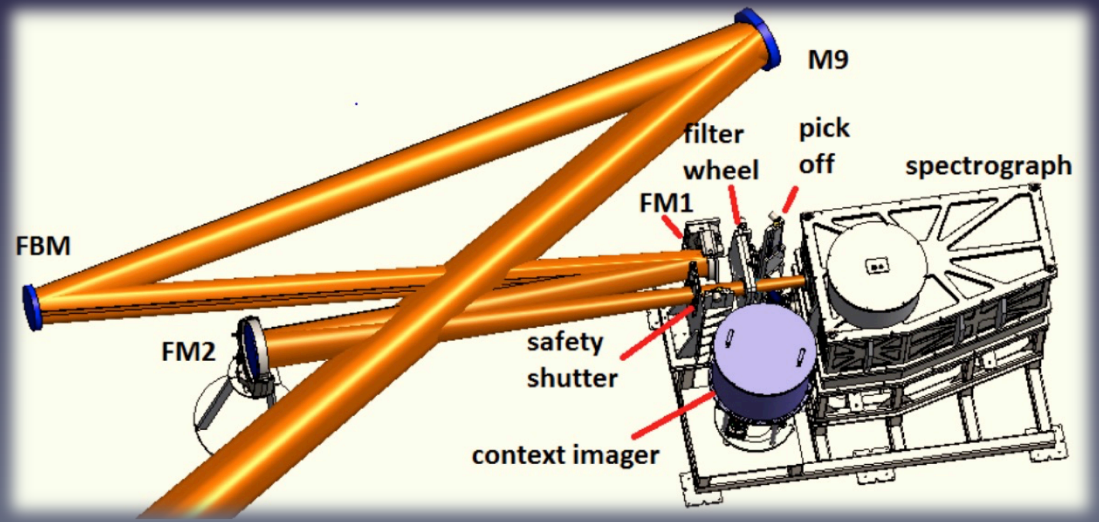
- Under construction at the Institute for Astronomy at the University of Hawaii.

- 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

- **Cryo**genic **N**ear **I**nfra**R**ed **S**pectro**P**olarimeter
- 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.

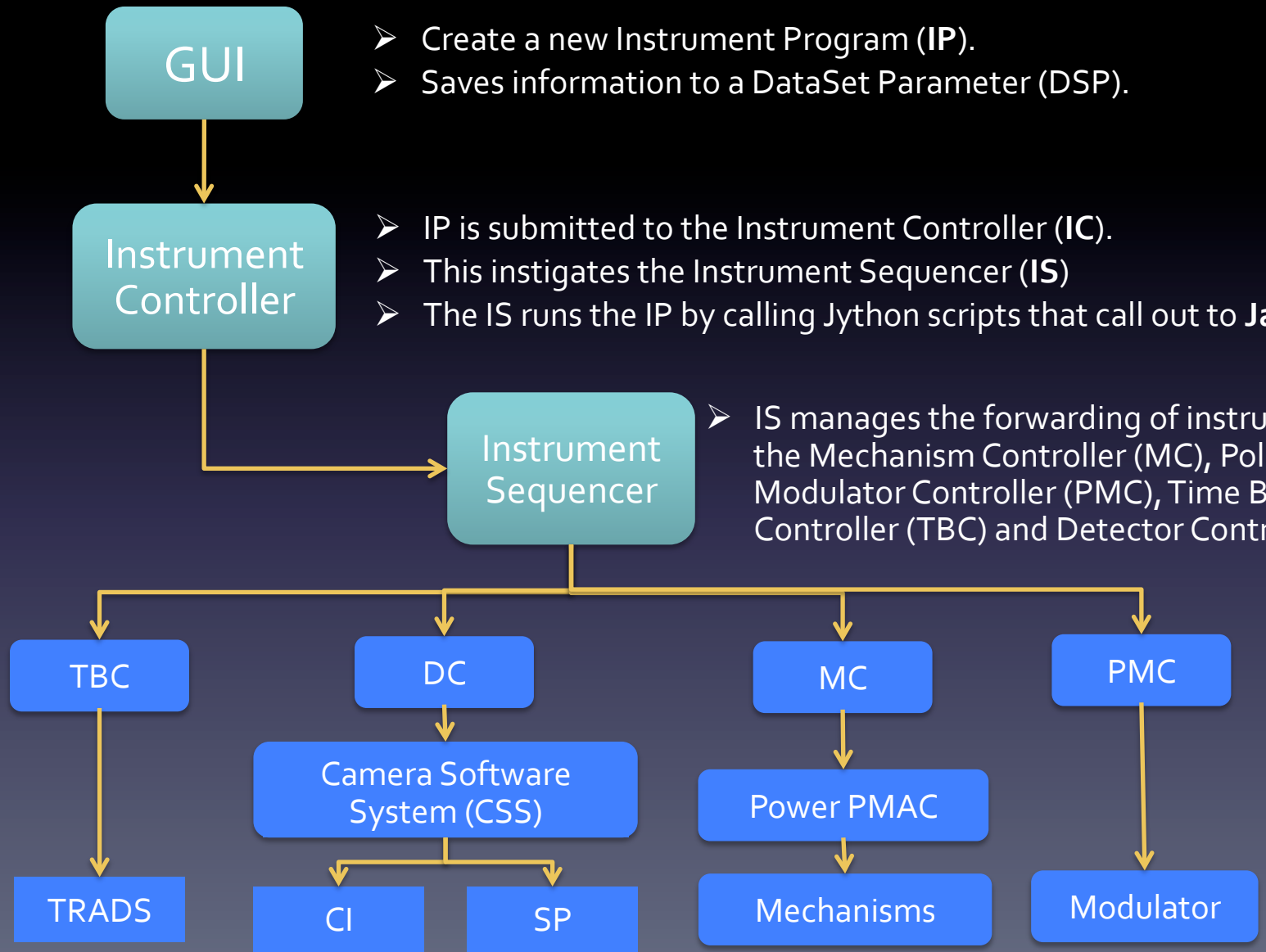
The Software : Requirements

- 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

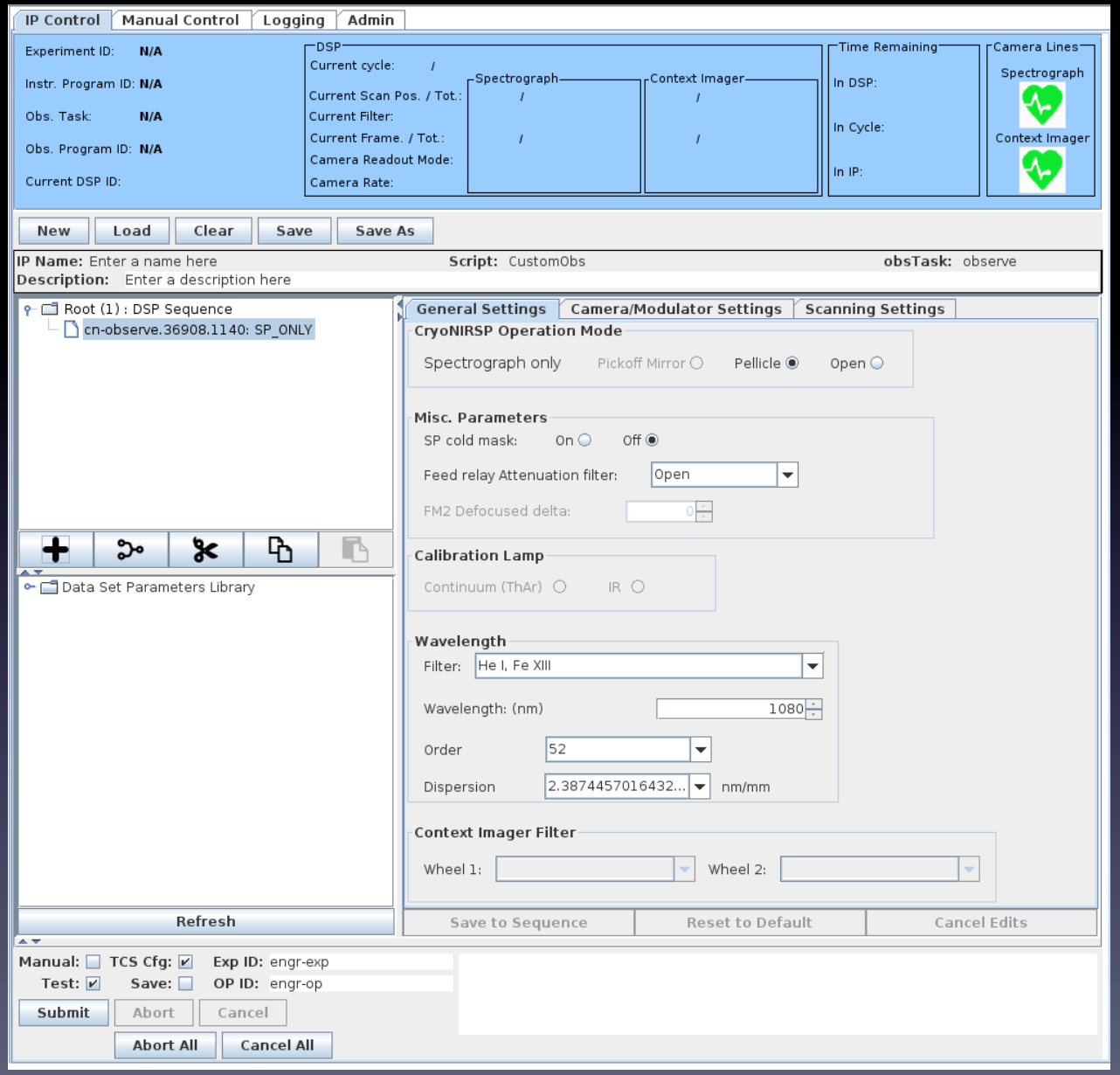


- Create a new Instrument Program (**IP**).
- Saves information to a DataSet Parameter (DSP).

- 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.

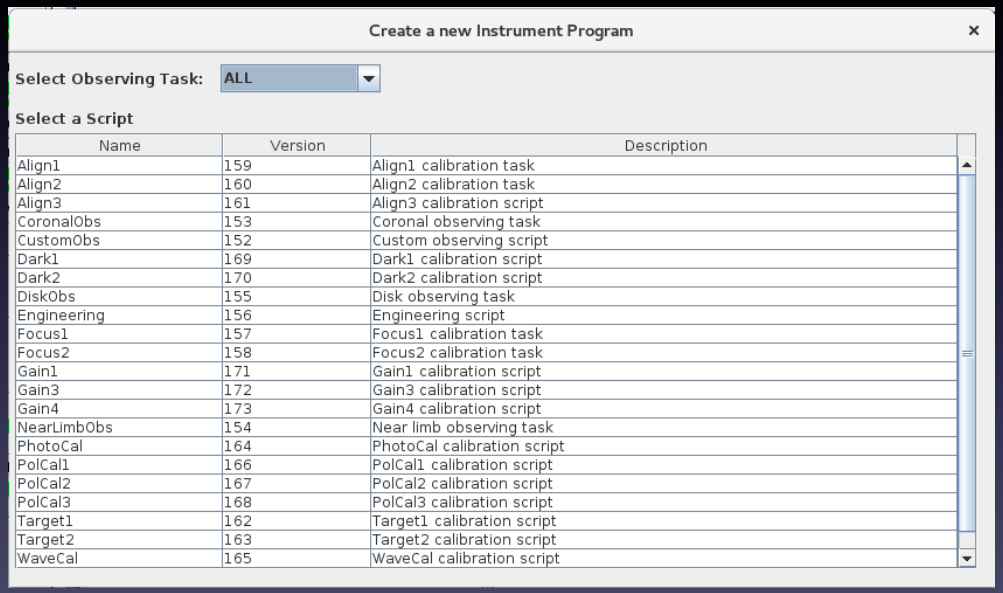
- IS manages the forwarding of instructions to the Mechanism Controller (MC), Polarizing Modulator Controller (PMC), Time Base Controller (TBC) and Detector Controller (DC).

Main Panel
-> IP Control



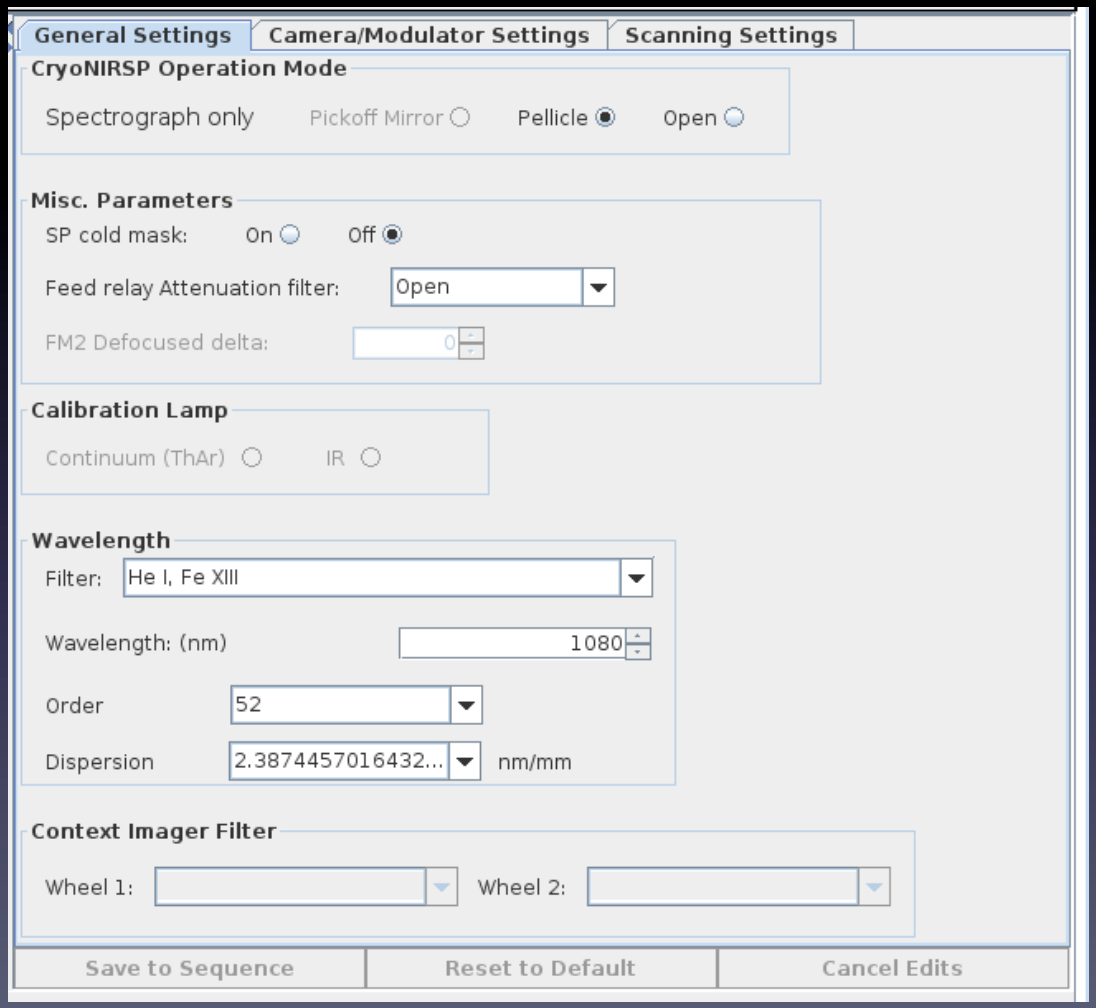
GUI : IP Control

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

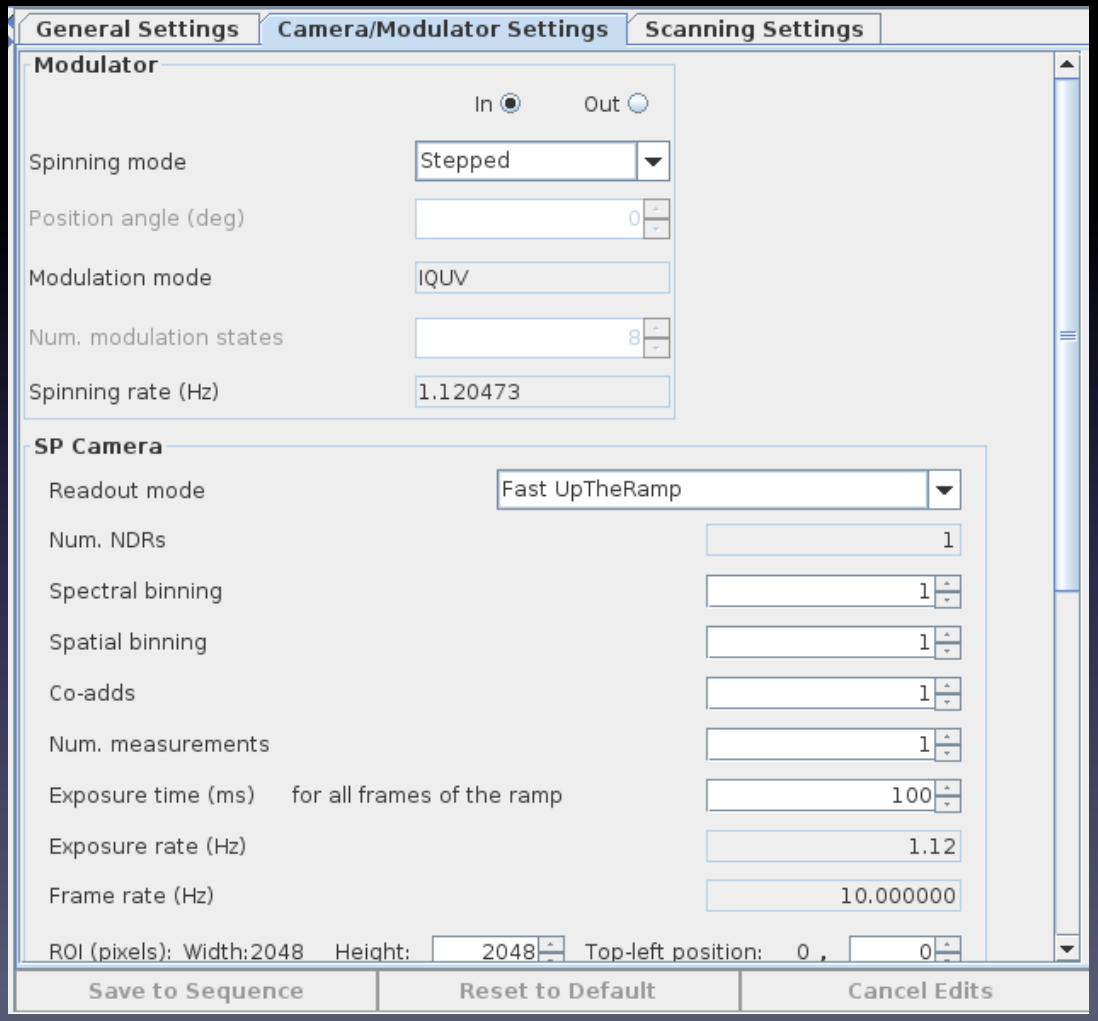


Name	Version	Description
Align1	159	Align1 calibration task
Align2	160	Align2 calibration task
Align3	161	Align3 calibration script
CoronalObs	153	Coronal observing task
CustomObs	152	Custom observing script
Dark1	169	Dark1 calibration script
Dark2	170	Dark2 calibration script
DiskObs	155	Disk observing task
Engineering	156	Engineering script
Focus1	157	Focus1 calibration task
Focus2	158	Focus2 calibration task
Gain1	171	Gain1 calibration script
Gain3	172	Gain3 calibration script
Gain4	173	Gain4 calibration script
NearLimbObs	154	Near limb observing task
PhotoCal	164	PhotoCal calibration script
PolCal1	166	PolCal1 calibration script
PolCal2	167	PolCal2 calibration script
PolCal3	168	PolCal3 calibration script
Target1	162	Target1 calibration script
Target2	163	Target2 calibration script
WaveCal	165	WaveCal calibration script

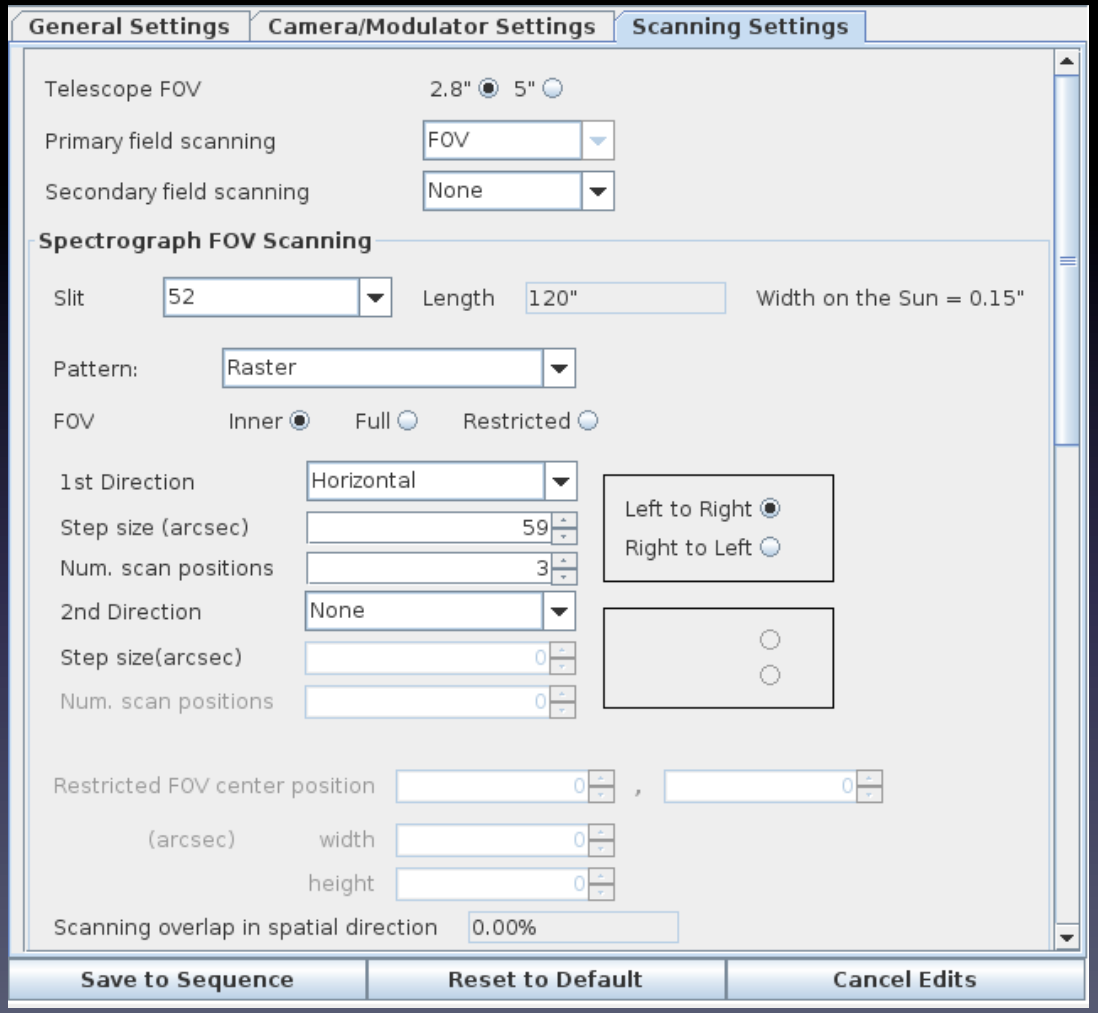
GUI : IP Control



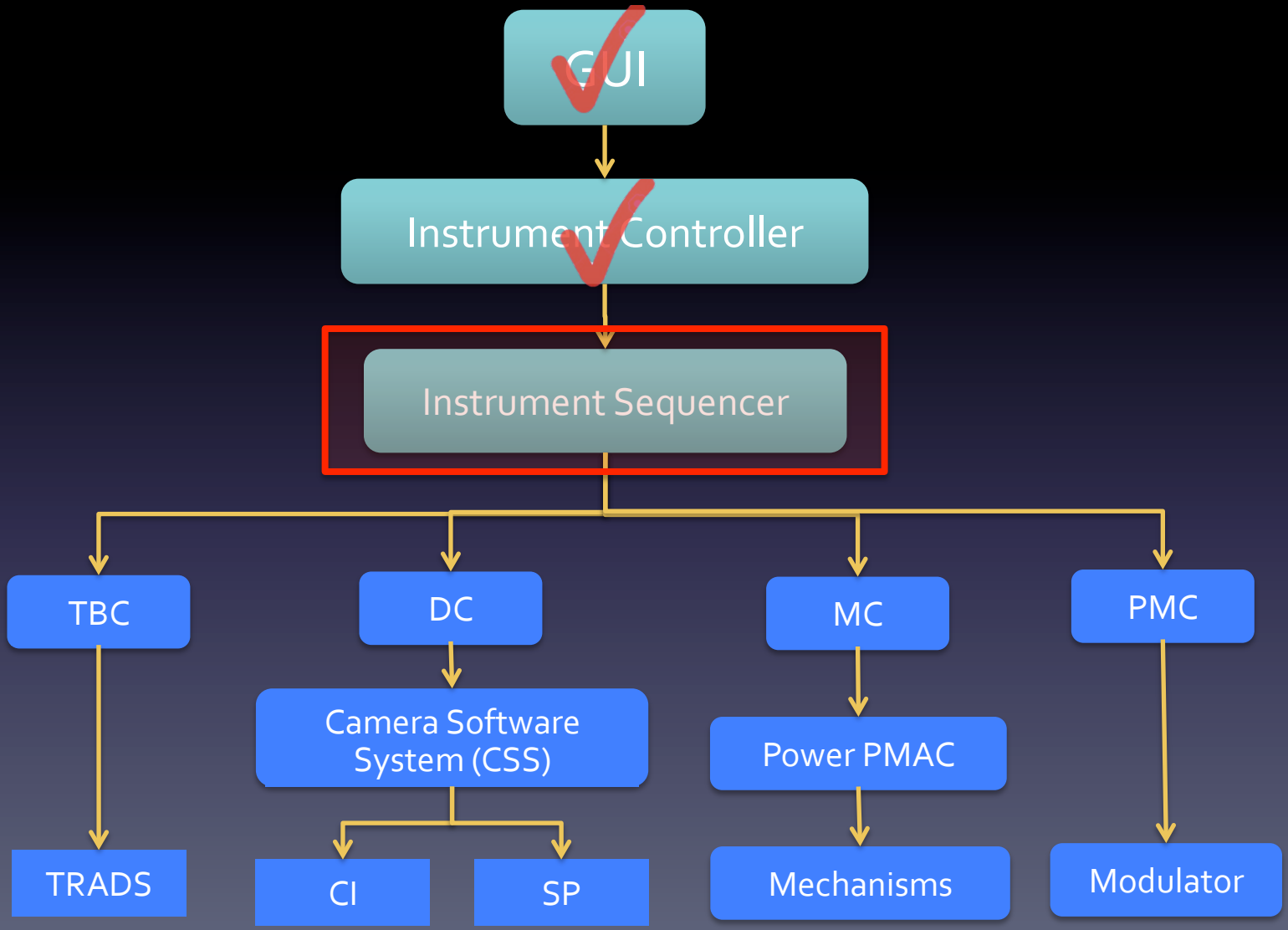
GUI : IP Control



GUI : IP Control



Running an observation



Running An Observation: The Setup Phase

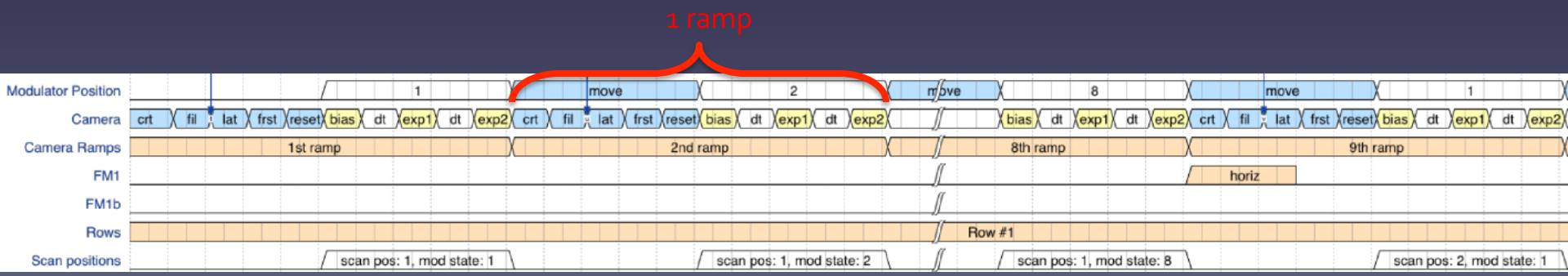
- Mechanisms are moved to their defined positions by the Mechanism Controller.

- 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.

Timing

- 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

```
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.
```

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

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.