Overview of NISP Calibration NIR/SGS perspective

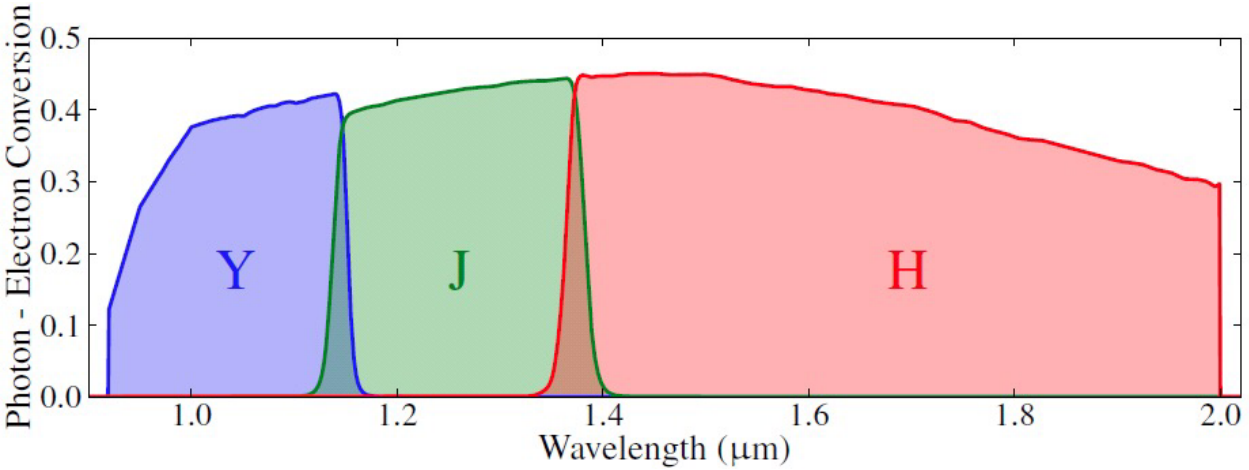
P. Capak, G. Polenta, NISP Team

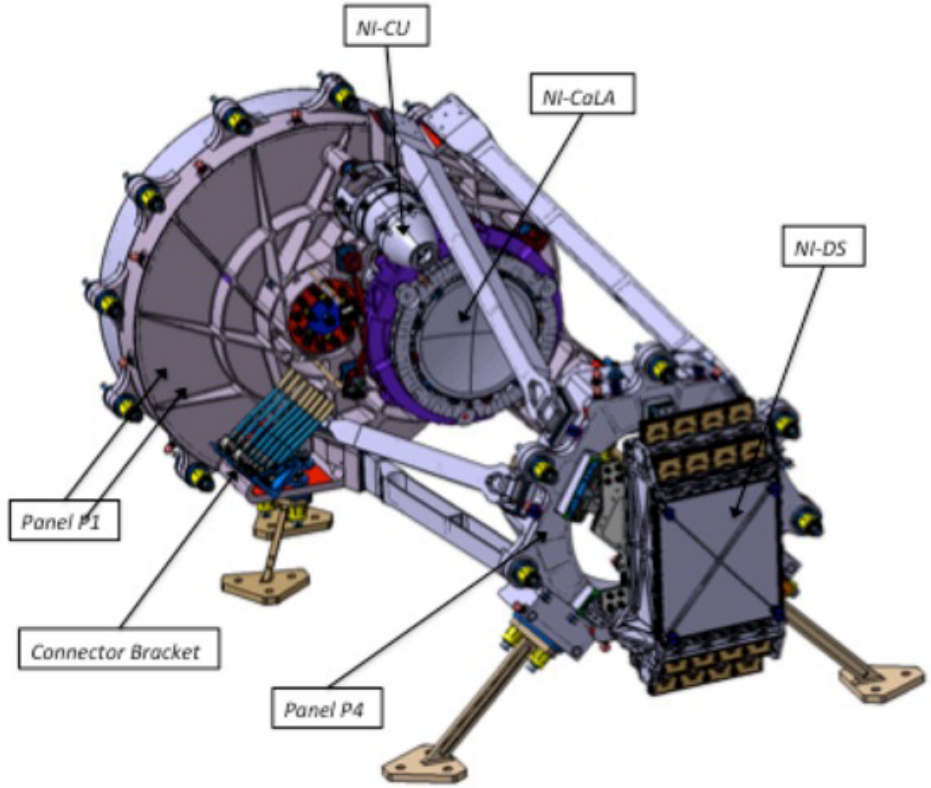
Overview

- Description of the NISP Instrument
- Calibration Requirements
  - Photometry
  - Spectroscopy
- Calibration Philosophy

NISP Instrument

- 0.55 deg FOV, 0.3" pixels
  - 16 HAWAII-2RG HgCdTe detectors
- Photometry in 3 bands, 0.9-2um
  - Y, J, H
- Spectroscopy in 4 GRISMS
  - 3 cover 1.25-1.85um
    - At 0, 90, 180 degrees
  - 1 covers 0.92-1.25um at 0 degrees
    - only in the deep field
  - R>380 for a 0.5" object
- Dark stop/shutter



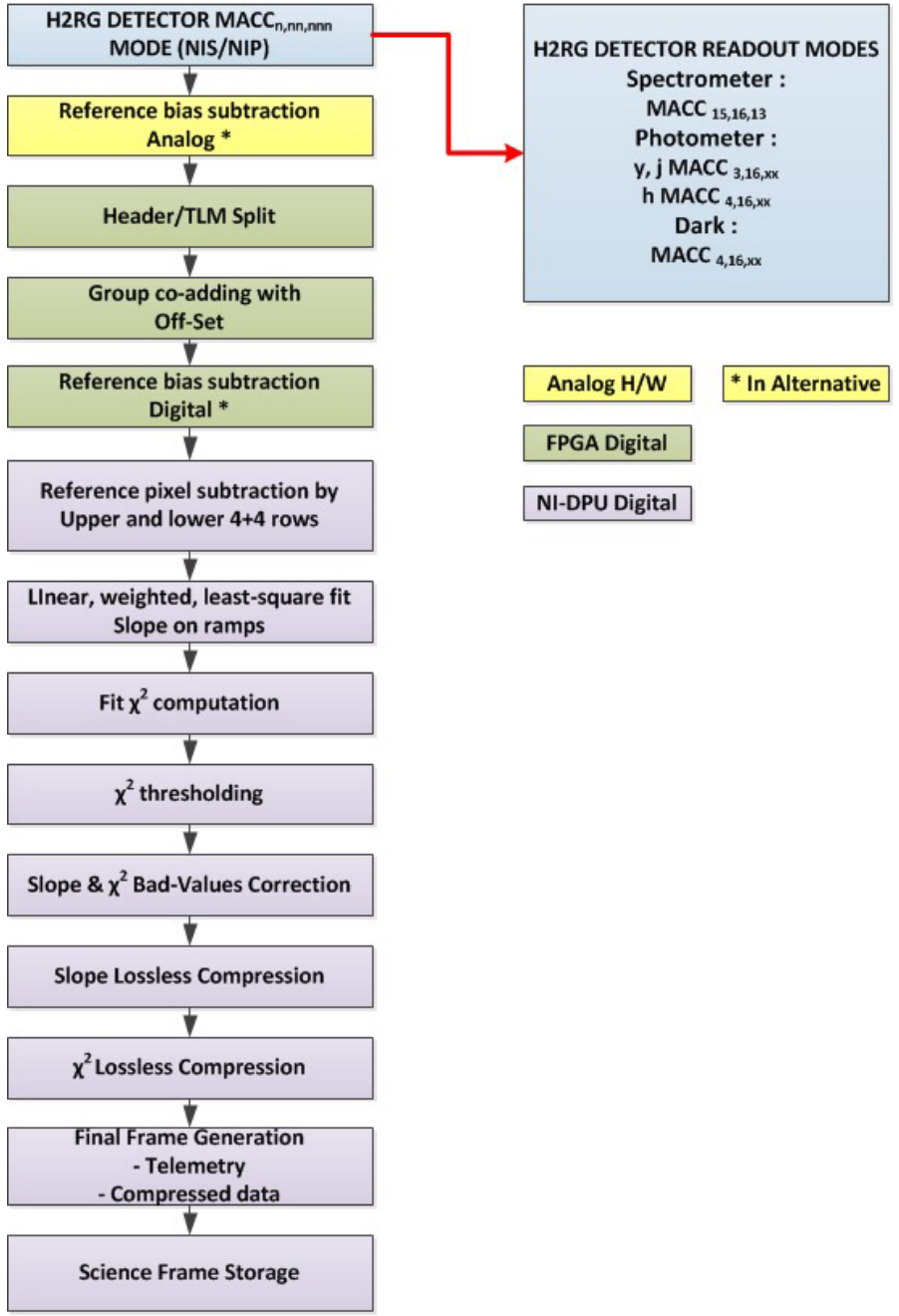


NISP Observing

- Normal "Wide Field" observing
  - ~20 fields per day, 4 dithers per field
    - Dither 1, 565s red 0 deg GRISM
      - 121s Y, 116s J, 81s H
    - Dither 2 , 565s red 90 deg GRISM
      - Same Photometry
    - Dither 3, 565s red 180 deg GRISM
      - Same photometry
    - Dither 4, 565s red 90 deg GRISM
      - Same photometry
    - Dark during slew

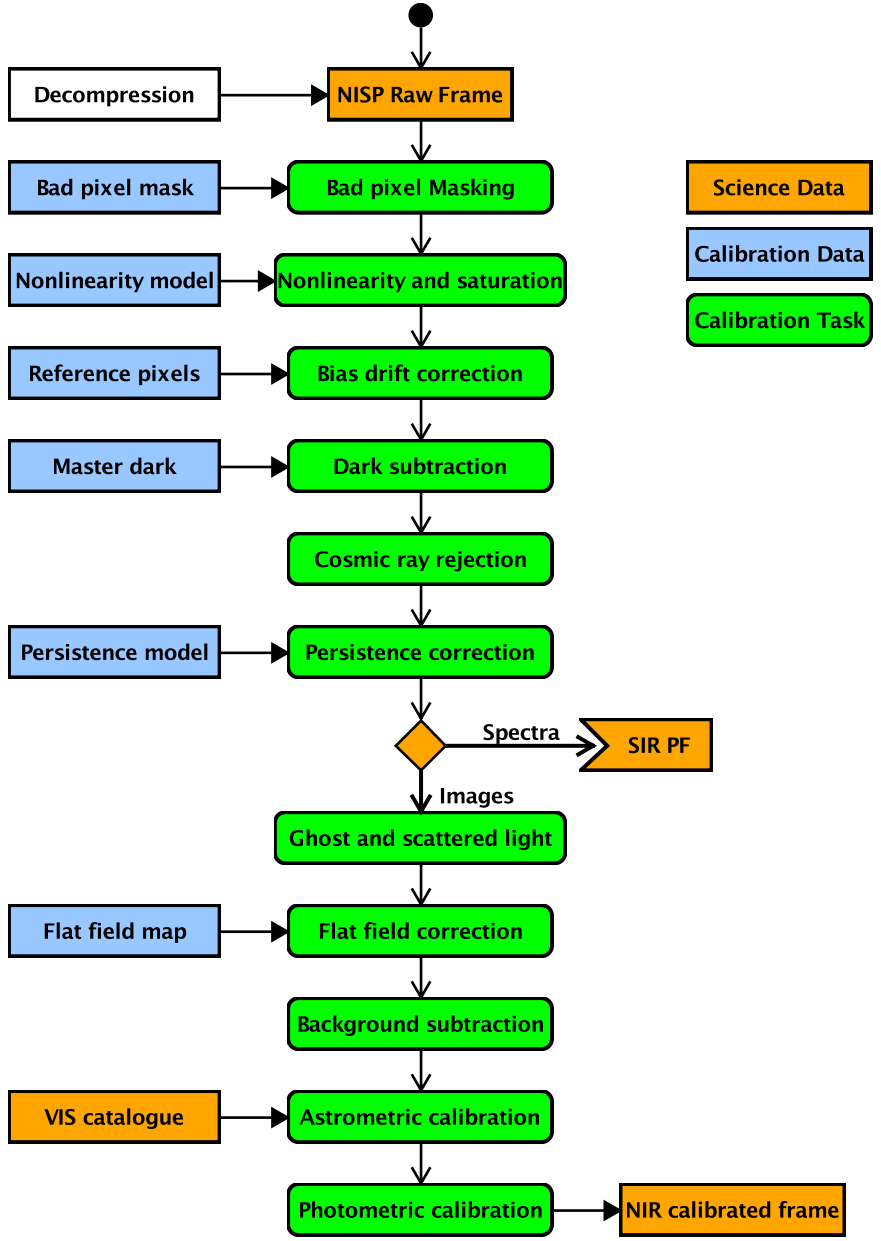
NISP Onboard Processing

- Detectors continuously read on board
  - To reduce noise
- Telemetry limits data downlink rate
  - Must combine reads on board
  - Only downlink image + flags
    - Chi-sq for Spectroscopy
    - 1-bit threshold for imaging
    - Will get full data set for some pixels
- Must calibrate processed data



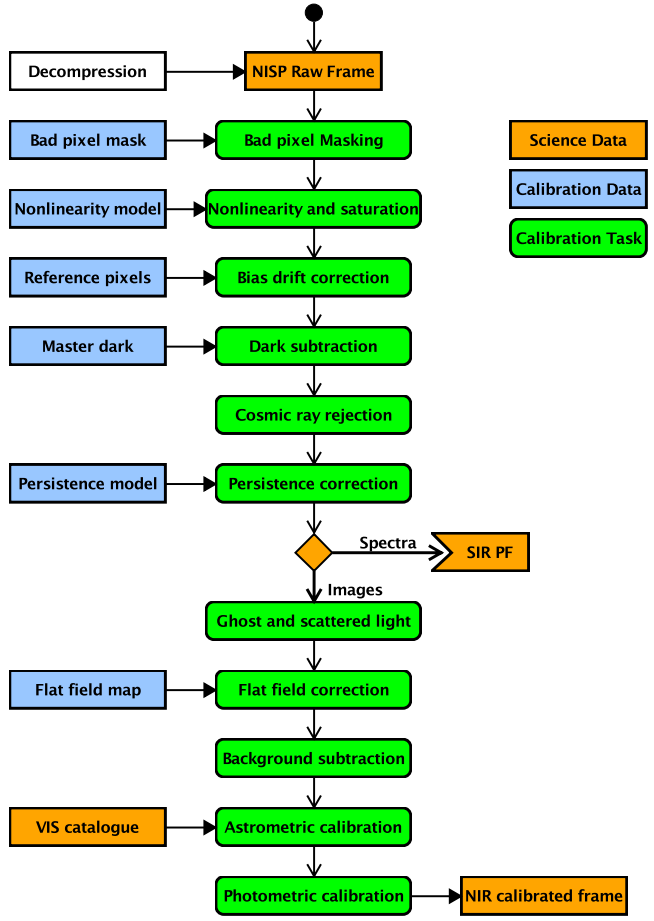
Calibration Requirements

- Photometry
  - Stability over time
    - Sources from photo-z bias stability requirement in SCI-RD
- Spectroscopy
  - Stability of wavelength calibration
    - Sources from redshift precision requirement for BAO in the SCI-RD
  - Knowledge of sensitivity variation
    - Sources from need to know sampling mask for BAO in SCI-RD



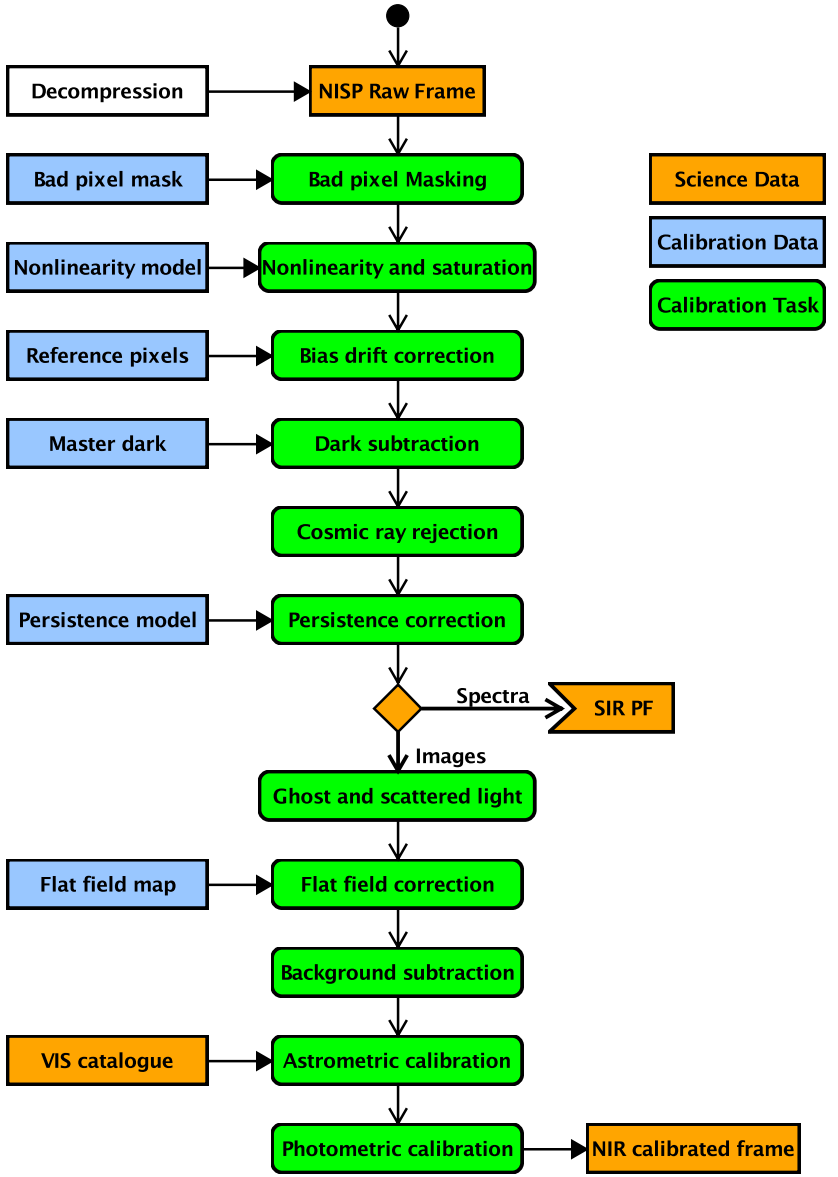
Calibration Requirements - Challenges

- Need very high stability
  - Not only measured but verified with errors
- On-board processing
  - Loss of information
- Tracking sensitivity
  - Noise, masks, systematics



Calibration Philosophy

- Photometry and Spectroscopy share the basic calibration pipeline
  - Bad pixels
  - Bias/Dark
  - Non-linearity/Saturation
  - Persistence mitigation
  - Cosmic ray removal
- Calibrate as much as possible on the ground
  - Verify and re-calibrate in flight



Photometric Calibration Strategy

- 1.5% per band photometric stability driving requirement
- Must measure and verify performance over time
- Will require re-processing of data
  - Must extrapolate calibration to future to enable pipeline processing
  - There will have to be “version” flags in the MDB
- Detector chain calibration shared with spectroscopy
- Absolute calibration to 5% goal

- Bad Pixels
  - Active trending
  - Calibration and science data
- Darks
  - Trend darks over time
  - Possible variation with temperature and age
- Flat
  - Small scale flat, determined with lamps
  - Large scale flat, self calibration field
    - Possible self-calibration with data
  - May interact with non-linearity
- Non-linearity
  - Measured with lamps
    - trended with time

Spectral Calibration Strategy

- BAO sensitive function main driver
  - <0.5% knowledge of field to field variation in spectrophotometric depth
  - 1.5% relative stability per object
  - 5% absolute spectrophotometric calibration goal
- Plan based on HST WFC3 heritage with some differences
  - Long-term spectrophotometric stability
  - Wide field of view
- Must rely on ground calibration for spectral response function
  - Spectra flats and QE measurements
  - Can not be done in detail during flight
- Can only measure/verify in flight for limited cases
  - Only 5 lamps on NIR
  - Establish calibration during PV phase based on ground data
  - Monitor during mission

Detector Chain Calibration

Error Source	Allocated Margin	Requirement	Implementation
Bias	0.3%	R-CAL-B-NP-1410	R-GDP-CAL-142
Dark Subtraction	0.5%	R-CAL-B-NP-1420	R-GDP-CAL-140
Non-linearity	0.3%	R-CAL-B-NP-1440	R-GDP-CAL-141
Intra-pixel sensitivity	0.47%	R-CAL-B-NP-1460	Ground Test
Persistence	0.5%	R-CAL-B-NP-1470	
Electronic Cross Talk	0.3%	R-CAL-B-NP-1480	Ground Test
Margin	0.1%		
Total	1.0%	R-CAL-A-NP-1000 R-CAL-B-NP-1400	

Detector Chain

- Bias
  - Reference Pixels
- Dark
  - On the order of ~480 darks to get 0.5% calibration
    - ~6 days of clock time
    - Should try to match exposure times
  - Monitoring to ensure dark does not vary by more than 2.8% on timescales less than a month
  - Need accurate persistence mask/correction
- Nonlinearity
  - Expensive because we need to download full ramps
  - Calibrations every ~6 months
    - Onboard lamps
  - Interpolate between
  - Verify with sample ramps
- Intra-Pixel Sensitivity
  - Ground calibration + dithering
- Persistence
  - Ground calibration
  - Darks at end of each sequence
  - Resets
- Electronic Cross Talk
  - Ground testing

Relative Photometry Calibration Plan

Error Source	Allocated Margin	Requirement	Implementation
Detector Chain	1.0%	R-CAL-B-NP-1400	R-GDP-CAL-140,141,142
Small Scale Flat	0.5%	R-CAL-B-NP-1100	R-GDP-CAL-120
Large Scale Flat	0.6%	R-CAL-B-NP-1200	R-GDP-CAL-130
Source Extraction	0.6%	R-CAL-B-NP-1300	R-GDP-CAL-170
Background Subtraction	0.5%	R-CAL-B-NP-1500	R-GDP-CAL-160
Data Processing	0.14%		
Margin	0.1%		
Total	1.5%	R-CAL-A-NP-1000	

Photometry Calibration

- Small Scale Flat (<100 pixels)
  - Internal LED lamps
  - Ground testing of QE and Lamp illumination
- Large Scale Flat (>100 pixels)
  - Generated via self calibration
    - Repeat observations of objects
  - Self calibration field
    - ~4 deg, 60 dithers
    - Same exposure time as science data
    - ~ Monthly visits
  - Also use science data
    - Requires optimization of dither pattern
    - Not guaranteed to meet requirements
- Source Extraction
  - Flow down from GDPRD
  - See OU-MER presentation
  - Implicit requirement on PRF knowledge
- Background subtraction
  - Develop background illumination model

Absolute Photometric Calibration

Error Source	Allocated Margin	Requirement	Implementation
Relative measurement error	1.5%	R-CAL-B-NP-3210,3220	
Measurement Noise	0.5%	R-CAL-B-NP-3100	
Error in absolute knowledge of transmission function	2%	R-CAL-B-NP-3200	
Knowledge of spectrophotometric response Per 10nm	3.8%	R-CAL-B-NP-3210, 3220	
Error in knowledge of standards	2%	R-CAL-B-NP-3300	
Margin	0.5%		
Total	5%	G-CAL-A-NP-3000	

Absolute Photometric Calibration

- Determine spectral response in ground calibration
  - Telescope responses 20nm steps
  - Instrument response 10nm steps
  - Filter response 10 nm steps
  - Detector QE 10nm steps
- Standard Stars
  - Range of exposure times
    - Multiple stars ranging from 14-22nd ABmag
  - >50 observations per star per year
  - Yearly observations of standards

Overview of Early Calibration

- Ground
  - Darks
  - Bias
  - Bad pixels
  - Non-linearity
  - Inter-Pixel Capacitance
  - Intra-pixel sensitivity variation
  - Mono-chromatic flats
    - Per-pixel QE
  - Filter, Instrument, Telescope throughput
  - Persistence
  - Astrometric model
- SV phase
  - Darks
  - Bias
  - Bad pixels
  - Non-linearity
  - Lamp flats
  - Self-calibrated flats
  - PSF verification of stars
  - Persistence model verification
  - On-board processing verification
  - Standard star observations
  - Astrometric calibration

In Mission Calibration

- Continuous
  - Bad Pixels
  - Bias
  - Persistence
  - On-board processing verification
- Once a month
  - Darks
  - Flats
- Every six months or more
  - Non-linearity
  - Astrometry
  - Calibration stars

- Will require re-processing
  - Updates and trending of calibrations
  - Nominal cadence ~6 months

Spectroscopy Wavelength Calibration Plan

Error Source	Allocated Margin	Requirement	Implementation
Zero-Point determination	0.6 pixels	R-CAL-B-NS-1100	R-GDP-CAL-171,175
Solution Calibration	0.5 pixels	R-CAL-B-NS-1200	
Total	0.8 pixels	R-CAL-A-NS-1000	

Wavelength Calibration

- Zero-point calibration
  - Astrometric calibration
    - Imaging and spectroscopy
    - Zeroth order to imaging calibration
  - Ground calibration needed
    - Verified in flight
- Relative calibration
  - Ground calibration
    - relative order positions
    - Wavelength solution
  - In-flight
    - spectral trace calibration
    - Planetary Nebula
    - Open Clusters
    - ~6 month cadence

Relative Spectroscopy Calibration Plan

Error Source	Allocated Margin	Requirement	Implementation
Detector Chain	1.0%	R-CAL-B-NS-2400	R-GDP-CAL-140,141,142
Small Scale Flat	2.5%	R-CAL-B-NS-2100	R-GDP-CAL-120
Large Scale Flat	2.5%	R-CAL-B-NS-2200	R-GDP-CAL-130
Source Extraction	1%	R-CAL-B-NS-2300	R-GDP-CAL-170
Background Subtraction	1%	R-CAL-B-NS-2600	R-GDP-CAL-160
Margin	0.7%		
Total	4%	R-CAL-A-NS-2000	

Relative Spectroscopy Calibration Plan

- Detector chain shared with photometry
- Small Scale Flat (<100 pixels)
  - Ground based QE measurements
    - Detector, GRISM, Optics, Telescope
  - Flat field lamps in flight
    - Monthly cadence
- Large Scale Flat
  - Open cluster flat field observations
    - Yearly
  - Self calibration based on data
- Source extraction
  - GDPRD requirement
- Background subtraction
  - GDPRD requirement

Absolute Spectroscopic Calibration

Error Source	Allocated Margin	Requirement	Implementation
Relative measurement error	1.5%	R-CAL-B-NP-3210,3220	
Measurement Noise	0.5%	R-CAL-B-NP-3100	
Error in absolute knowledge of transmission function	2%	R-CAL-B-NP-3200	
Knowledge of spectrophotometric response Per 10nm	3.8%	R-CAL-B-NP-3210, 3220	
Error in knowledge of standards	2%	R-CAL-B-NP-3300	
Margin	0.5%		
Total	5%	G-CAL-A-NP-3000	

Absolute Spectroscopic Calibration

- Same plan as photometry
- Determine spectral response in ground calibration
  - Telescope responses 20nm steps
  - Instrument response 10nm steps
  - Filter response 10 nm steps
  - Detector QE 10nm steps
- Standard Stars
  - Range of exposure times
    - Multiple stars ranging from 14-22nd ABmag
  - >50 observations per star per year
  - Yearly observations of standards