
PRE-FLIGHT CALIBRATION & CHARACTERIZATION OF THE ENMAP SENSOR

LIVING PLANET SYMPOSIUM 2022 | BONN –
SESSION B6.03.1 ENMAP – THE GERMAN SPACEBORNE IMAGING SPECTROSCOPY MISSION

BERNHARD SANG | OHV-SYSTEM AG, 19.05.2022

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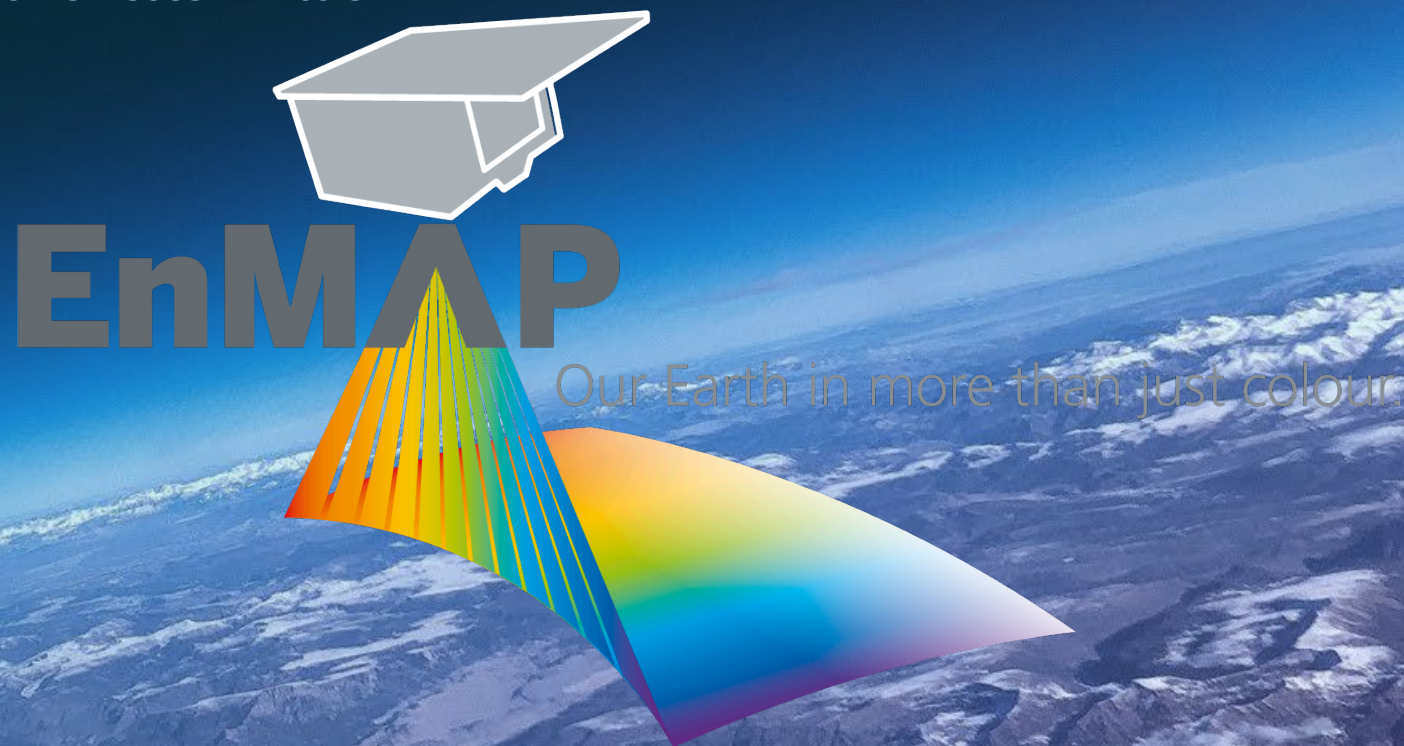
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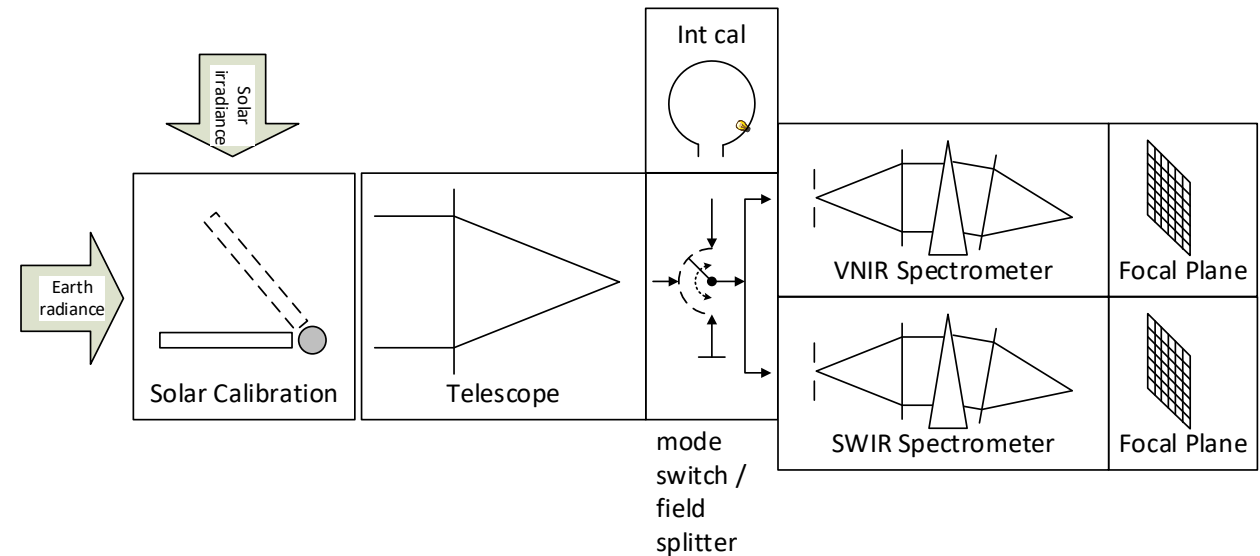


ENMAP SENSOR SPECIFICATION & CONCEPT

main sensor specifications

Parameter	VNIR	SWIR
GSD	30m Nadir @ 653km alt	
Swath	30km Nadir	
Spectral range	420-1000nm	900-2450nm
Spect. sampling int.	6.5 nm avg	10nm avg
Spectral resolution	< 1.25 * SSI	
Spectral accuracy	0.5nm	1nm
Smile	< 0.2 SSI	
Keystone	< 0.2 GSD	
MTF	> 25% @ Nyquist	
Radiometric accuracy	5%	
Polarization sens.	< 5%	
SNR @ Lref (10nm eqv. BW)	> 500 @495nm	> 150 @2200nm

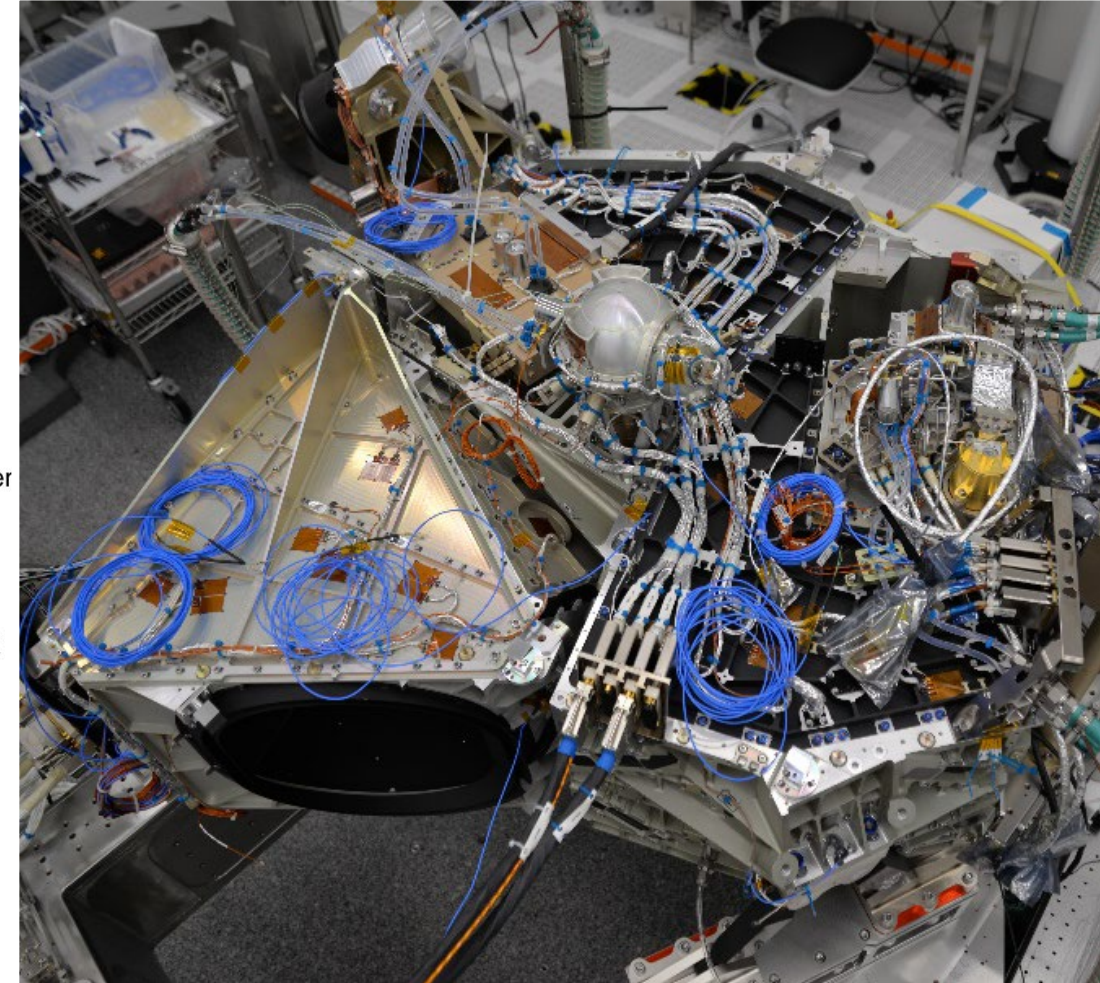
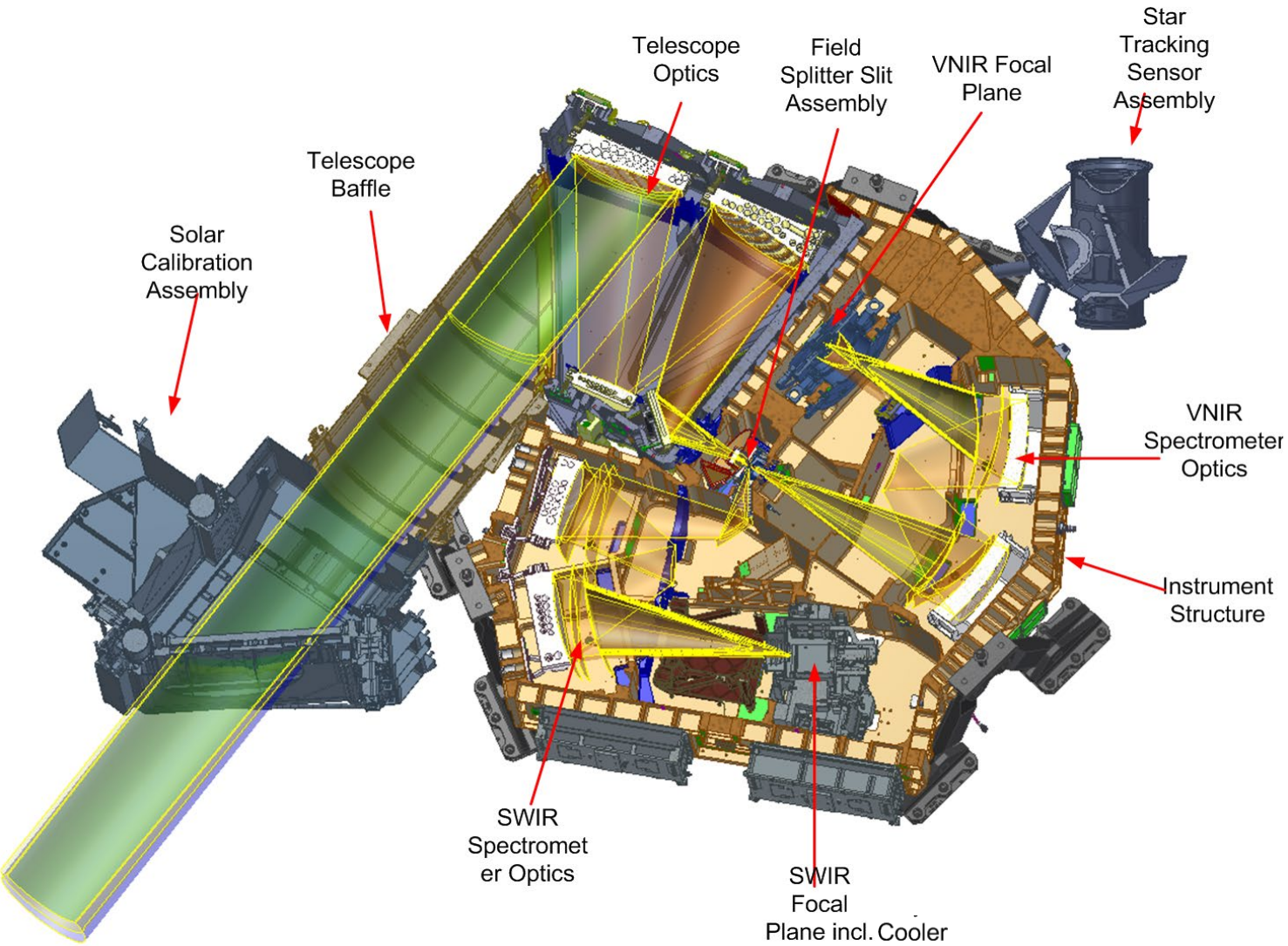
Sensor concept



- Pushbroom imaging spectrometer
- Dual prism based spectrometers VNIR / SWIR
- Separated FOVs for VNIR/SWIR
- Calibration devices for radiometric and spectral referencing

ENMAP HYPER SPECTRAL IMAGER

OPTICAL UNIT DESIGN



PRE-FLIGHT CALIBRATION SETUPS

RADIOMETRIC SETUPS

White light large aperture Ulbricht Sphere illumination

Optional full aperture polarizer

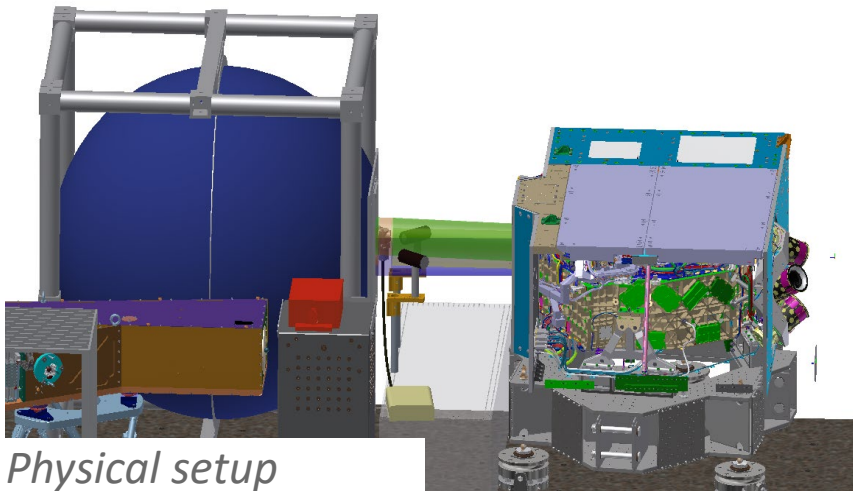
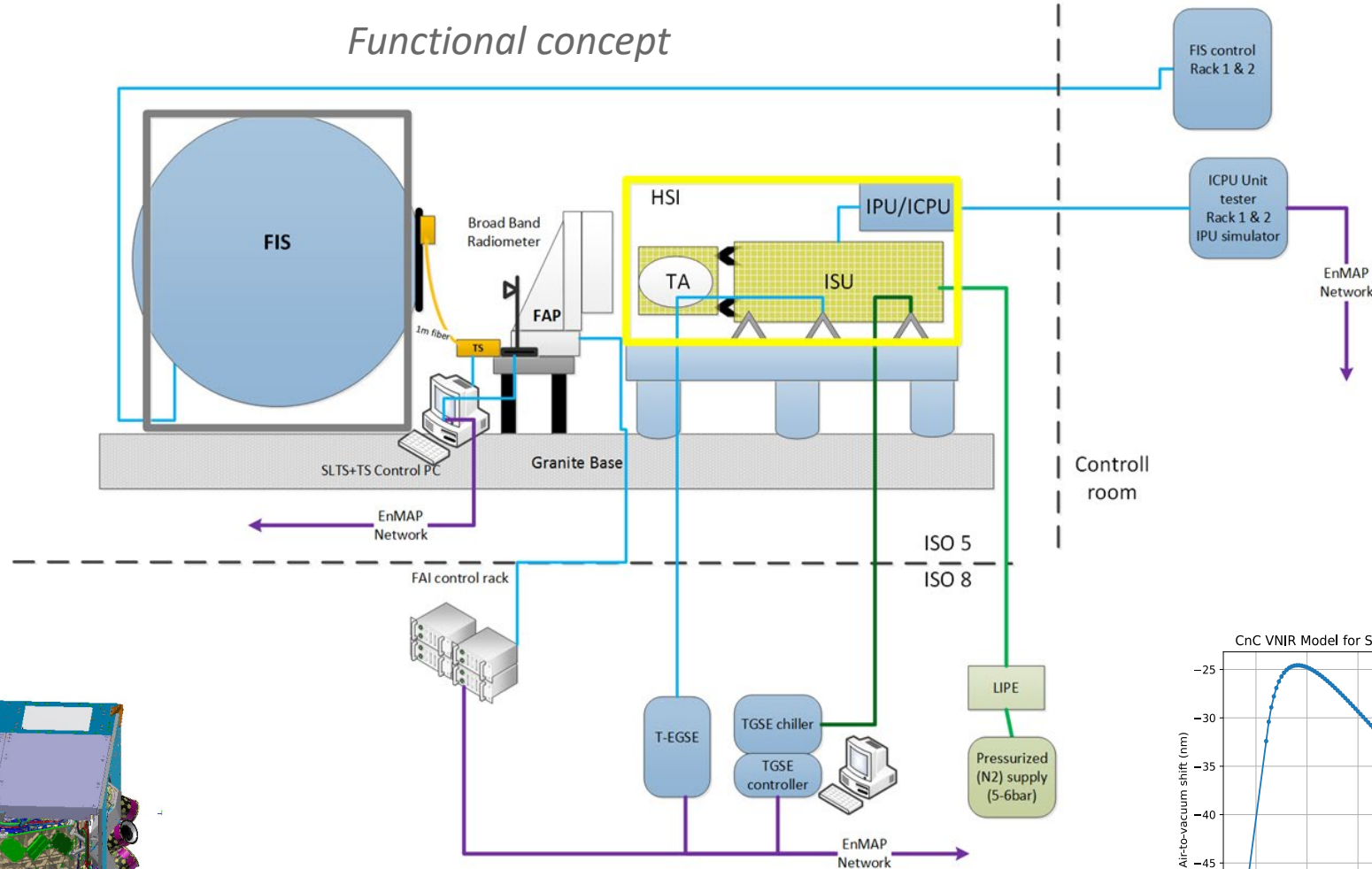
All calibrations performed in air data corrected for pressure

Clean room thermal control $\pm 0.5^\circ\text{C}$

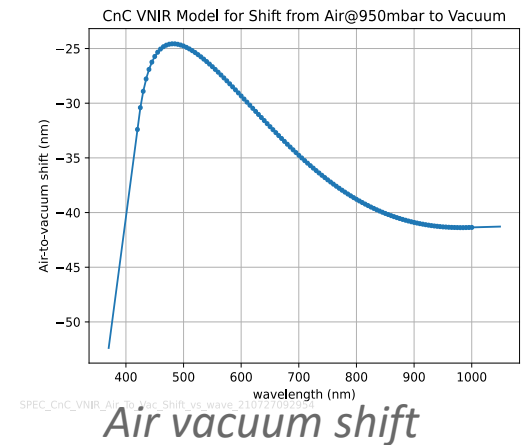
Active thermal control of HSI

High degree of automation

Functional concept



Physical setup



PRE-FLIGHT CALIBRATION SETUPS

GEOMETRIC, SPECTRAL AND STRAY LIGHT SETUP

Three setup configurations

- Internal geometry and MTF
- Spectral C&C
- Stray light

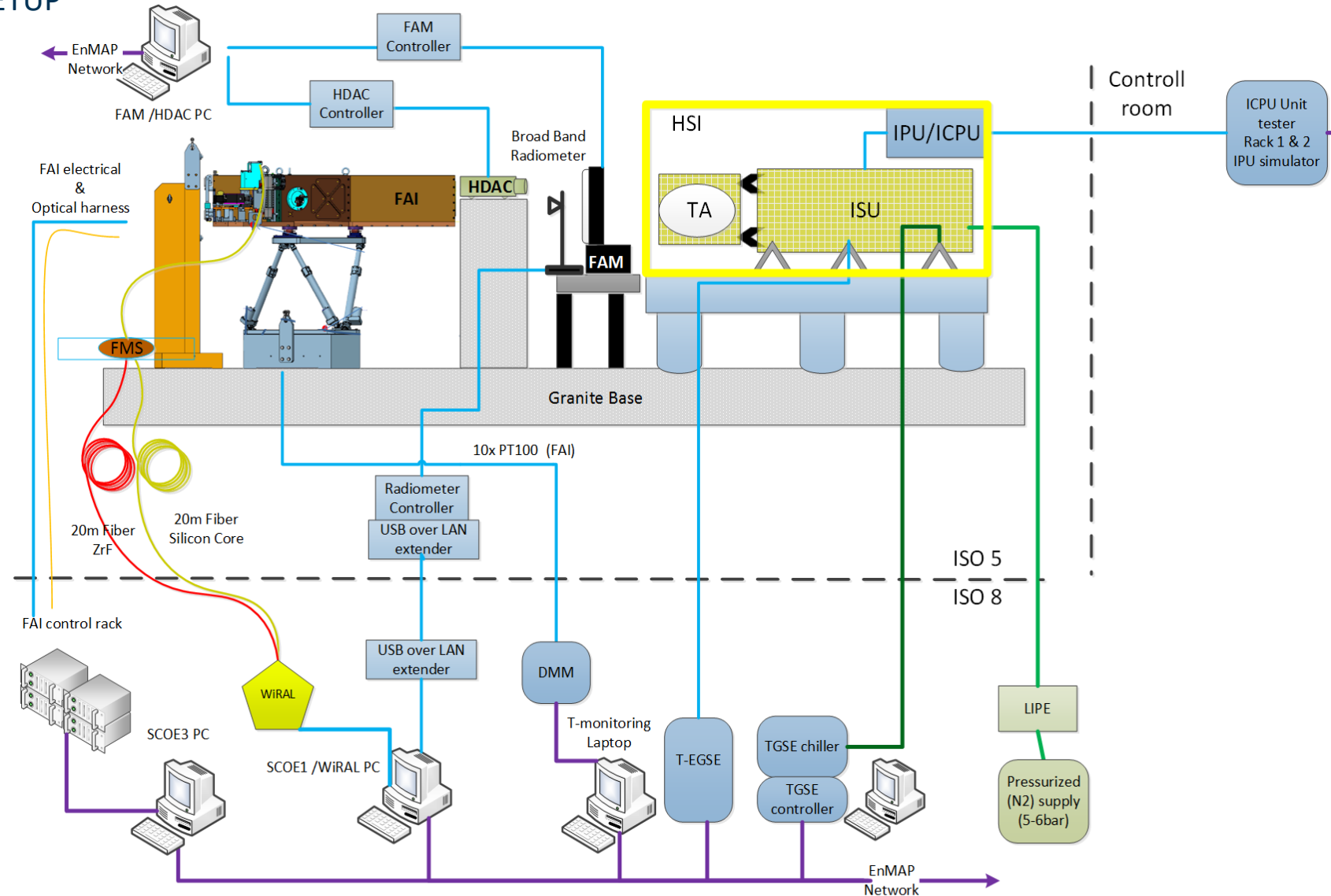
FAI – full aperture illuminator incl focal plane target and WFS

WIRAL – wide range adjustable light source

HDAC – high dynamic range autocollimator

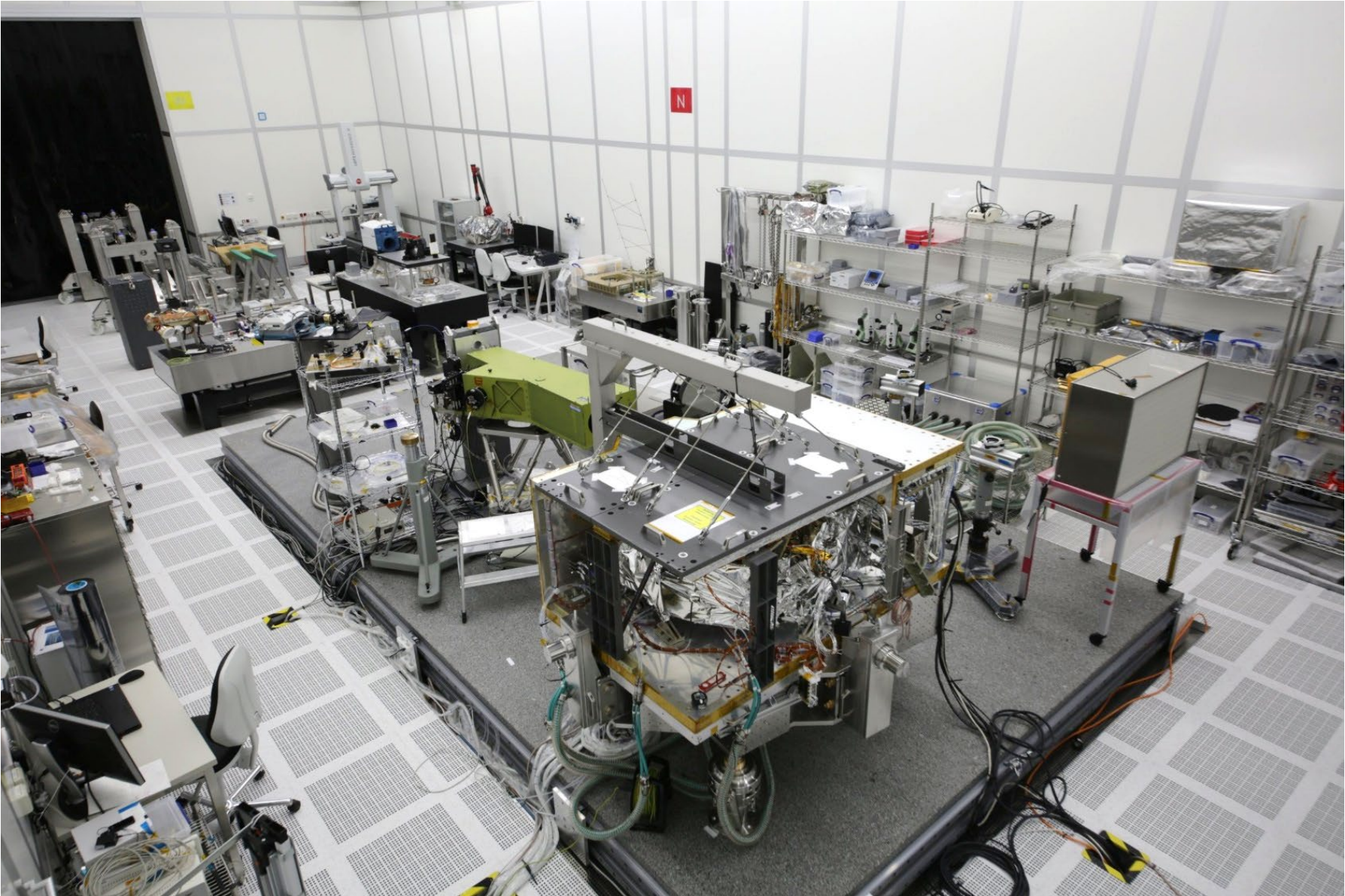
FAM – full aperture mirror

Setup on floating 40t granite base – for ultimate geometric precision



Functional concept

ENMAP HSI INTEGRATION & CHARACTERIZATION

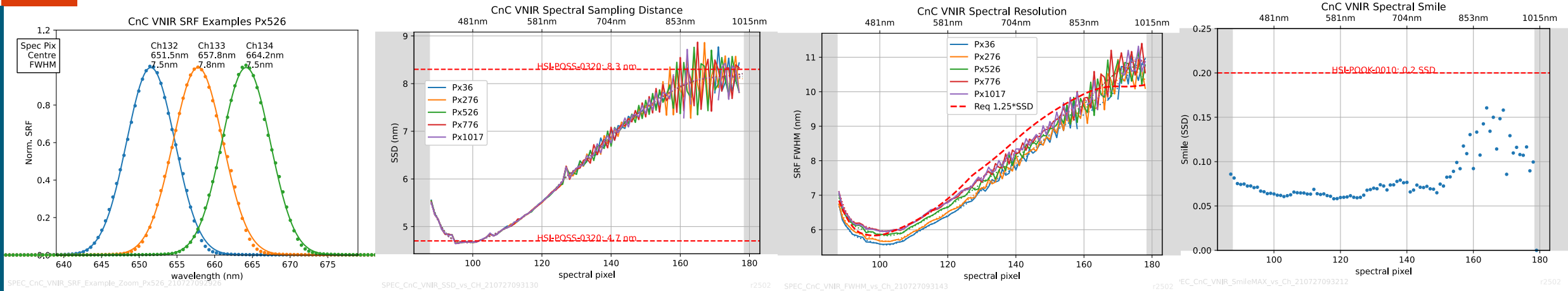


SPECTRAL CALIBRATION

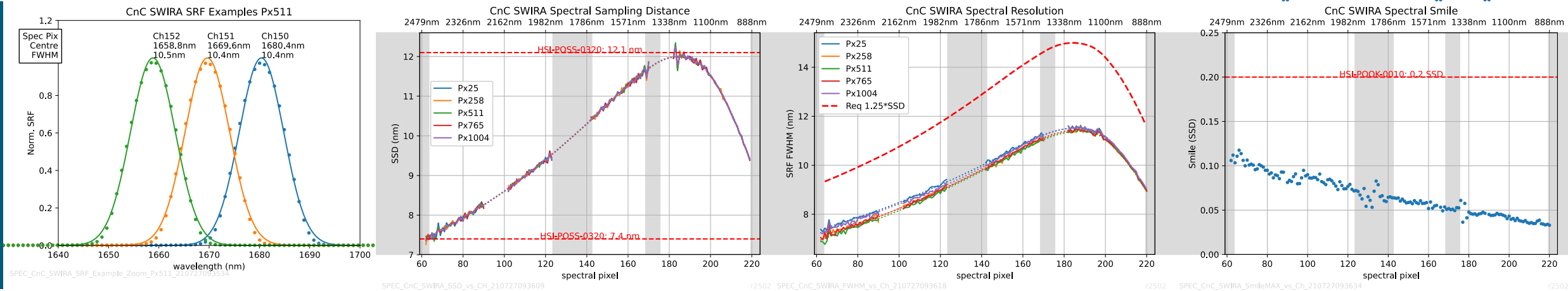
MAIN RESULTS: SSI, FWHM, SMILE



VNIR



SWIR



SRF examples

spectral sampling interval

spectral resolution FWHM

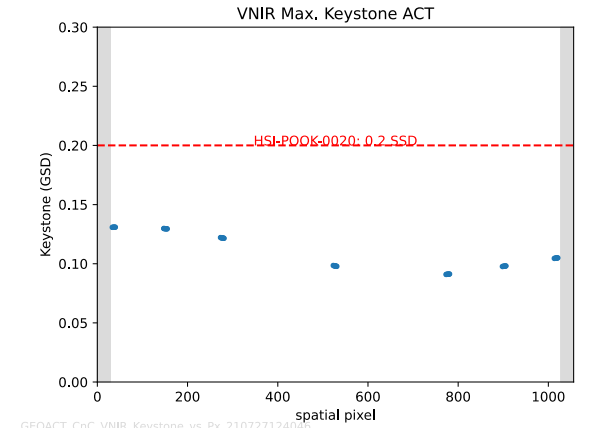
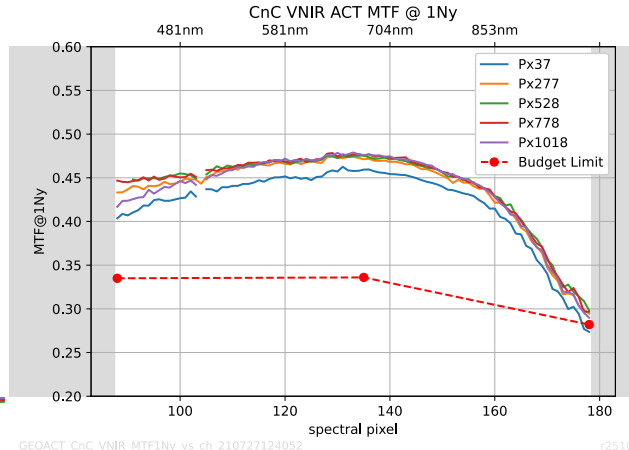
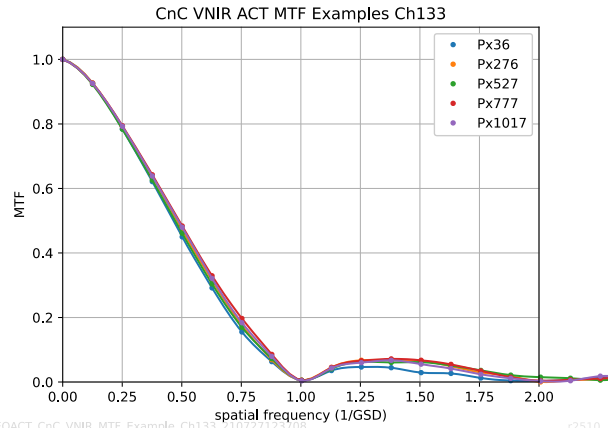
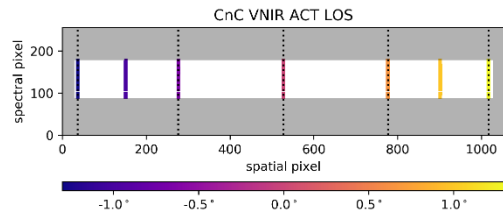
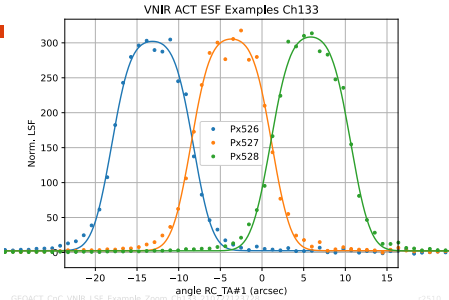
spectral smile

GEOMETRIC CALIBRATION

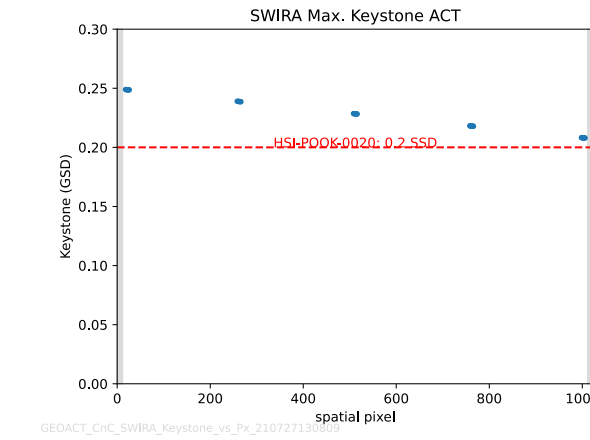
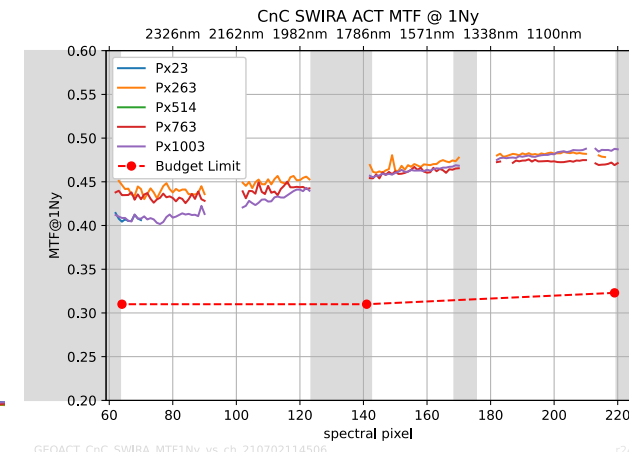
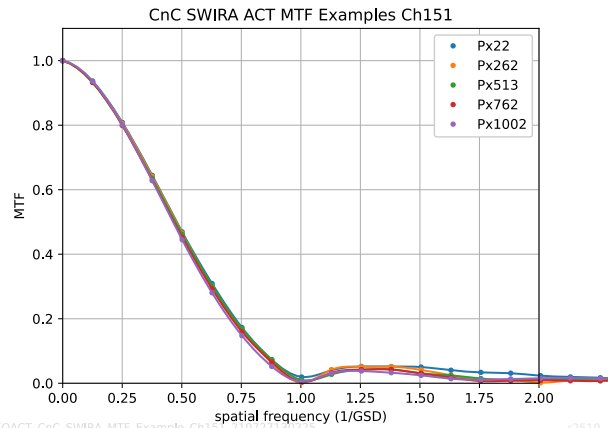
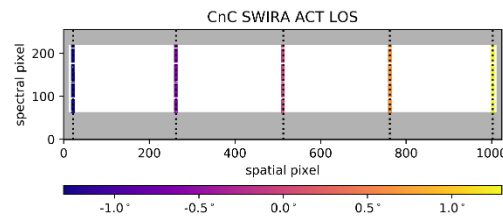
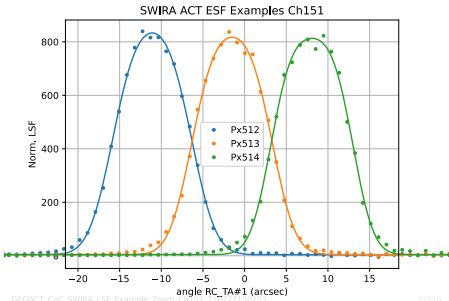
MAIN RESULTS: MTF ACROSS TRACK | KEYSTONE



VNIR



SWIR



PSF examples / scans

MTF vs spatial freq

MTF @ Nyquist

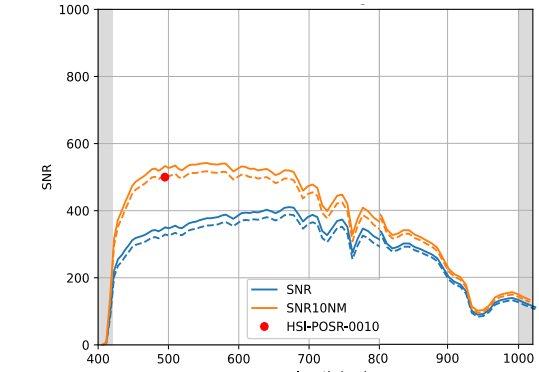
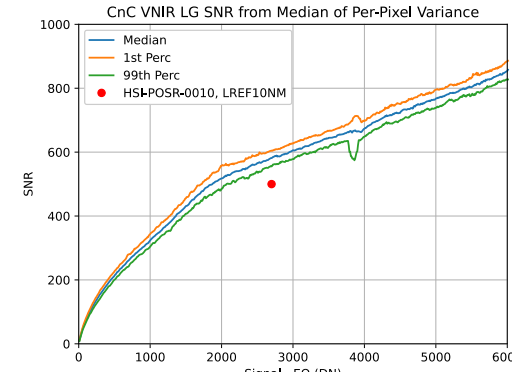
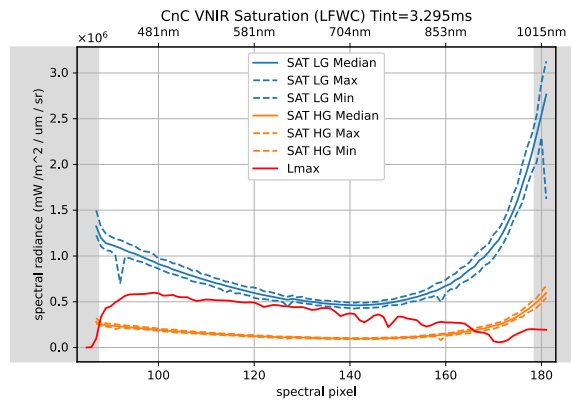
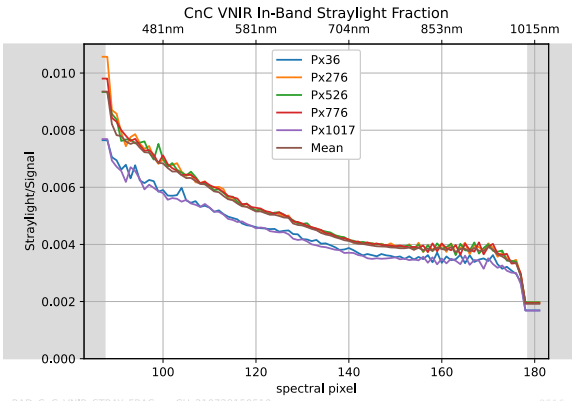
keystone

RADIOMETRIC CALIBRATION

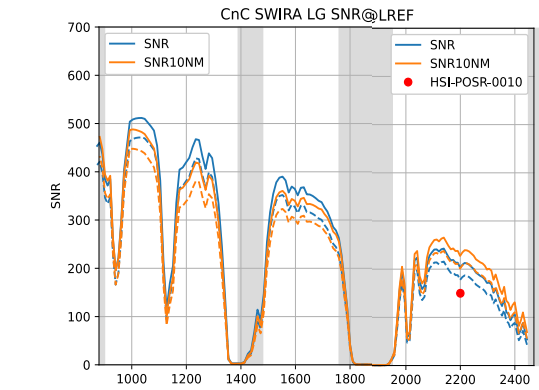
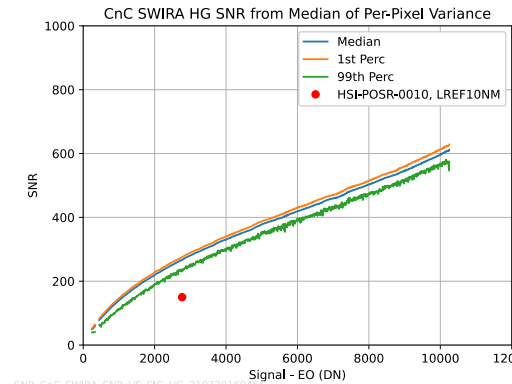
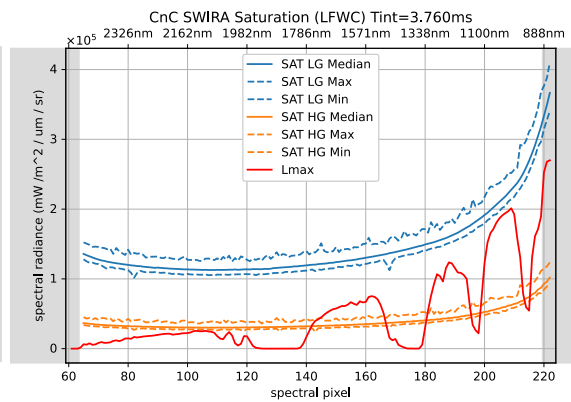
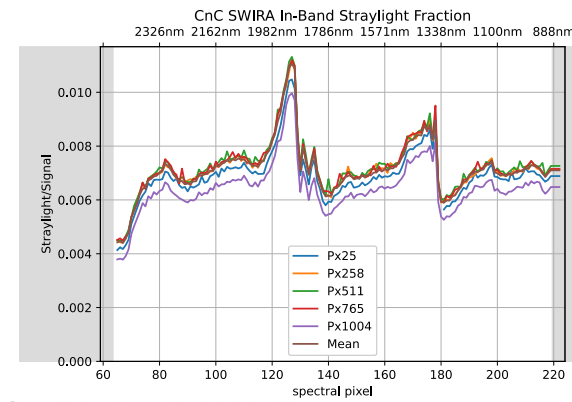
MAIN RESULTS: STRAY LIGHT, DYNAMIC RANGE, SIGNAL TO NOISE



VNIR (tint 3.295ms)



SWIR (tint 3.76 ms)



stray light fraction

dynamic range

SNR vs signal

SNR vs wvl @ Lref

MEASUREMENT UNCERTAINTIES

AS DETERMINED DURING C&C CAMPAIGN



Parameter	Required C&C Accuracy	Achieved Acc. VNIR Range	Achieved Acc. SWIR Range
Spectral Registration	0.5nm	0.14nm	0.13nm
Smile	0.02 SSI	0.017 SSI	0.007 SSI
Spectral resolution	1 nm	0.175 nm	0.174 nm
Sensor geometry	1 arcsec	0.492 arcsec	
Keystone	0.2 arcsec	0.043 arcsec	
MTF	5%	3%	
IFOV	1 arcsec	0.145 arcsec	
Rad acc	5%	1.13% + ref std uncert	2.34% + ref std uncert
RNU	0.5%	0.22%	0.15%
SNR	10%	4%	2%
Polarization sensitivity	0.5%	0.181%	

All setup measurement uncertainties exceed requirements and confirm excellent setup design and operations

ENMAP FIRST LIGHT

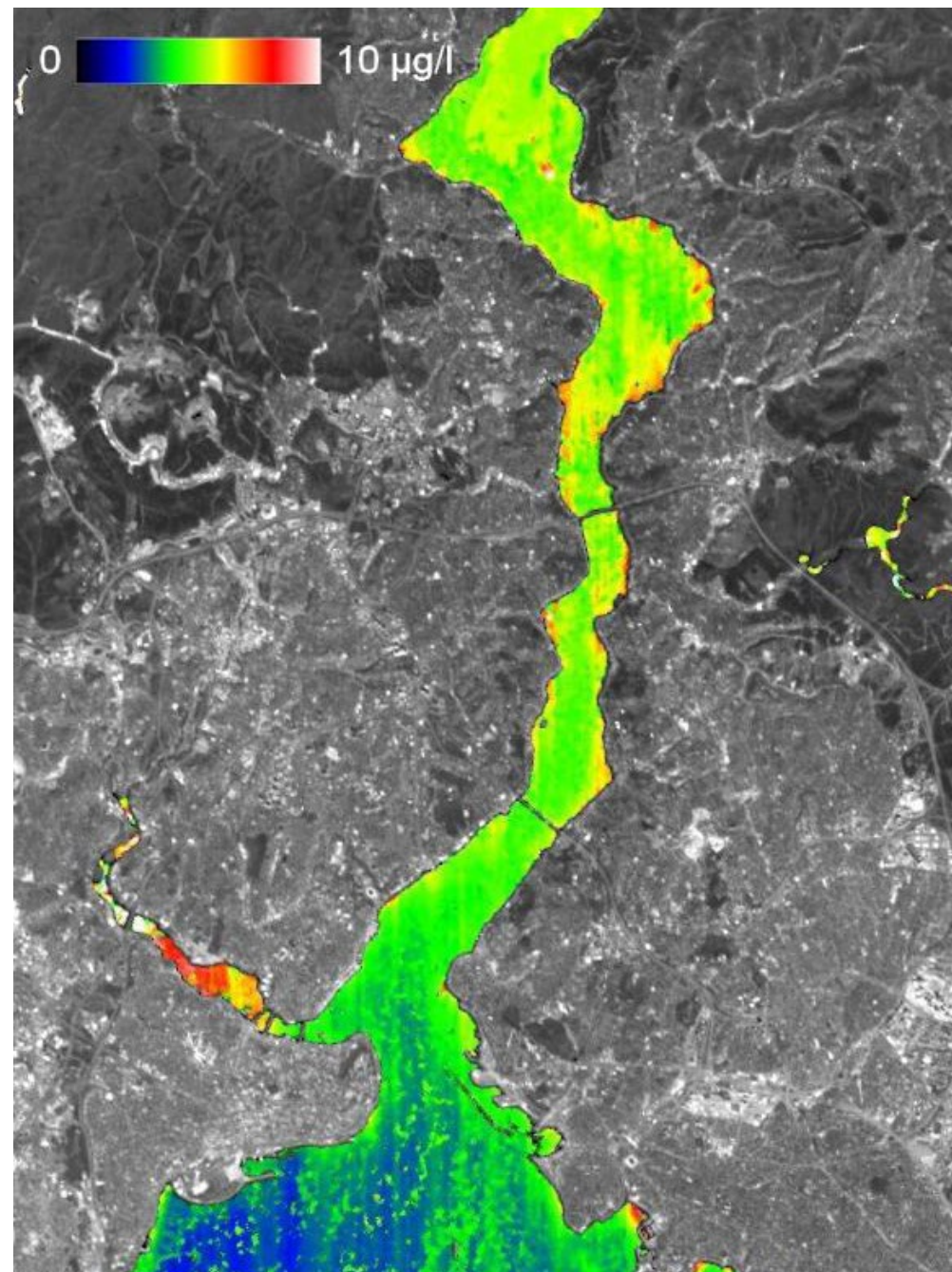
Location: Bosporus

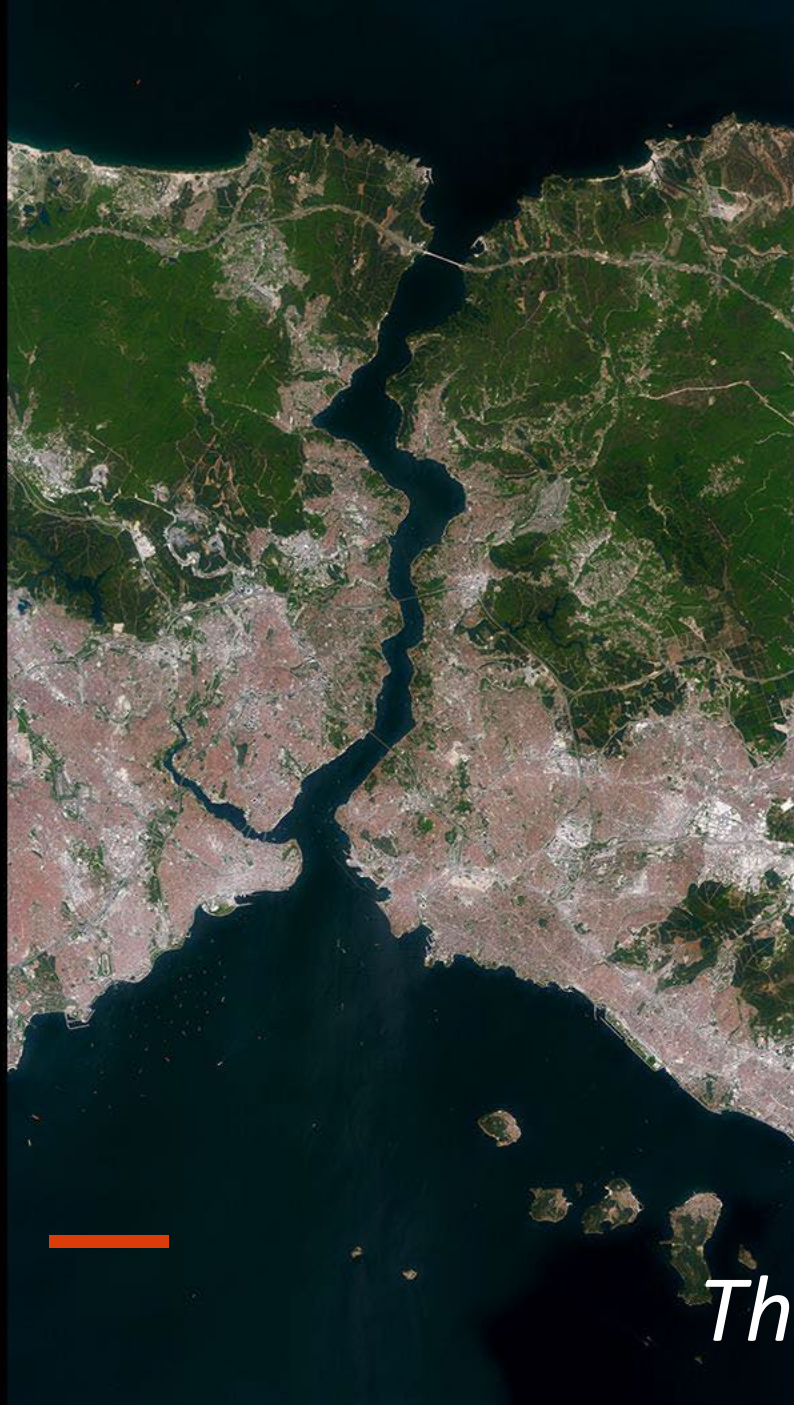
Data product: concentration of chlorophyll

First L2 data product (demonstration)

Use of pre-flight calibration for L1 processing

High data quality of product even w/o in-flight calibration



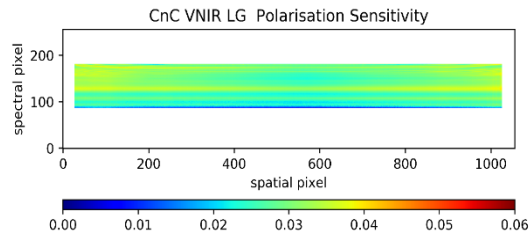


Thank you for your patience

RADIOMETRIC CALIBRATION

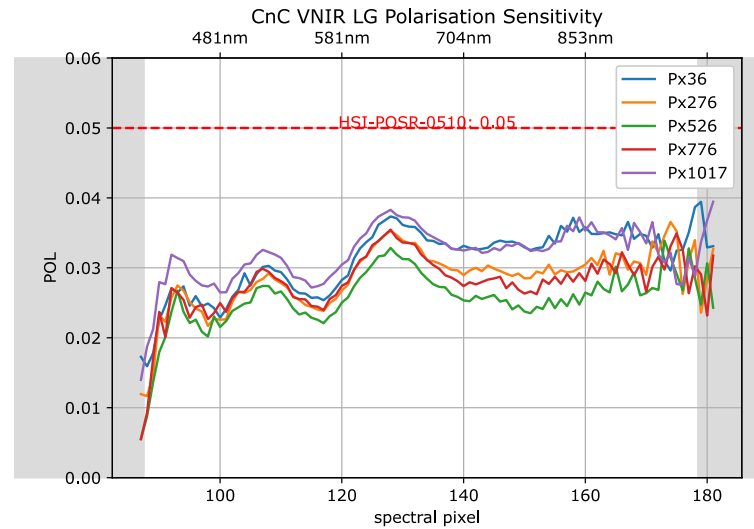
POLARIZATION SENSITIVITY

VNIR



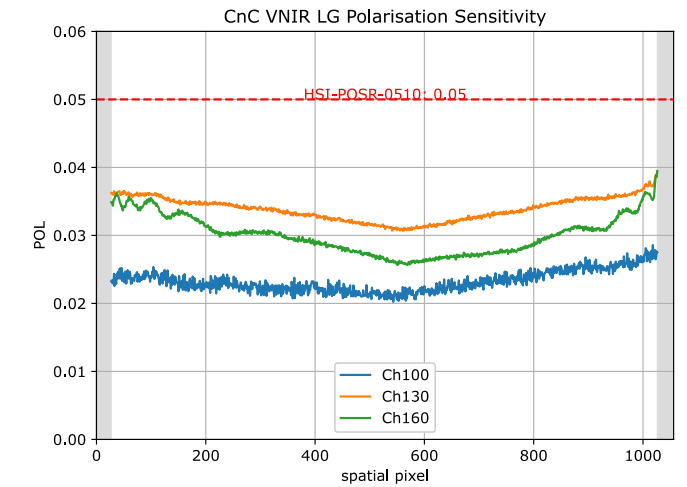
POL_CnC_VNIR_POL_MAP_210614174741

r2454



POL_CnC_VNIR_POL_VS_CH_210614174742

r2454

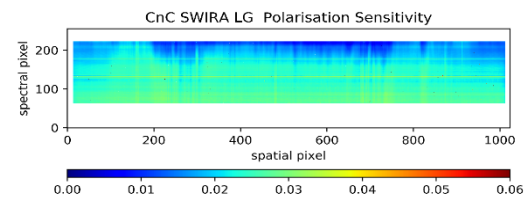


POL_CnC_VNIR_POL_VS_PX_210614174743

r2454

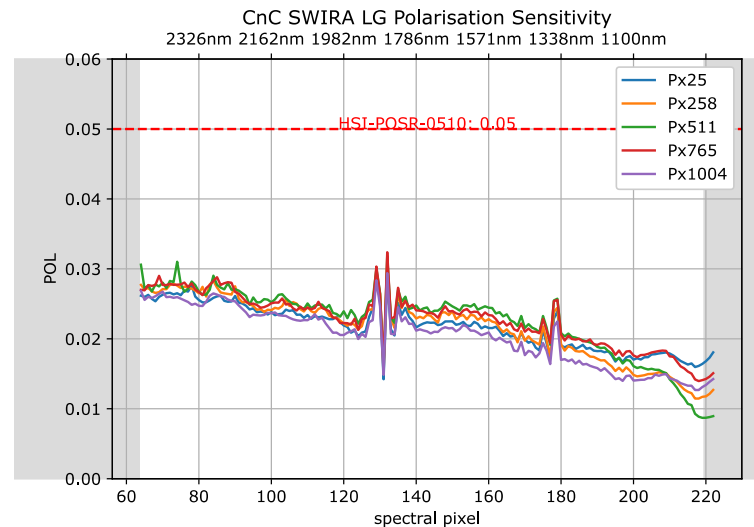
Polarization sensitivity less than 4% for all spectral channels and fields

SWIR



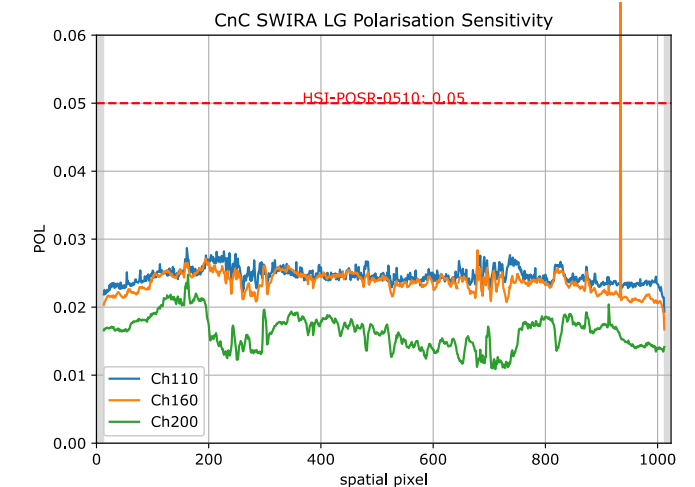
POL_CnC_SWIRA_POL_MAP_210614174757

r2454



POL_CnC_SWIRA_POL_VS_CH_210614174758

r2454



POL_CnC_SWIRA_POL_VS_PX_210614174800

r2454

PS maps

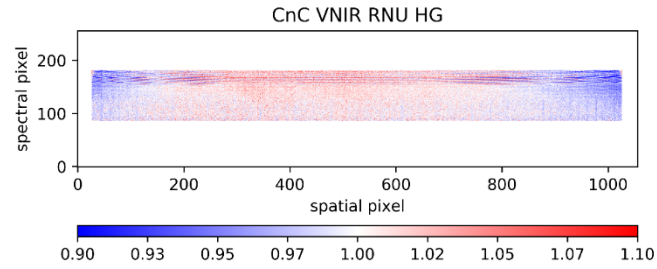
PS vs spectral bands examples

PS vs field examples

RADIOMETRIC CALIBRATION

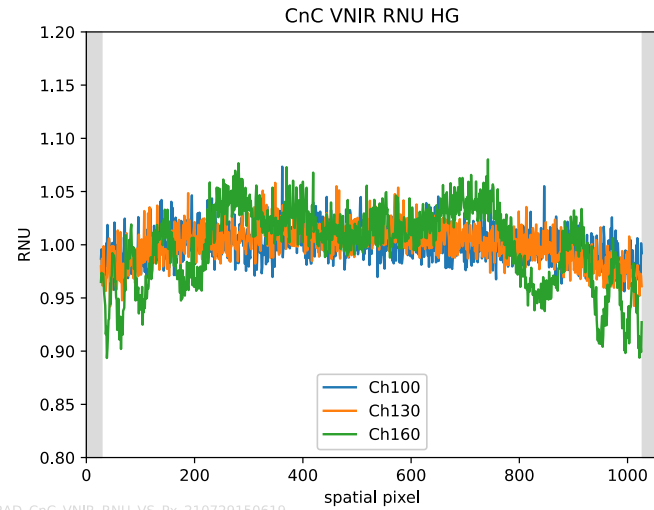
RELATIVE NON-UNIFORMITY

VNIR



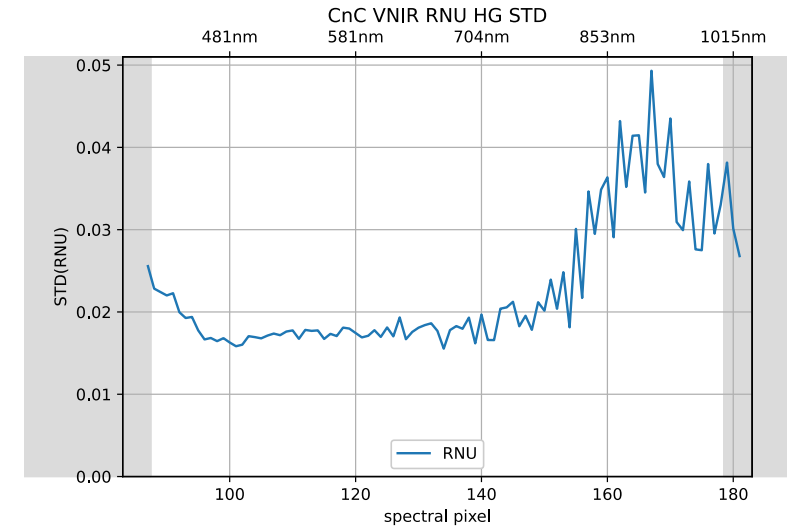
RAD_CnC_VNIR_RNU_MAP_210729150616

r2516



RAD_CnC_VNIR_RNU_VS_Px_210729150619

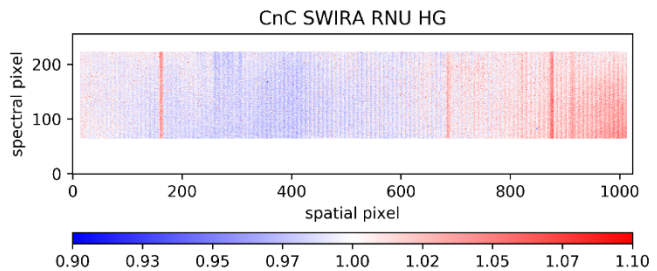
r2516



r2516

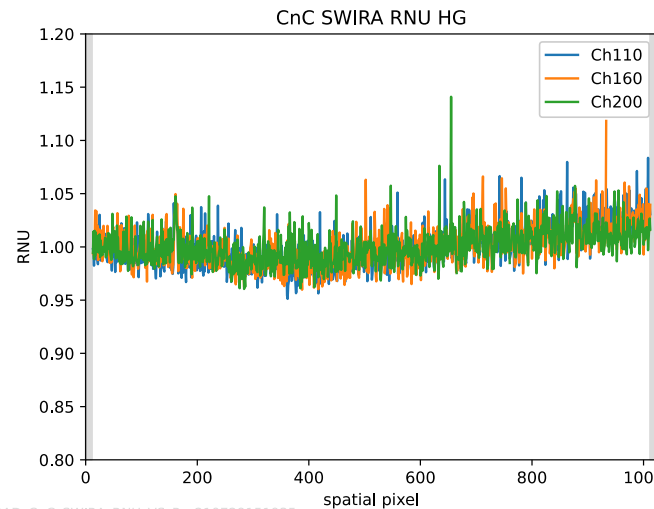
r2516

SWIR



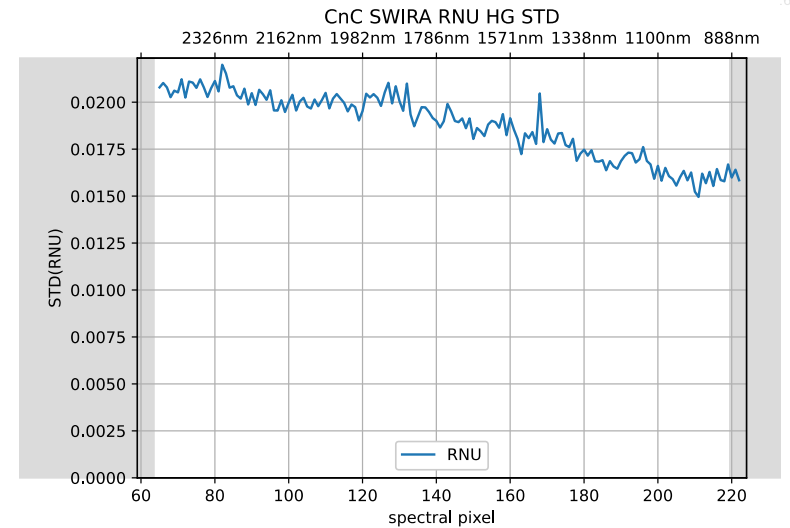
RAD_CnC_SWIRA_RNU_MAP_210729151932

r2516



RAD_CnC_SWIRA_RNU_VS_Px_210729151935

r2516



r2516

RAD_CnC_SWIRA_RNU_STD_vs_Ch_210729151940

r2516

RNU maps

RNU vs field examples

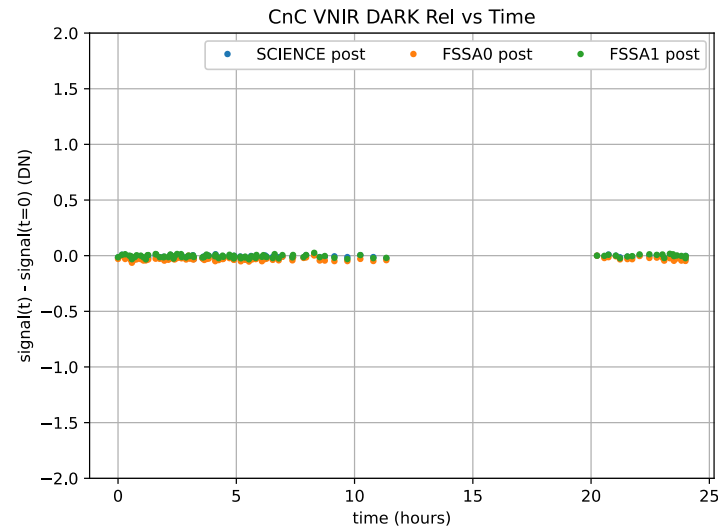
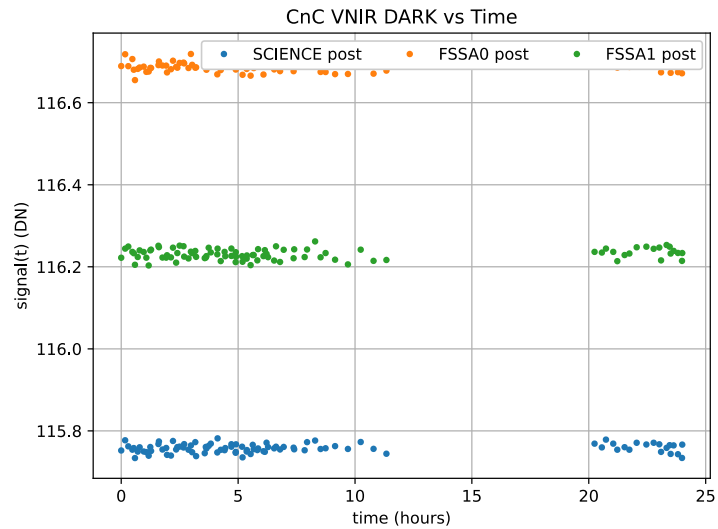
stdev (RNU) per band

RADIOMETRIC CALIBRATION

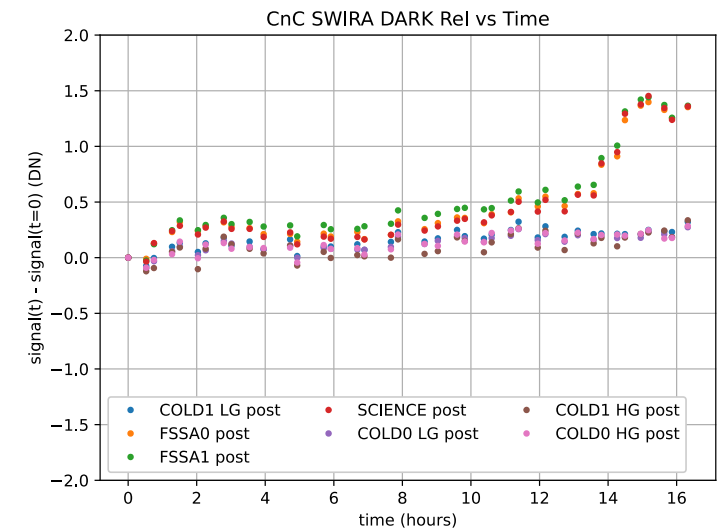
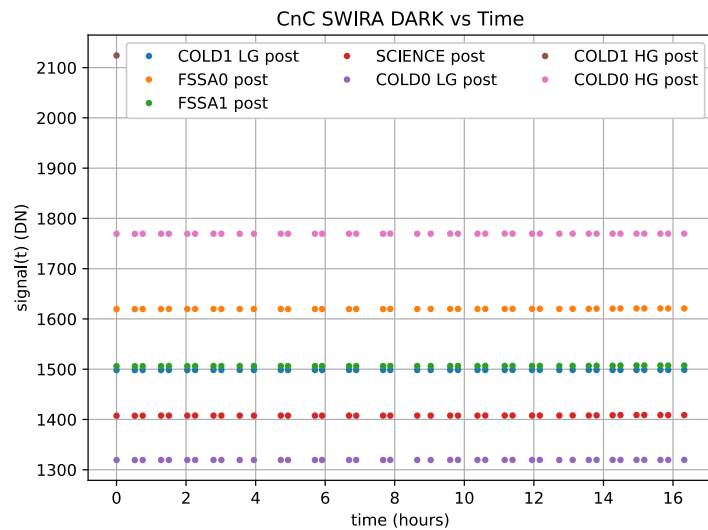
DARK SIGNAL STABILITY



VNIR



SWIR



Very high dark signal stability

VNIR < 0.1 DN / 24h

SWIR < 1.5 DN / 24h