Agenda for breakout workshop #8 at IOCS 2019: Sensor Calibration

Chair: Gerhard Meister, NASA

IOCS 2019

International Ocean Color Science Meeting

Busan, South Korea, April 11 2019

Agenda for this meeting:

- 9:30 Gerhard Meister: Introduction
- 9:35 Gerhard Meister: Calibration program for the Ocean Color Instrument (OCI) on the PACE mission
- 9:50 Jack Xiong: JPSS-2 VIIRS pre-launch calibration and characterization
- 10:05 Ludovic Bourg: OLCI-B straylight correction performance assessment using Moon observation
- 10:20 Shihyan Lee: Estimating straylight impact on ocean color products based on point-spread functions
- 10:35 Kibeom Ahn: On-orbit calibration results of GOCI and pre-launch test results of GOCI-II
- 10:50 Menghua Wang or alternate: NOAA VIIRS calibration results
- 11:05 Break
- 11:15 Hiroshi Murakami: Radiometric calibration of SGLI on-orbit
- 11:30 Xianqiang He: On-orbit performance of the HY-1C/COCTS
- 11:45 Ewa Kwiatkowska or alternate: OLCI-A and OLCI-B calibration and characterization
- 12:15 Ludovic Burg: OLCI-A and OLCI-B cross-calibration using the tandem-flight period

Venue for next meeting:

- No IOCS in 2021
- Next IOCS in 2023 is too late for IOCCG Sensor Calibration Task Force
- Independent meeting may not attract enough attendance
- Possibilities include

  - Sentinel-3 Validation team meeting; timing/location unknown
  - SPIE Optics and Photonics meeting in San Diego (usually in August); good chance to obtain independent session in 'Earth Observing Systems' via Jim Butler and Jack Xiong
  - IVOS (part of CEOS); good chance we could get independent session or simply be part of everything (good thematic overlap); location unknown
  - Please email me other suggestions

- I will conduct survey by email after this meeting

More housekeeping:

- All our presentations will be put on the web (either IOCS or IOCCG)
  - if there are certain slides that you do not want to be made public, please send me a version of your presentation without them

- We will be recorded!
  - a request by KIOST, they want to add it to the IOCS website
  - if you prefer not to be recorded, please let us know, we can interrupt the recording for your talk

- We were asked to submit a sentence on ideal future impact and capability and 3 key recommendations (bullets)
  - let's take a few minutes after the last talk to discuss this

Calibration Program for the Ocean Color Instrument (OCI) on the Plankton, Aerosol, and Cloud ocean Ecosystem (PACE) mission

Gerhard Meister, PACE OCI Instrument Scientist, NASA Code 616

Acknowledging several OCI Engineers who provided slides for this presentation

IOCS 2019

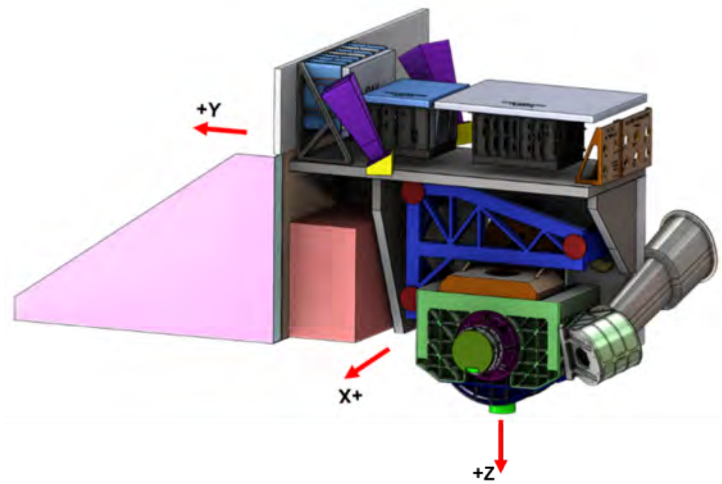
International Ocean Color Science Meeting

Busan, South Korea, April 11 2019

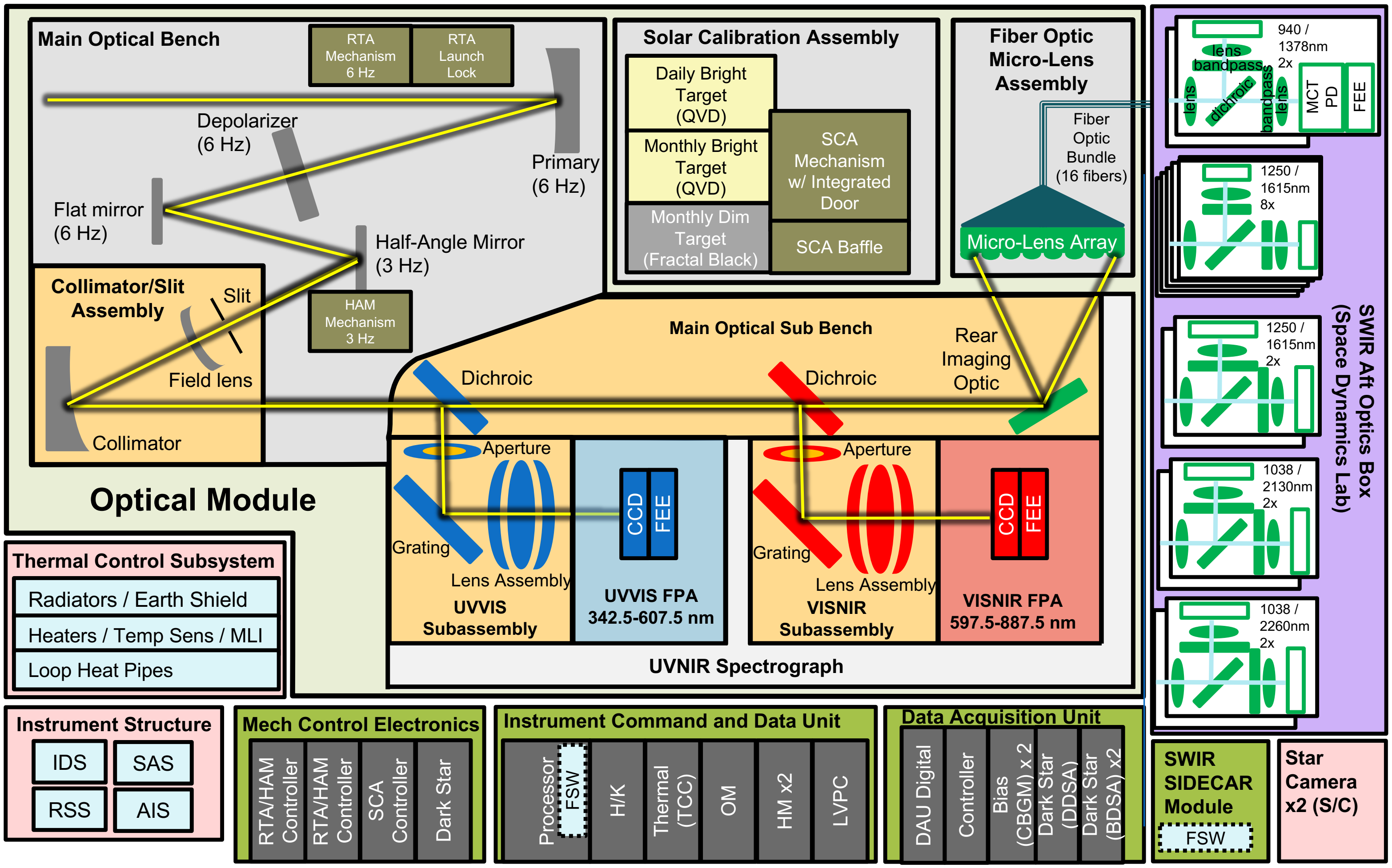
OCI Instrument Overview

Instrument Mass	260 kg CBE
Instrument Power	320 W CBE , Orbital Average
Thermal System	Passive Cooling
Mechanisms	Rotating Telescope Mechanism (~6Hz) Half Angle Mirror Mechanism (~3Hz) Solar Calibration Mechanism (<500 Cycle)
Deployments	Rotating Telescope Launch Lock Radiator Earth Shield (TBD)
Ground Sample Distance	1000m
Aperture	90mm
iFOV	0.08° Along Track x 1.42° Cross Track
Effective Focal Length	0.134m
System F/Number	1.48
Total Field of Regard	+/- 56.5°
Dynamic Range	SNR at L_{typ} , No Saturation at L_{max}
UVNIR Bands (nm)	340 – 890 , 5nm Resolution
NIRSWIR Bands (nm)	940, 1038, 1250, 1378, 1615, 2130, 2260
UVVIS & VISNIR FPAs	2 CCDs, 128 x 512, 26 micron Integrated 14 Bit ADC
NIRSWIR FPAs	32 Photodiodes, < 250 micron Analog output to remote SIDECAR ASIC
Relative Radiometric Accuracy	< 0.5% Pre-Launch 1-sigma
SNR @ L_{typ}	> 1000:1: 340 – 700nm > 600:1: 700 – 865nm > 50:1 940 – 2260nm
On-Board Solar Calibration Assembly	Daily and Monthly Solar Calibration Targets
Orbital Average Data Rate	13 Mbps up to 40 Mbps

- Cross-Track Rotating Telescope
- UVVIS & VISNIR Slit Grating Hyperspectral Spectrographs
  - 2 CCD FPAs with On-Chip TDI Synchronized with Rotating Telescope and Half Angle Mirror
- NIR-SWIR Fiber Coupled Multiband Filter Spectrograph
  - 32 InGaAs/MCT Single Photo Diode FPAs with Digital TDI
- Concept follows the heritage of the SeaWiFS, MODIS, and VIIRS
- Working engineering development unit demonstration (IIP)

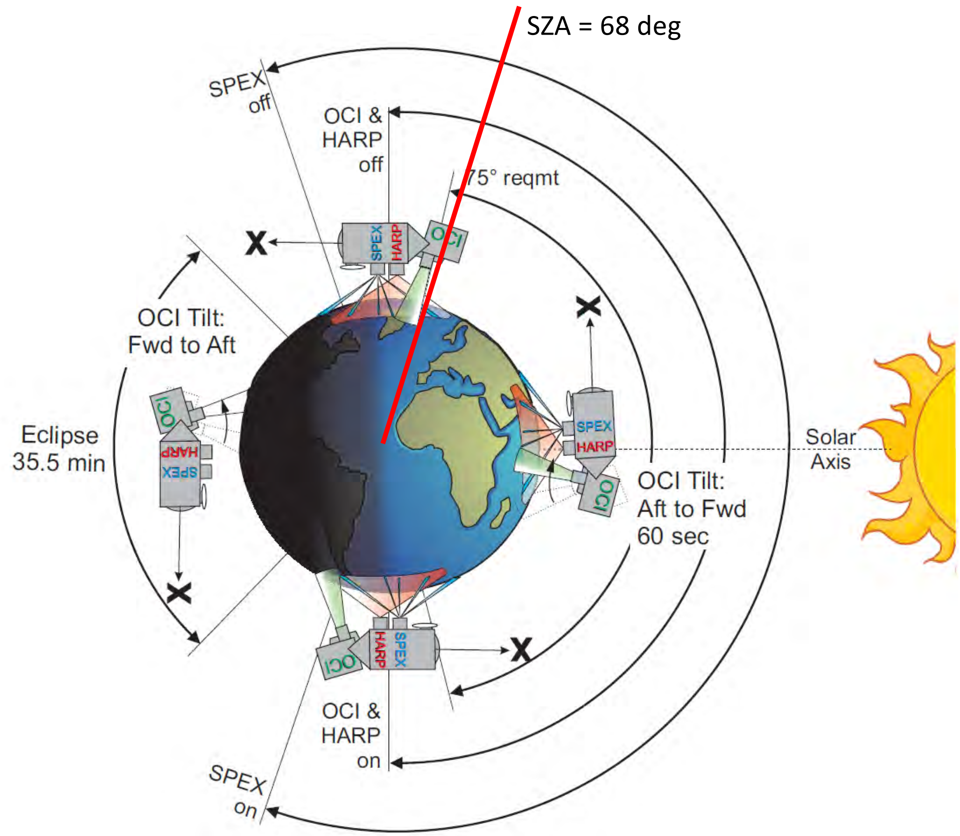


OCI Instrument System Block Diagram
2259624 Revision A



Orbit-in-the-Life: Normal OPS incl. solar calibration

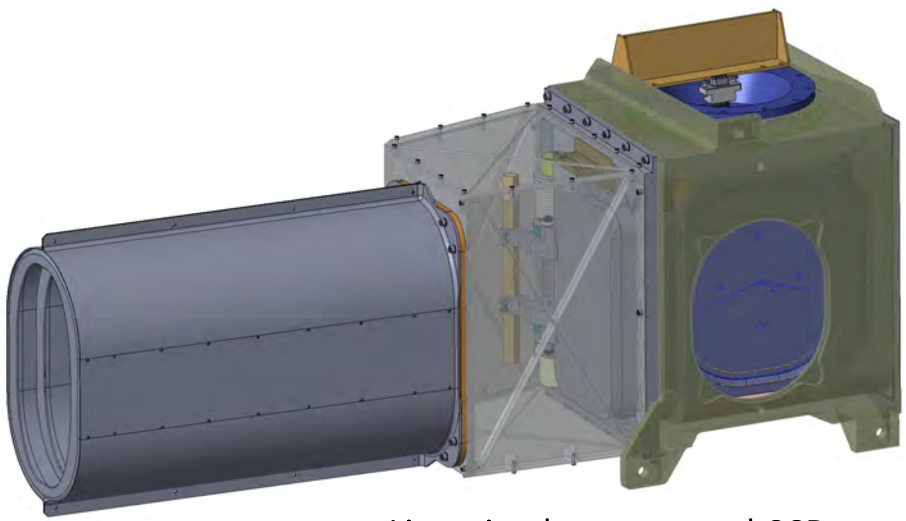
- OCI Data Collection:
  - Rqmt: To 75º solar zenith angle (SZA)
  - Goal: To 88°
- OCI Data Rate:
  - 20 Mbps orbit avg
- OCI Glint Avoidance:
  - 20º aft tilt in south
  - 20º forward tilt in north
- 40º tilt, aft to fore, near sub-solar point
  - 60 seconds data loss
  - Shifted every 2 days to fill in sub-solar region
- Solar calibration starts at 68º SZA

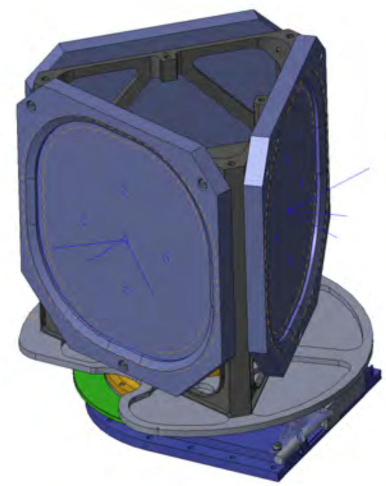


OCI Solar Calibration Assembly

Preliminary design drawings

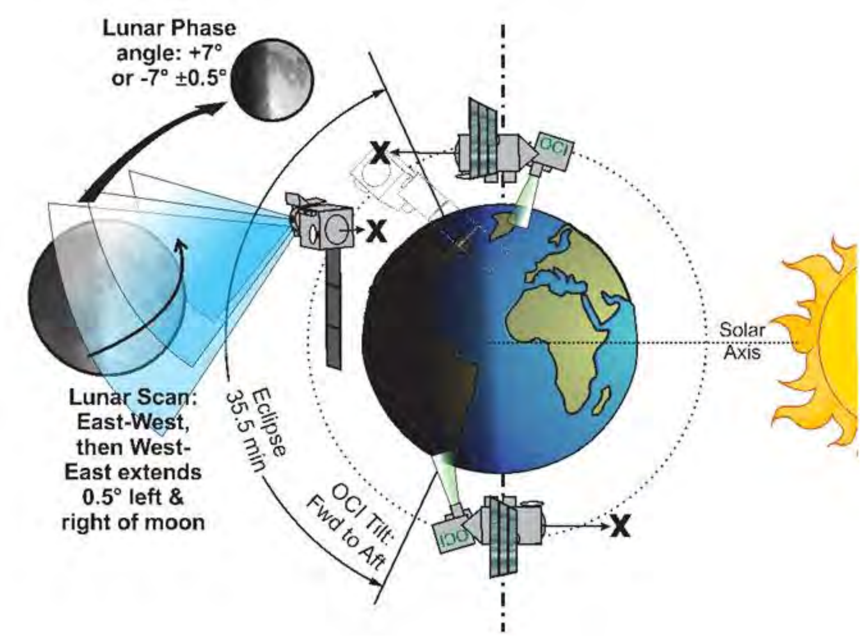
3 diffuser surfaces: 2 QVD (daily/monthly gain tracking) and 1 dim diffuser (linearity)





Linearity: hyperspectral CCDs accumulate several readout cycles (dim solar diffuser reflectance is lowest radiance, upper limit is saturation)

Lunar Calibration Maneuver



On-orbit Spectral Calibration

- No dedicated spectral diffuser (change from original plan)
- Every solar diffuser measurement will provide Fraunhofer lines (spectrum sampled with 5nm bandwidth every 0.625nm from UV to NIR)
- Once a month, a few minutes of earth view data will be acquired with 0.625nm sampling for spectral calibration using atmospheric absorption lines
- Spectral characteristics of SWIR bands are not expected to change on-orbit

OCI prelaunch calibration overview

Artifact	Measured Prelaunch	Measured Postlaunch	Applied during L1 processing	Applied during L2 processing
Absolute gain (K1)	Instrument level, TVAC	Solar calibration and vicarious calibration[1]	Yes (calibration equation)	
Temporal response (K2)	Instrument level, reduced accuracy	Solar and lunar calibration	Yes (calibration equation)	
Temperature correction (K3)	Instrument level, TVAC	Solar and lunar calibration[2]	Yes (calibration equation)	
Response vs. scan angle (RVS) (K4)	Instrument level, ambient	Verification with ocean color products	Yes (calibration equation)	
Linearity (K5)	Instrument level, TVAC	Solar calibration[3]	Yes (calibration equation)	
Tilt angle (K6)	Spacecraft level (verification only)	Verification with ocean color products	N/A	
Polarization sensitivity	Instrument level, ambient	Verification with ocean color products		Yes (atmosphere polarization)
Stray light sensitivity	Instrument level, ambient	Verification with lunar cal.		Yes
Crosstalk	Instrument level, ambient	Verification with lunar cal.	Maybe	Yes
Relative spectral response	Instrument level, TVAC	Verification with solar calibration (Fraunhofer and atm. abs. lines)	N/A (part of K1 calculation)	Yes(atmospheric correction)
Offset (DN0)	Every scan	Every scan	Yes	

[1]Vic. Cal.: Visible and some NIR bands only

[2]If seasonal variations are observed in K2

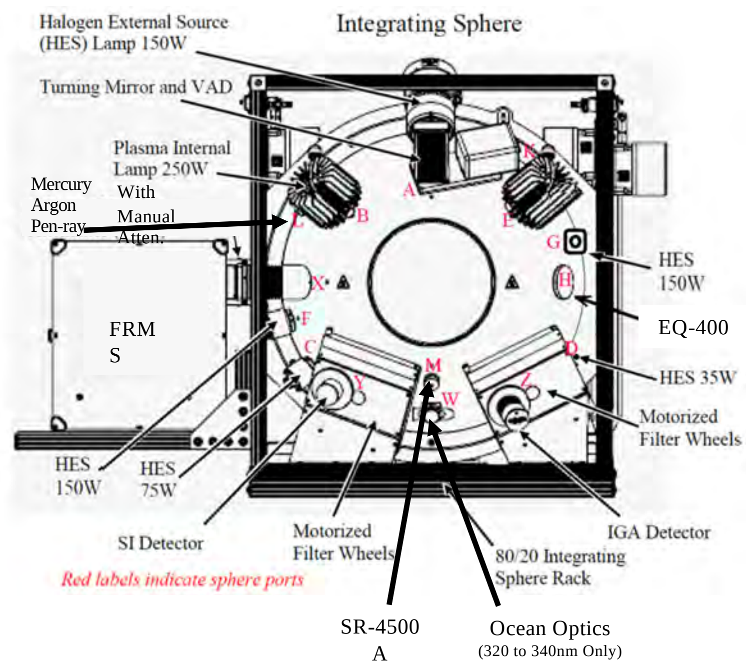
[3]New technique developed for OCI (dim diffuser)

Ground support equipment: 20inch integrating sphere (8inch exit aperture)

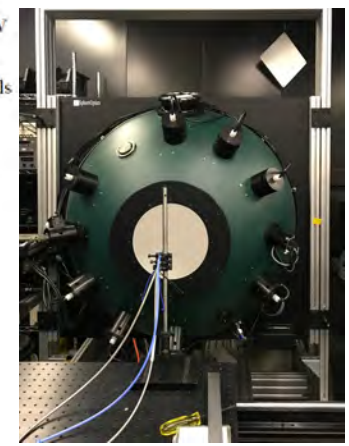
Attachments:

Various light sources (halogen, plasma, EQ-400, attenuators)

and sensors (SR4500, Ocean Optics, FRMS, Filter wheel (Si and InGaAs)



All light sources will be calibrated by NASA GSFC Code 618 Calibration Facility



Summary

- OCI will start a rigorous calibration program in September 2019 with the ETU (Flight Unit: summer 2020)
- Goal is to minimize uncertainties due to image artifacts described here in order to achieve overall radiometric uncertainty of 0.5% (excluding absolute calibration)
- OCI will provide excellent temporal stability over mission life time (2 solar diffusers, lunar measurements twice a month)
- Linearity will be verified on-orbit with dim solar diffuser (new approach)

Calibration Equation for each channel

$$L_m = K_1 * K_2(t) * (1-K_3*(T-T_{ref})) * K_4(\theta) * K_5(dn, T) * K_6(\omega) * dn$$

L_m = radiance measured in a hyperspectral or SWIR band
K_1 = absolute gain factor
$K_2(t)$ = relative gain factor as a function of time t
K_3 = temperature correction factor
T = Instrument temperature measured at relevant location (electronics? housing? T.b.d.)
T_{ref} = Reference Temperature (used during TVAC prelaunch characterization, close to expected on-orbit temperature)
K_4 = response versus scan
θ = scan angle (usually replaced by science pixel number per scan)
K_5 = nonlinearity factor
$K_6(\omega)$ = correction for tilt position ω (+/- 20^o)
DN = digital number measured at a certain θ
DN_0 = average of the digital numbers measured during dark current collection (average of ~40 numbers, once per scan)
dn = DN – DN_0

Note: out-of-band, polarization and straylight/crosstalk correction are handled later in the processing stage (need other information, such as surrounding radiances for straylight, amount of rayleigh/aerosol/glint for polarization)