OCEAN COLOR INSTRUMENT (OCI) ON THE PLANKTON, AEROSOL, CLOUD AND OCEAN ECOSYSTEM (PACE) MISSION: CURRENT CONCEPT

GERHARD MEISTER
PACE INSTRUMENT SCIENTIST

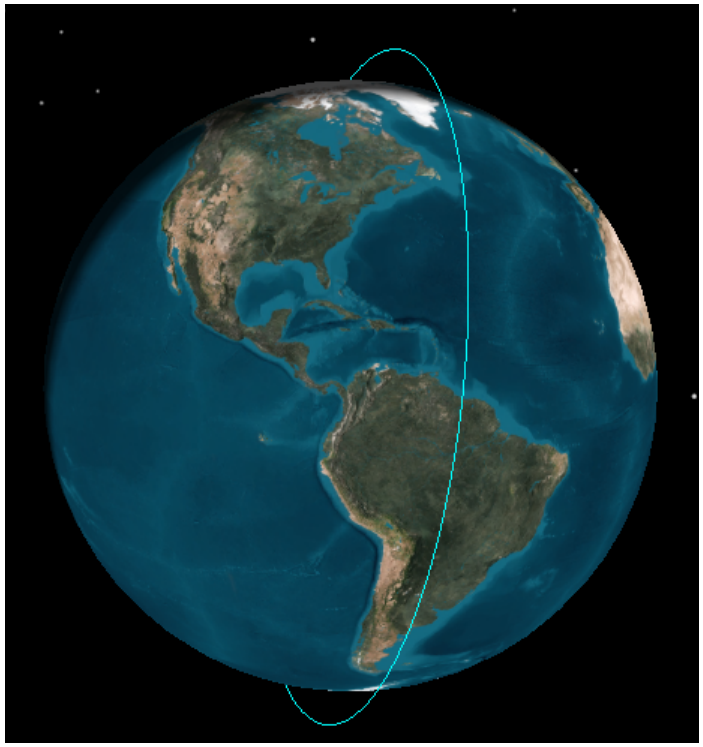
MATERIAL PROVIDED BY OCI TEAM (ERIC GORMAN, OCI SYSTEMS ENGINEER)

PACE/OCI threshold requirements (HQ) derived from SDT

- 2 day global coverage
- Hyperspectral (5nm) from 350nm to 800nm, plus SWIR bands
- Excellent long term trending (0.1%) accuracy via lunar measurements
- Low radiometric artifacts 0.5% (striping, polarization, straylight, etc.)
- Spatial resolution of 1km (at nadir) or better
- Mitigation of sun glint
- Equator crossing time: noon +/- 1hour
- Measurement of complete dynamic range of geophysical top-of-atmosphere radiances

PACE & OCI Orbit Overview

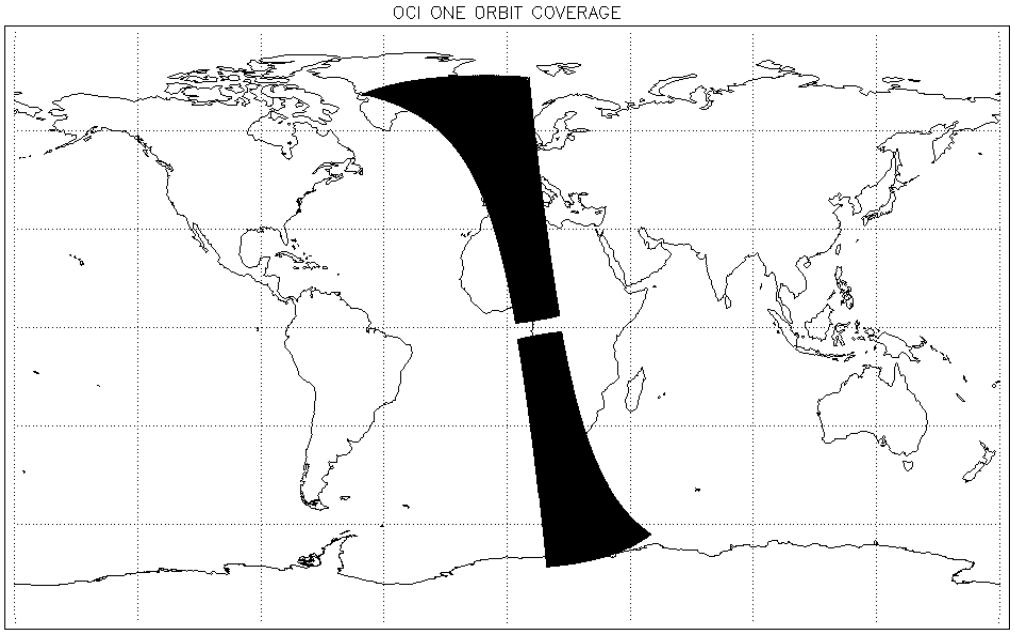
- Orbit Altitude
  - 675km
- Sun-Synchronous
  - Inclination ~98 degrees
- Ascending Node
  - 1300 Equator Crossing Time
- Orbit Period
  - ~98 Minutes
- Orbits Per Day
  - ~14.5
- Ground Velocity
  - ~6800 m/s or ~15,000 MPH



OCI Global Coverage

- Cross Track Scanner like SeaWiFS, MODIS, and VIIRS maximizes global coverage
- Rotating telescope does a continuous 360^{o} rotation
  - Rotation Rate ~6Hz or ~360RPM
- Field of Regard
  - Scan angle +/- 56.5^{o}
  - ~2000 km per Scan
  - Enables 1-day global coverage
  - 2 day global coverage considering sensor zenith angle limit of 60^{o}

  (corresponds to scan angle of ~48.5^{o} in this case)



OCI orbit operations – tilt and calibration

1. The S/C enters the day light over the south pole in an ascending node with the tilt mechanism is already set to the aft position (-20º)

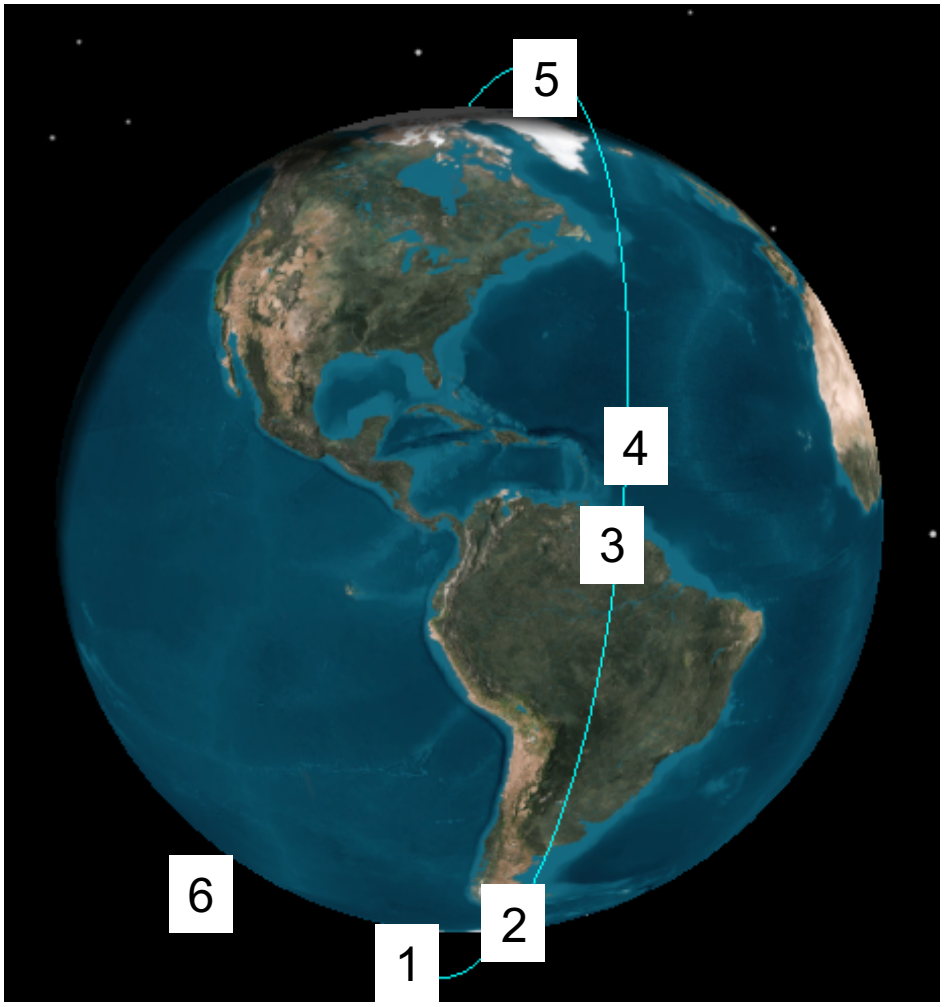
2. Collect science data starting when the S/C is at a 81.5º solar zenith angle

3. At the sub solar point move the tilt mechanism to the forward position (+20º)
   - Stagger the time of tilt every 2 days, 2 days south, 2 days north

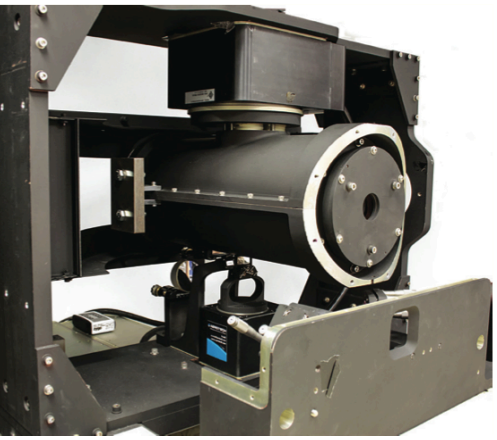
4. Continue to collect science data until the S/C is at a 81.5º solar zenith angle

5. Solar Calibration
   - The solar diffuser is mounted to view the aft sun.
   - Calibration occurs over the north pole before the S/C goes into the dark side

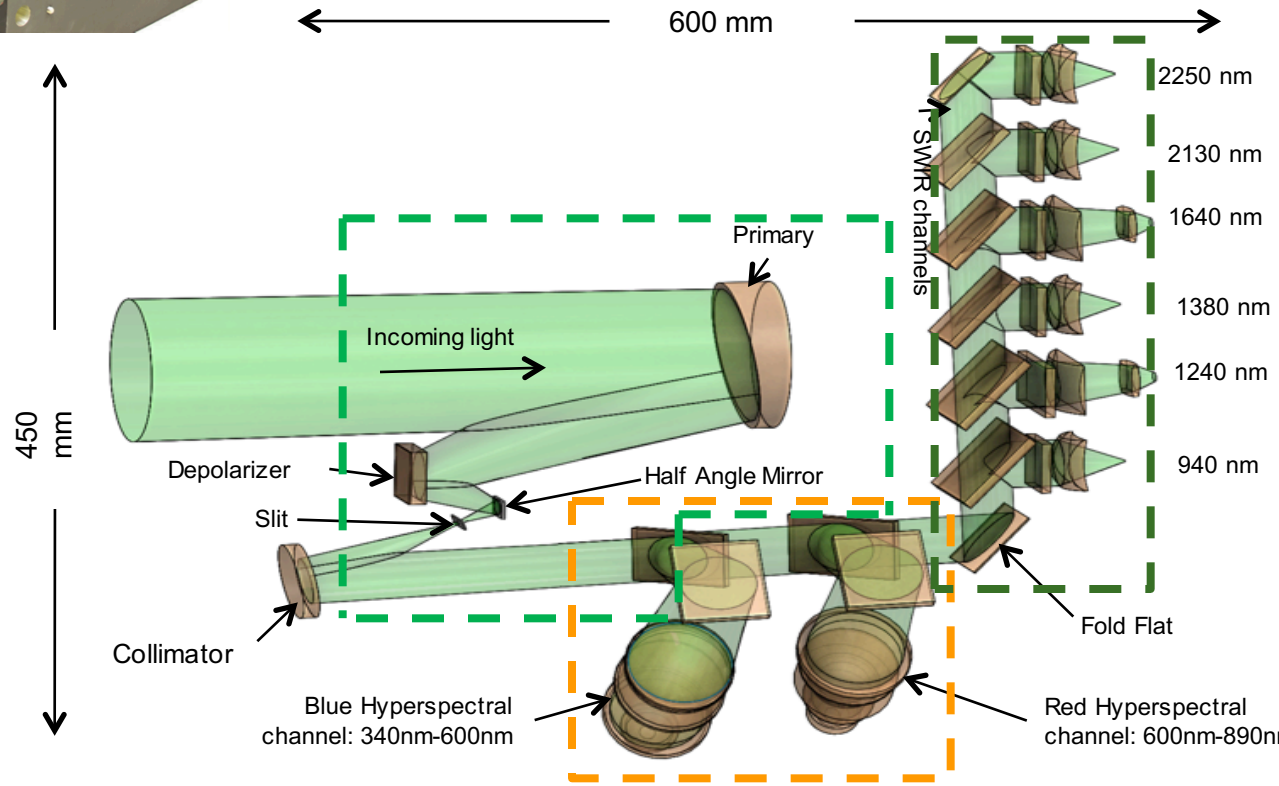
6. On dark side of the orbit reset the tilt mechanism to look aft (-20º). Twice a month, perform lunar calibration with pitch maneuver on the dark side



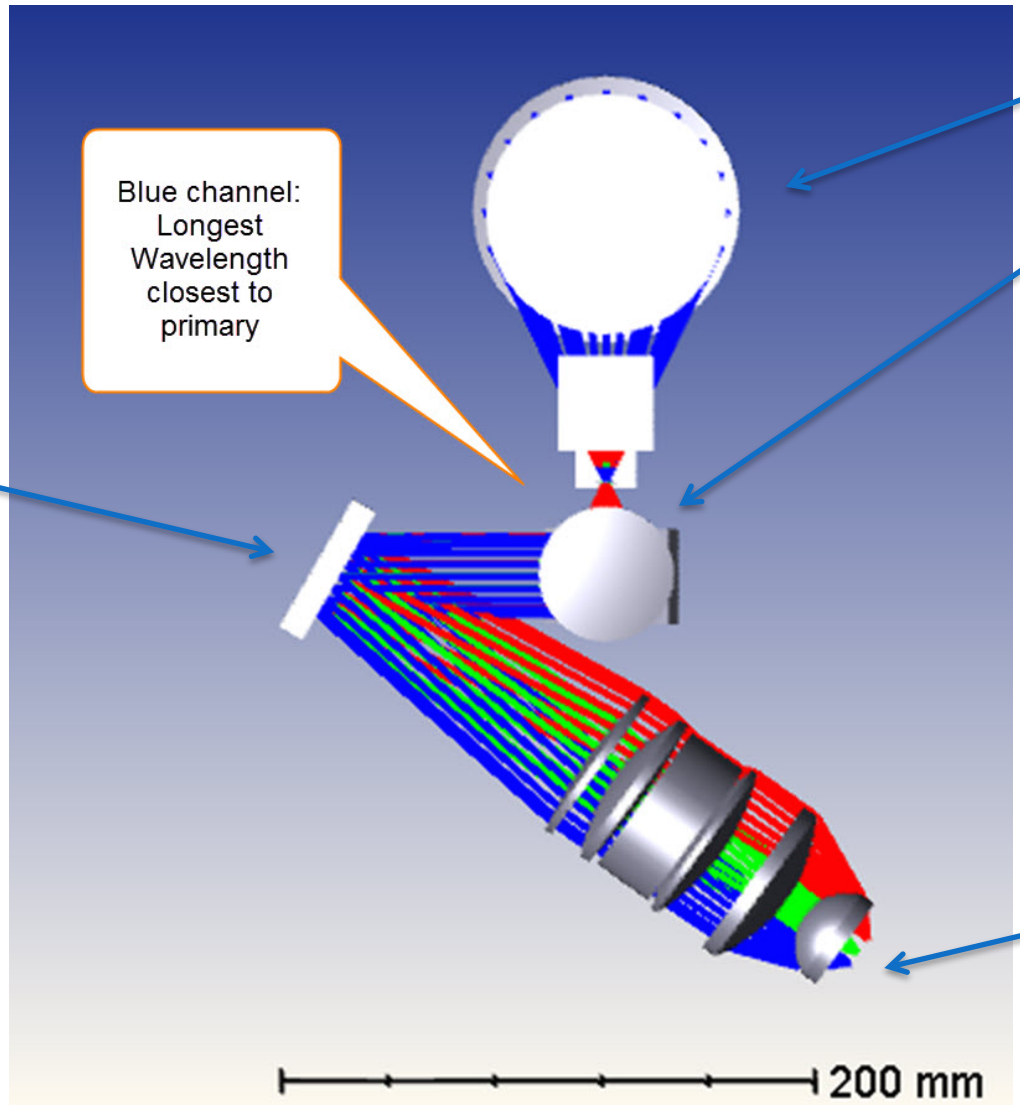
Optical System Concept Approach



- SeaWiFS and Instrument Incubator Program (IIP) designs used as starting point
- 2 hyperspectral channels, 6 separate SWIR channels
- Dichroics and filters distribute bands onto respective detectors



Grating disperses light on CCD for hyperspectral channels



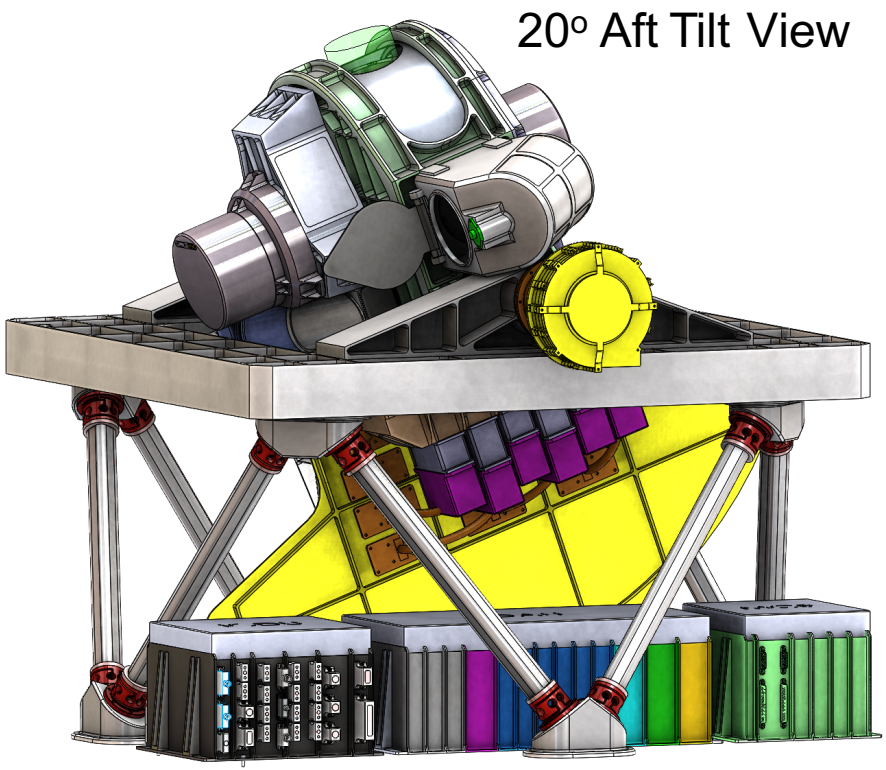
Telescope

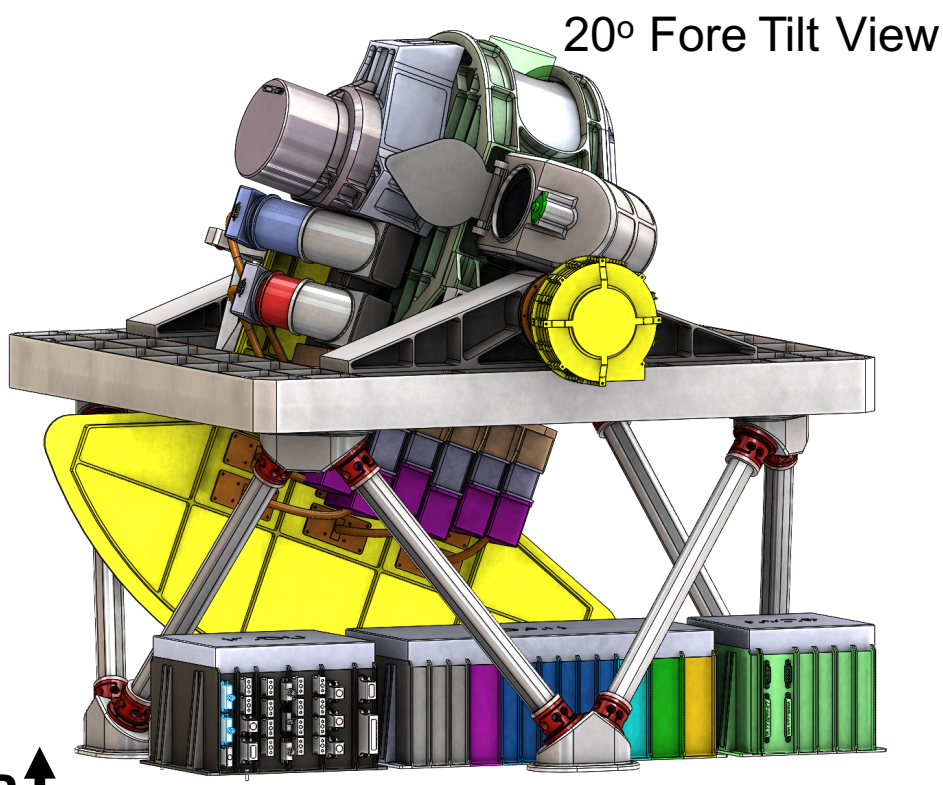
Dichroic

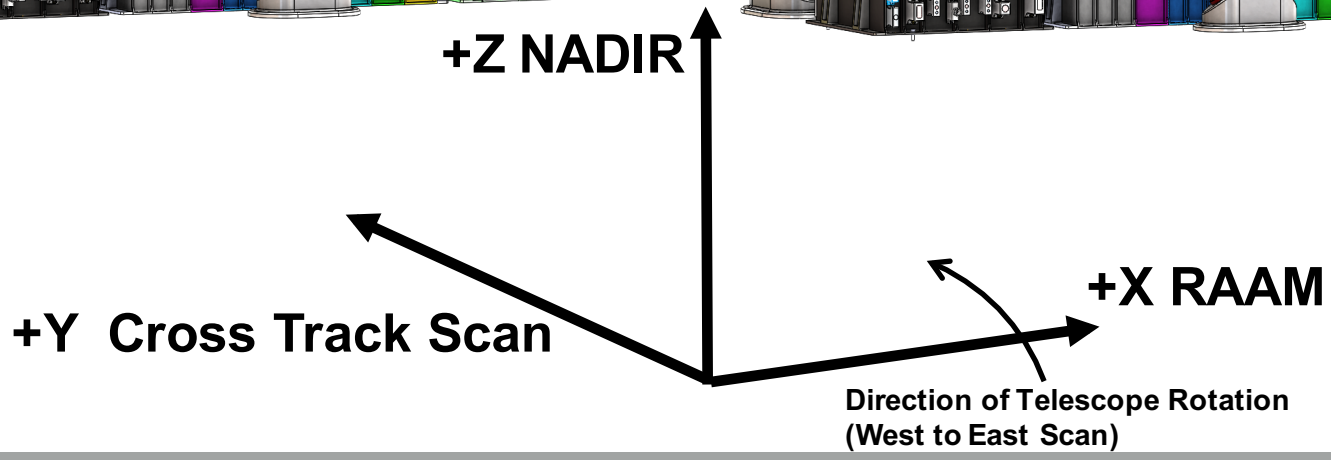
Grating

CCD
(not shown)

Main Optical Bench Tilts Fore and Aft for Glint Avoidance

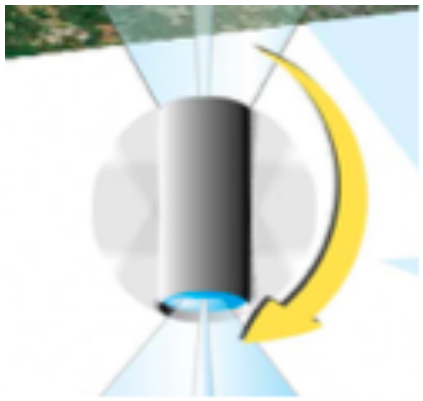


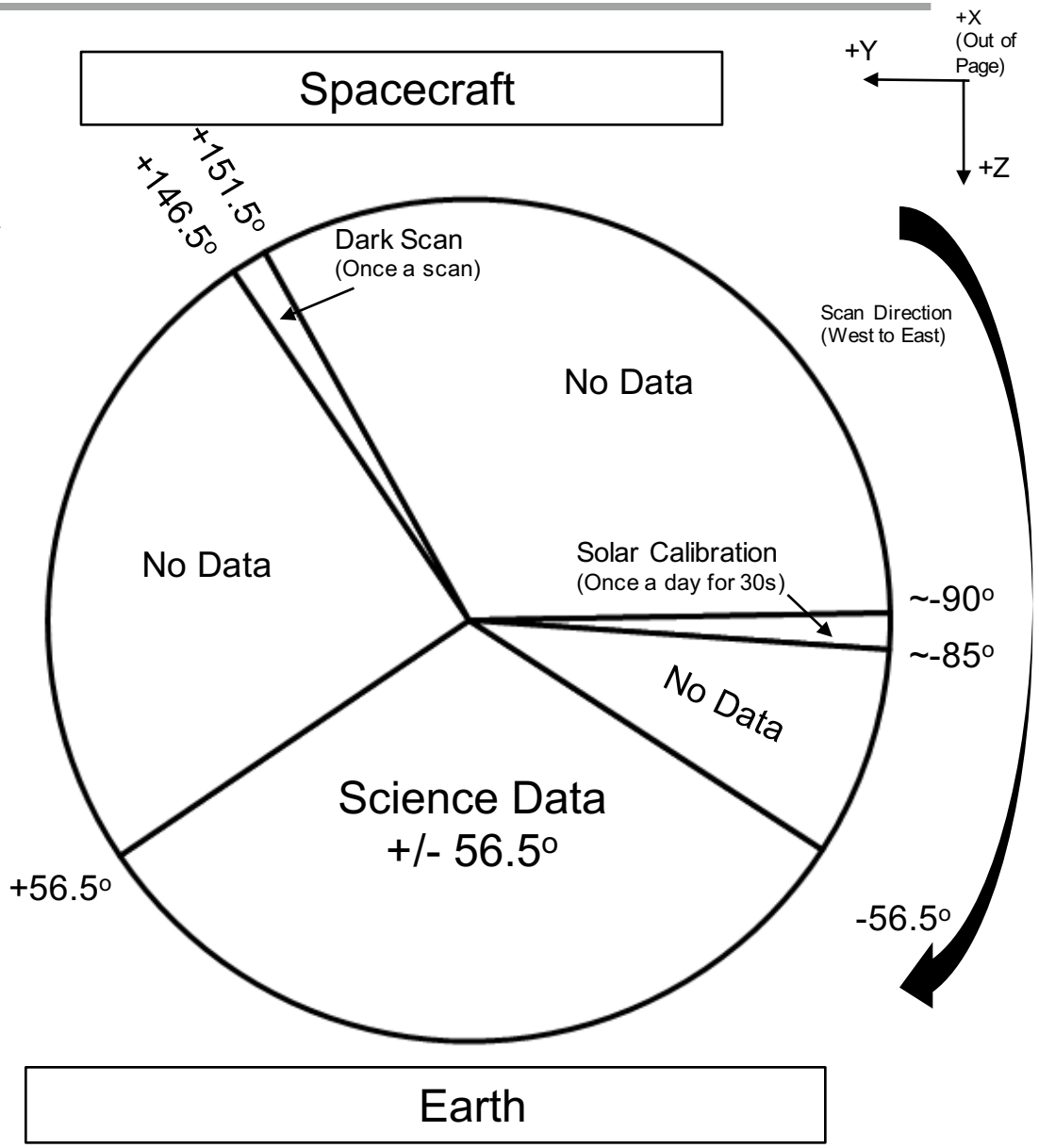




Data Acquisition as a function of scan angle

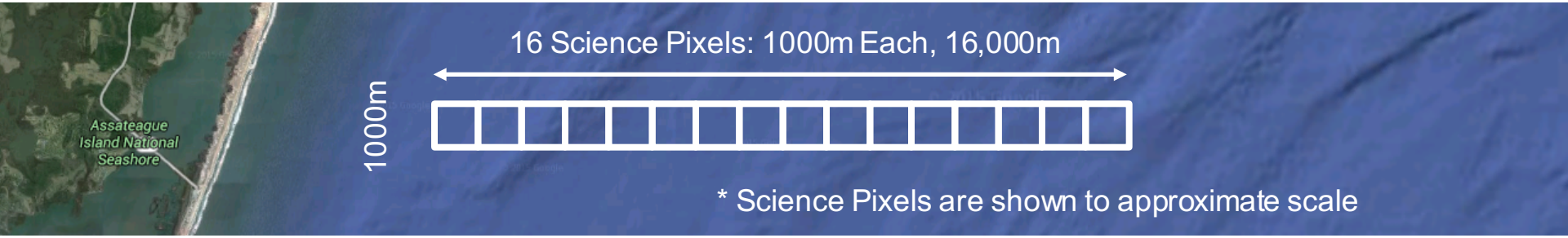
- Similar to SeaWiFS, MODIS, and VIIRS
- Dark scan acquired every scan



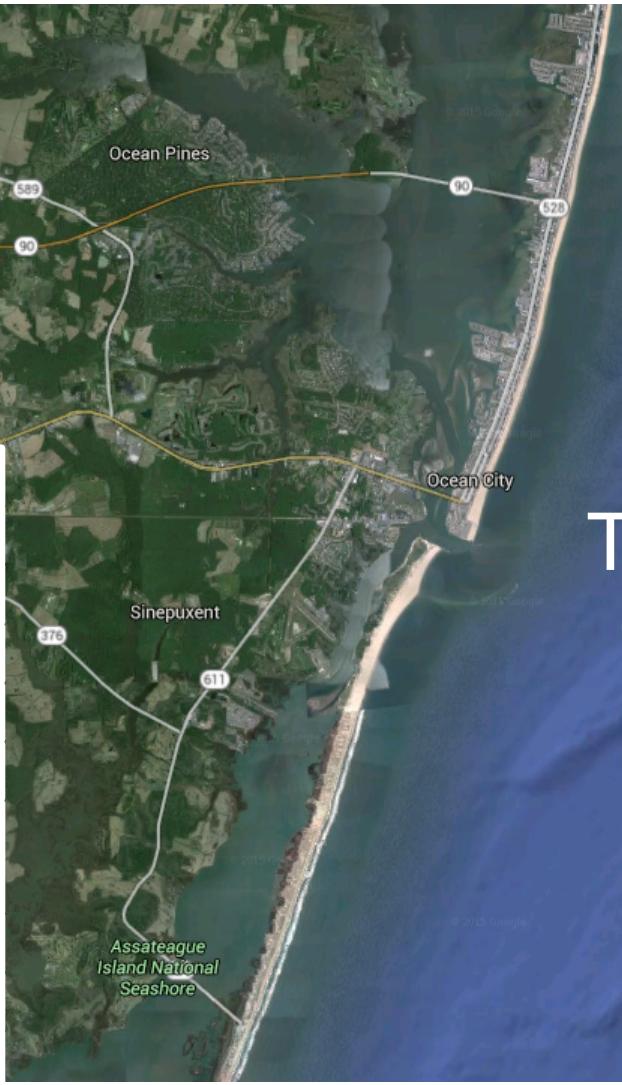


OCI Telescope Ground Coverage

- 1 Science Pixel = 1000m x 1000m at Nadir
- OCI optics projects 16 science pixels onto a slit. The slit is re-imaged onto detectors (CCDs and SWIR detectors)
- This is 16,000m x 1000m of ground area
- If you stop the telescope from rotating, the optics will only see 16 science pixels on the ground.



OCI Rotating Telescope Ground Coverage

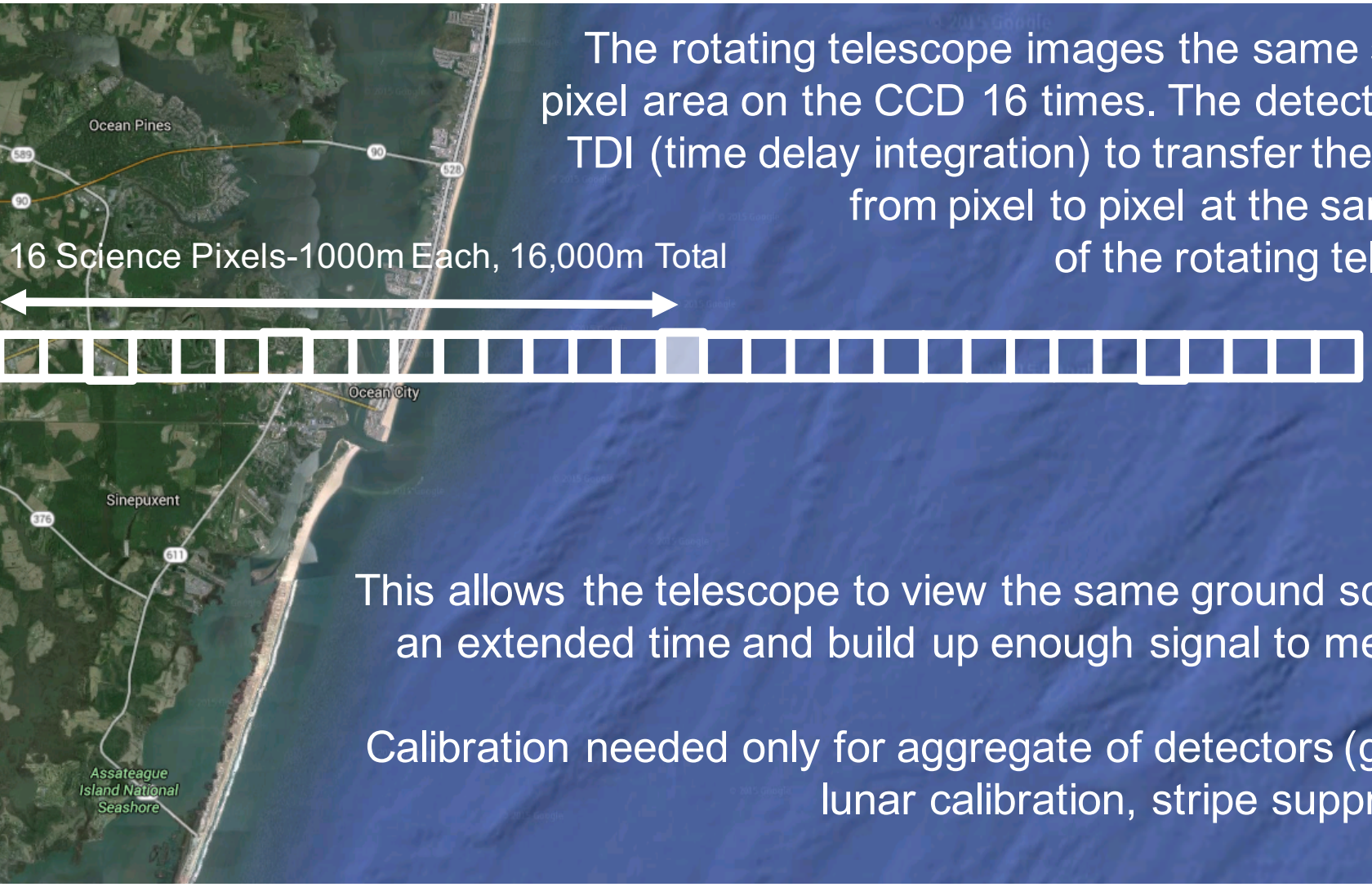


The rotating telescope moves the image of the 16 science pixels across the ground to cover the full field of regard

The telescope rotates fast enough so there are no gaps in coverage in the along track direction between scans (scan progression determined by spacecraft speed, upward in this example)

OCI Time Delay Integration

The rotating telescope images the same science pixel area on the CCD 16 times. The detector uses TDI (time delay integration) to transfer the charge from pixel to pixel at the same rate of the rotating telescope

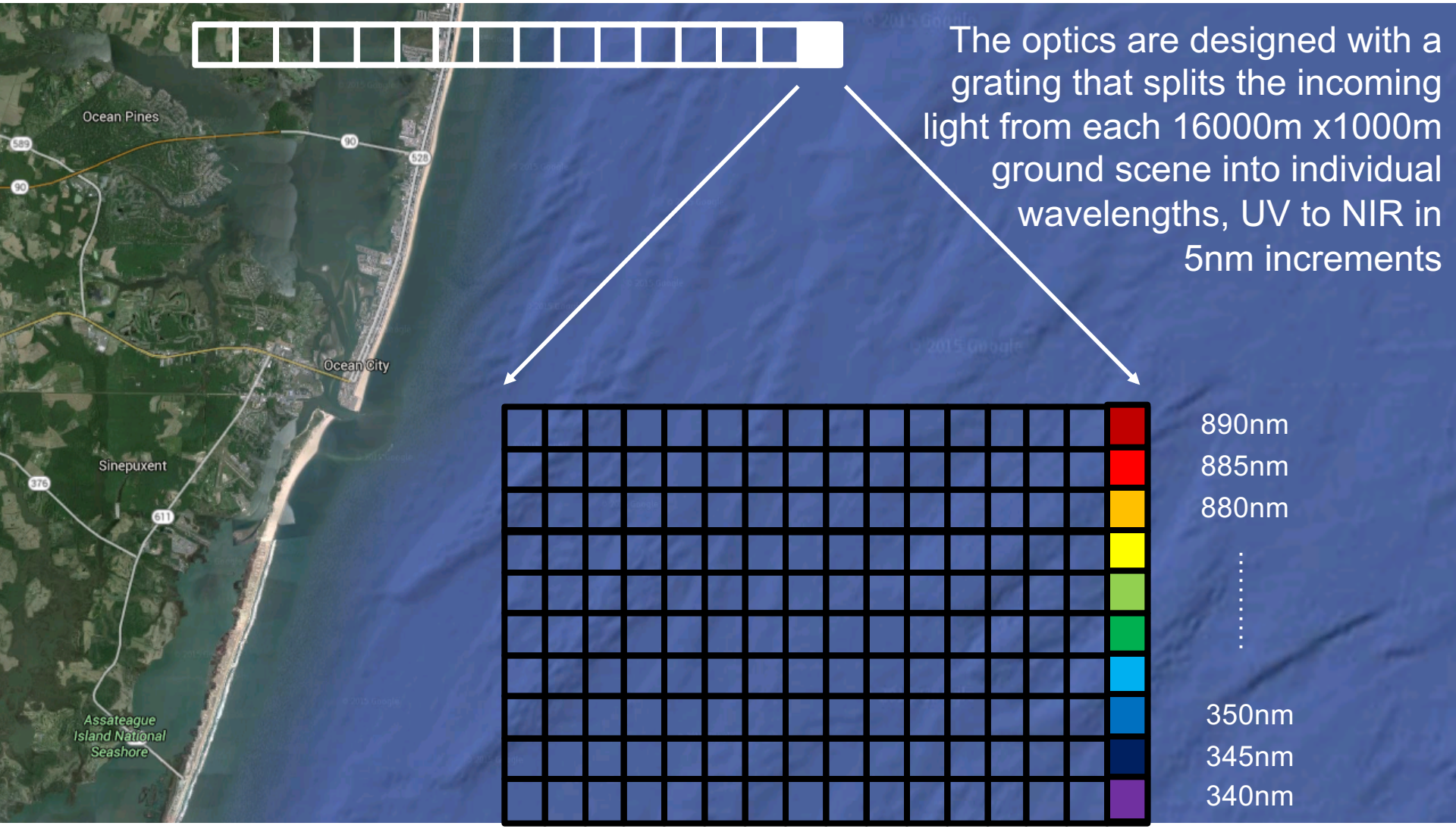


This allows the telescope to view the same ground scene for an extended time and build up enough signal to meet SNR

Calibration needed only for aggregate of detectors (good for lunar calibration, stripe suppression)

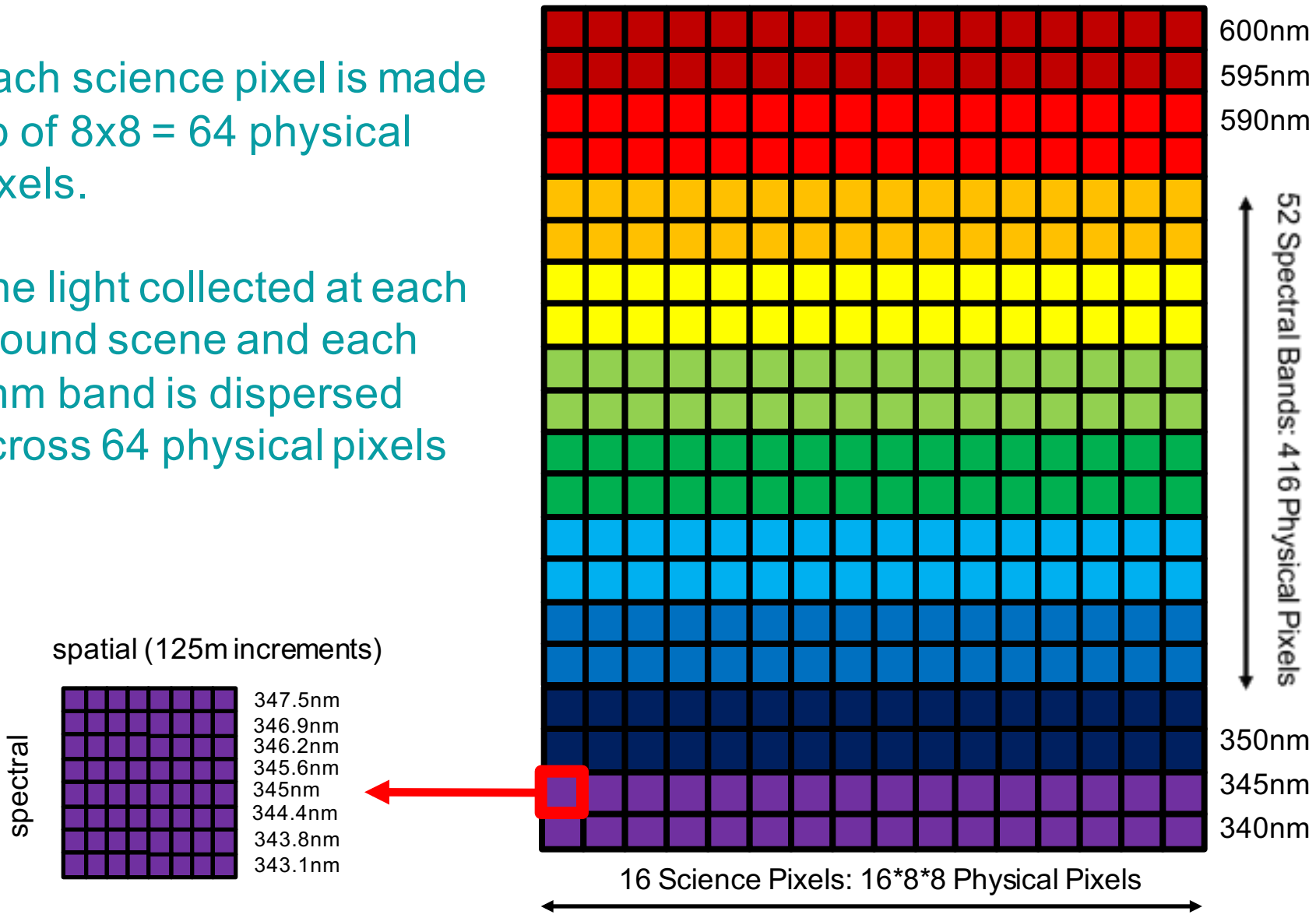
SeaWiFS used TDI with 4 photodiodes

OCI -Time Delay Integration - Hyperspectral

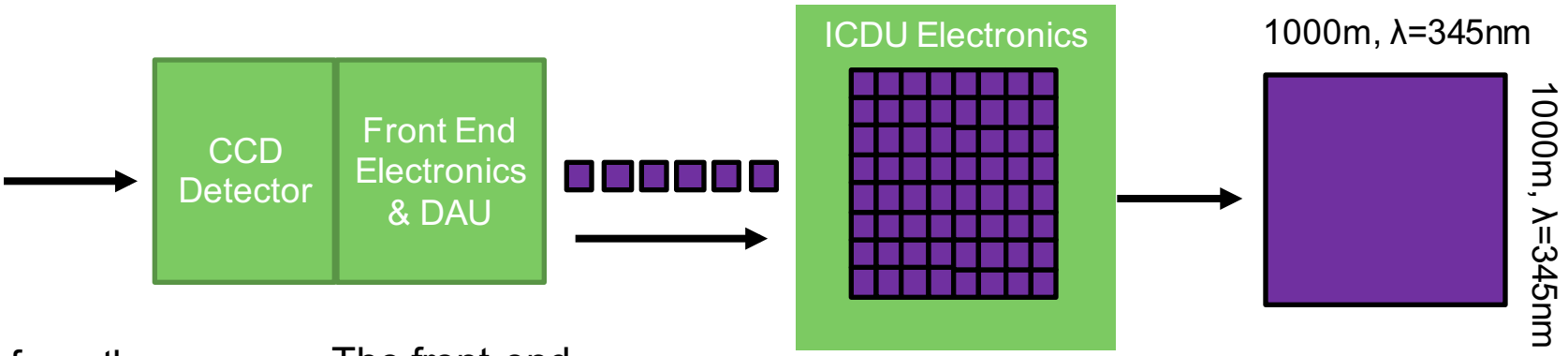


OCI CCD Detector

- Each science pixel is made up of 8x8 = 64 physical pixels.
- The light collected at each ground scene and each 5nm band is dispersed across 64 physical pixels



OCI System Pixel Read Out & Pixel Aggregation



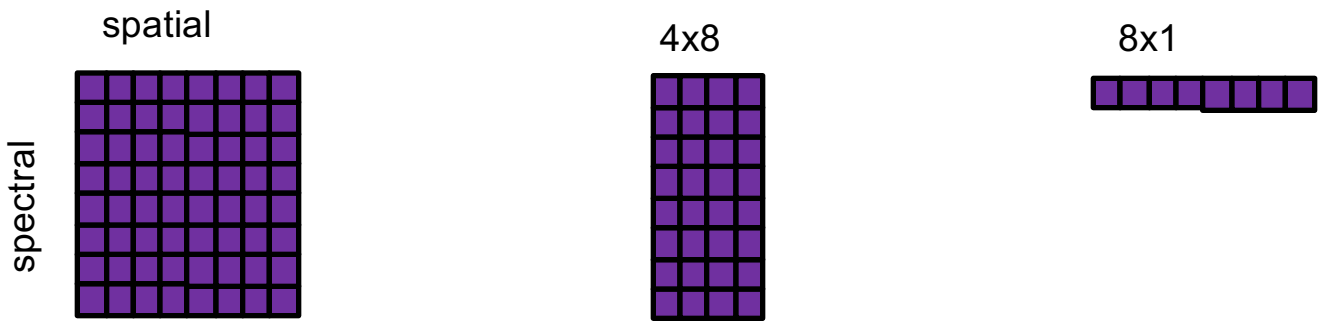
Light from the earth is projected on the detector, TDI is done on the CCD

The front end electronics reads and digitizes the physical pixels and sends them to the ICDU (Instrument Command and Data Unit)

The ICDU aggregates 8x8 physical pixels into a science pixel and sends it to the spacecraft

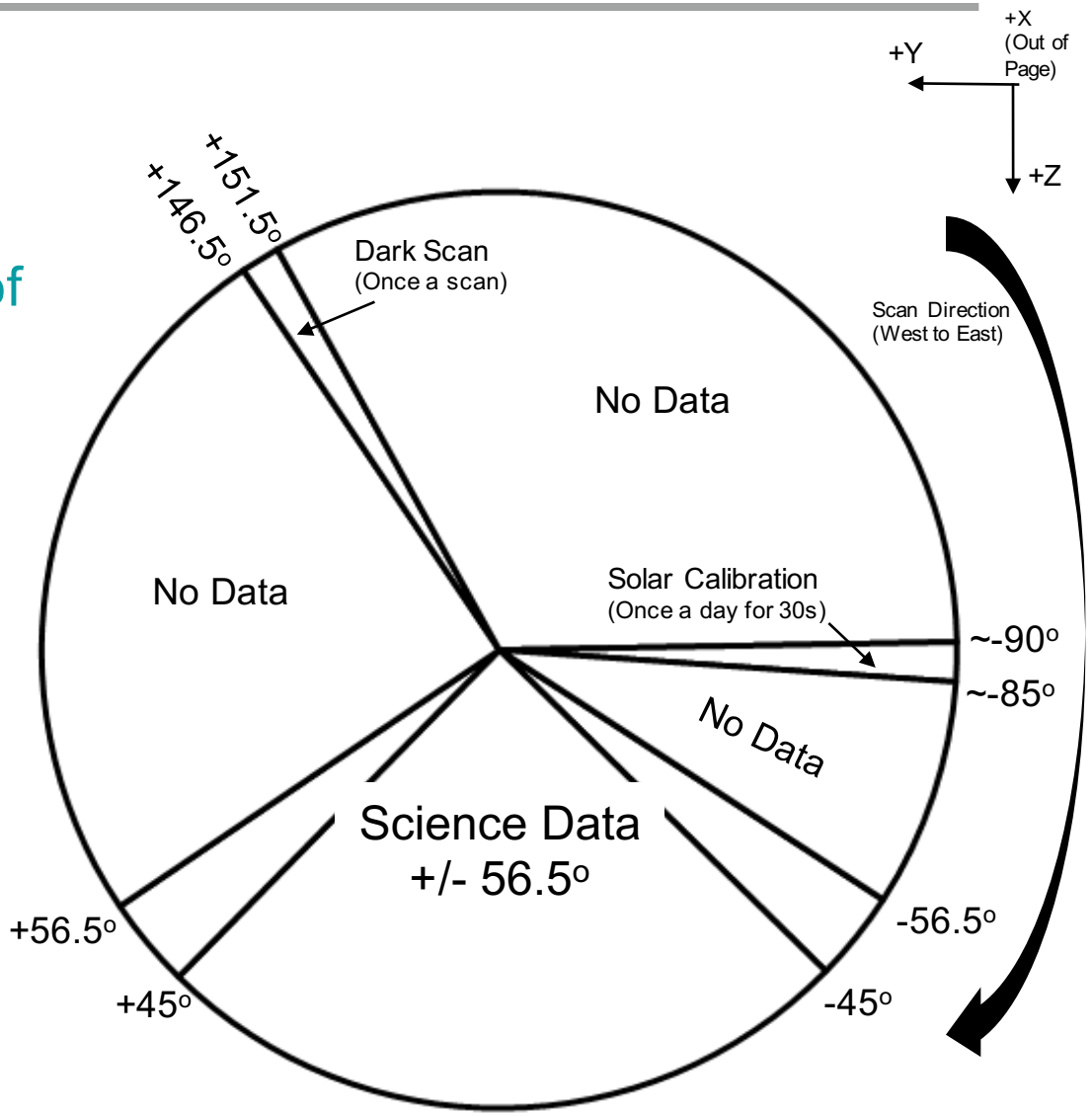
OCI CCD Detector Aggregation Options

- Aggregating 8x8 pixels optimizes SNR for 1km x 1km, 5nm pixel
- Other aggregation options: 4x8 (4 in scan direction) produces a pixel that is only half as wide in scan direction, producing a 500m x 1km pixel (with lower SNR)
- Other aggregation options: 8x1 (1 in spectral direction) produce pixels at different center wavelengths (but bandwidth is still 5nm, determined by slit width). E.g. the 345nm band could be sampled at 343.125, 343.75, 344.375, 345.0, 345.625, 346.25, 346.875, and 347.5nm, again at lower SNR
- Potentially useful for ocean Raman scattering, FLH, aerosol altitude; need to select spectral regions of interest, otherwise data volume issue



Potential for varying spatial aggregation:

- Pixel size on the ground grows substantially for large scan angles
- Possible option: instead of aggregating 8x8 pixels, aggregate 4x8 (similar to VIIRS aggregation)
- Doesn't apply to SWIR bands
- Other options (e.g. 6x8) possible, but lead to mismatch with SWIR bands
- Downside: lower SNR, more calibration modes



Options for CCD readout

- Several spectral columns are read from the CCD in a “tap”
- A “tap” is the read-out register for a number of columns of pixels
- Project is studying various options for number of taps per CCD (influences e.g. readout speed, crosstalk, cost for electronics)
- Shown below is which tap reads which 5nm channel for a 10 tap example
- This is important because gains on the CCD are set for each tab

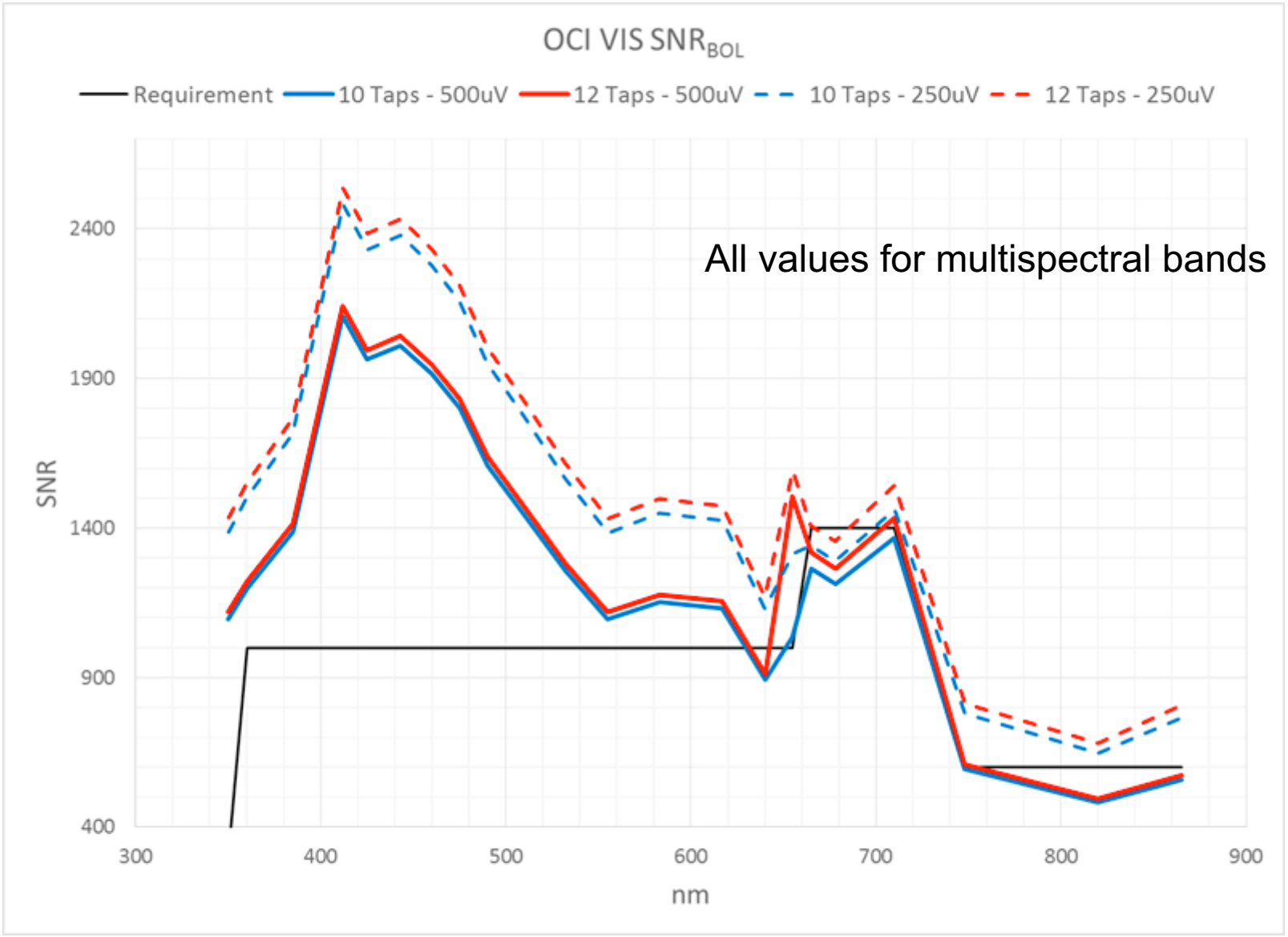
Band	Tap 1	Tap 2	Tap 3	Tap 4	Tap 5	Tap 6	Tap 7	Tap 8	Tap 9	Tap 10	Tap 11	Tap 12	Tap 13	Tap 14	Tap 15	Tap 16	Tap 17	Tap 18	Tap 19	Tap 20
1	305	335	365	395	425	455	485	515	545	575	595	625	655	685	715	745	775	805	835	865
2	310	340	370	400	430	460	490	520	550	580	600	630	660	690	720	750	780	810	840	870
3	315	345	375	405	435	465	495	525	555	585	605	635	665	695	725	755	785	815	845	875
4	320	350	380	410	440	470	500	530	560	590	610	640	670	700	730	760	790	820	850	880
5	325	355	385	415	445	475	505	535	565	595	615	645	675	705	735	765	795	825	855	885
6	330	360	390	420	450	480	510	540	570	600	620	650	680	710	740	770	800	830	860	890
7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

OCI SNR and Lmax at red wavelengths

- PACE Project Science asked OCI team to increase SNR in red to 1400 (from 1000 PACE SDT) for FLH product
- OCI team said this is only possible if we reduce the dynamic range for these bands by adjusting the CCD gain
- The exact wavelength range is determined by CCD tap layout, which is not final at this moment (shown below: 10 tap example)
- One option currently considered: Lmax reduced by 2/3 for ~650nm-720nm (see email to PACE Science Team from May 27, 2016)

Band	Tap 1	Tap 2	Tap 3	Tap 4	Tap 5	Tap 6	Tap 7	Tap 8	Tap 9	Tap 10	Tap 11	Tap 12	Tap 13	Tap 14	Tap 15	Tap 16	Tap 17	Tap 18	Tap 19	Tap 20
1	305	335	365	395	425	455	485	515	545	575	595	625	655	685	715	745	775	805	835	865
2	310	340	370	400	430	460	490	520	550	580	600	630	660	690	720	750	780	810	840	870
3	315	345	375	405	435	465	495	525	555	585	605	635	665	695	725	755	785	815	845	875
4	320	350	380	410	440	470	500	530	560	590	610	640	670	700	730	760	790	820	850	880
5	325	355	385	415	445	475	505	535	565	595	615	645	675	705	735	765	795	825	855	885
6	330	360	390	420	450	480	510	540	570	600	620	650	680	710	740	770	800	830	860	890
7	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

OCI SNR examples: high in the blue, little margin in red



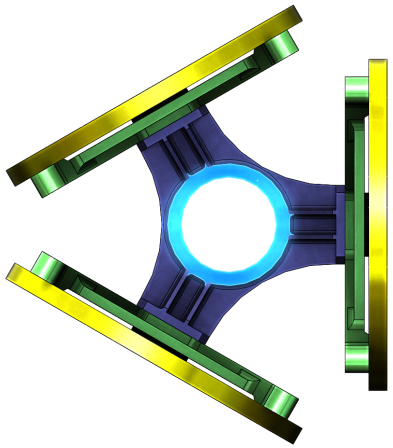
Solar Diffuser calibration

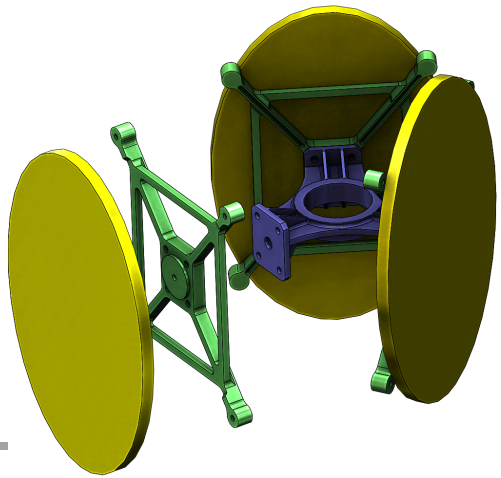
- Solar diffuser assembly has 3 panels which are rotated mechanically into position:

-White, daily: Exposed, for daily monitoring of sudden changes in radiometric responsivity of the instrument

- White, monthly: Protected, exposed once a month (28 Days) for long term trending

- Doped, monthly: Protected, exposed once a month (28 days), to check spectral alignment of CCDs





Lunar Calibration

- Occurs twice a month (one month is 28 days) on the dark side of the orbit
- Similar maneuver as SeaWiFS, but spacecraft pitch rate is accurately controlled (no need to estimate oversampling factor)
- ROLO model provides the model lunar irradiance (one value per band)
- Lunar radiances are aggregated to calculate lunar irradiance

=> one value per band (irradiance) per maneuver

OCI needs only one value per band for calibration (TDI)

Current Trades Considered by the Project

- Extend UV range to 315nm
- Spectral subsampling
- Spatial aggregation at scan edges
- Different tap layouts
- Dual gain for SWIR
- Reducing Lmax for additional wavelengths
- Bandwidths and Center Wavelengths for SWIR bands (e.g. 1640nm)

Conclusions

- Many trades still on-going, final OCI will be different from what was presented here

- OCI concept reduces number of gain coefficients per band to a minimum (one), eliminates striping, optimal for lunar calibration
- Allows wide spectral coverage (UV-SWIR)
- Provides 2-day global coverage, glint avoidance like SeaWiFS
- Cross-track scanning is not optimal for SNR, but we expect to meet PACE SDT requirements; current concept indicates margin in blue channel; some SWIR bands may be “dual gain”
- OCI concept anticipated to achieve requirements/objectives of PACE SDT option ‘OCI+’ and ‘Threshold Ocean Mission Requirements’ (Appendices I and II of PACE SDT)