CLARREO Pathfinder

National Aeronautics and Space Administration

NASA

CLARREO Pathfinder Mission Overview and Status

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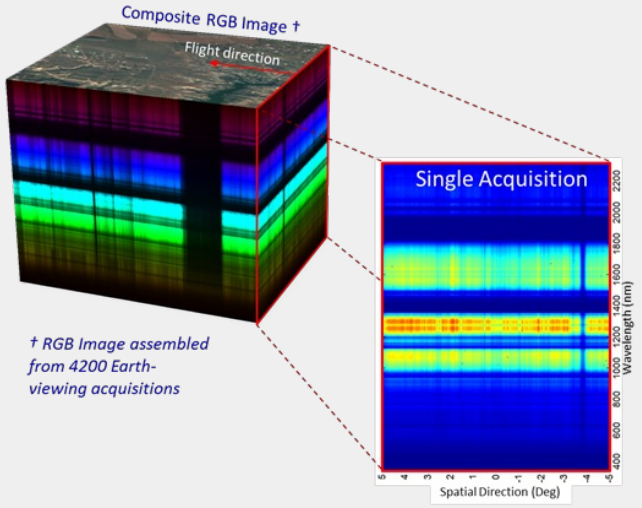
LASP

CLARREO Pathfinder: Mission Summary

Climate Absolute Radiance and Refractivity Observatory

- **Core Mission Objectives:** Take climate-critical high accuracy measurements of Earth reflectance and inter-calibrate with CERES (broadband) & VIIRS (multi-spectral)
- LASP-Led Payload & Reflected Solar Spectrometer (350 – 2300 nm)
- Hosted on International Space Station
- *Nominal* 1-year mission operations + 1-year science data analysis
  - But wait there will hopefully be more! On ISS schedule through end of ISS life (2030)!
- Launch: December 2023

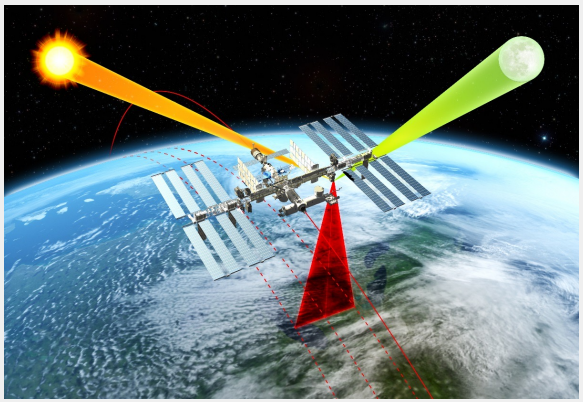
Spectrally-Resolved Earth Reflectance



https://clarreo-pathfinder.larc.nasa.gov/

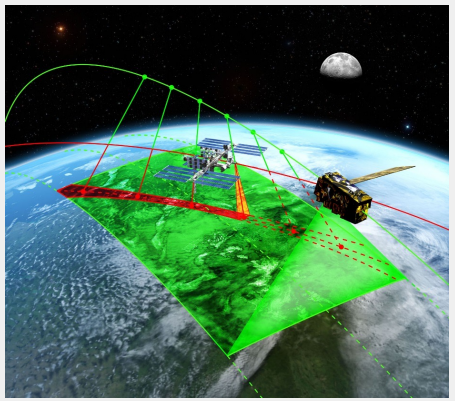
CPF Science Objectives

Objective #1: **High Accuracy SI-Traceable Reflectance Measurements**



Conduct on-orbit calibration to achieve reflectance uncertainty a factor of ***5-10 times better*** than the best operational sensors on orbit.

Objective #2: **Inter-Calibration Capabilities**

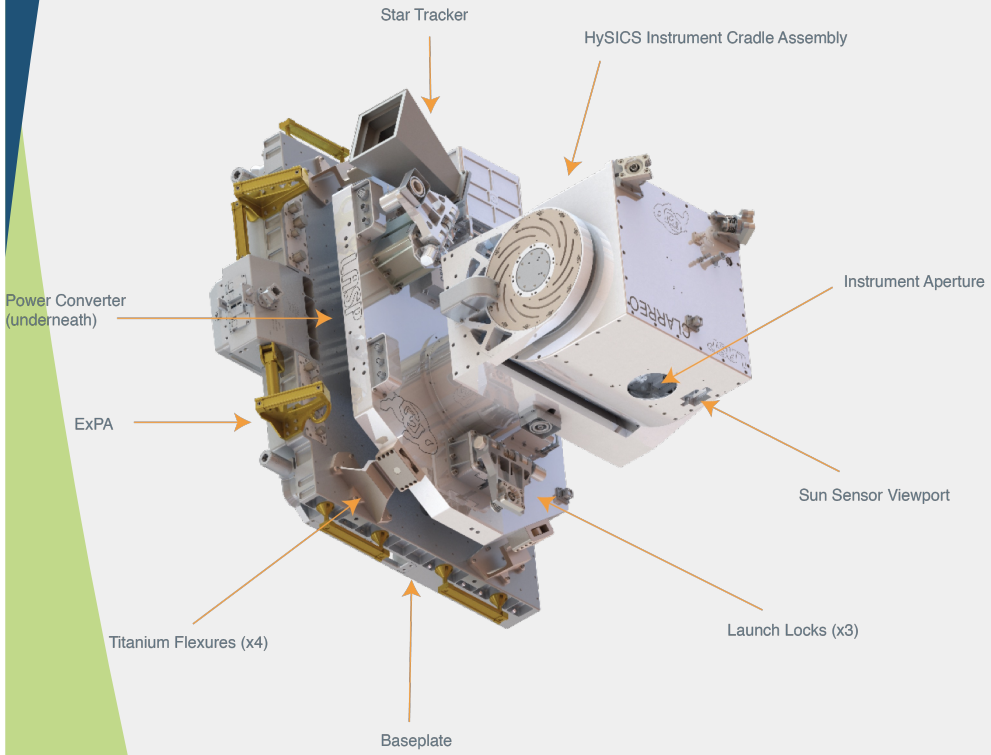


Transfer calibration accuracy to other key RS satellite sensors by inter-calibrating with CERES & VIIRS.

	Objective #1	Objective #2
Uncertainty	Spectrally-resolved & broadband reflectance: ≤0.3% (1σ)	Intercalibration Methodology Uncertainty: ≤0.3% (1σ)
Data Product	Level 1A: Highest accuracy, best for inter-cal, lunar obs Level 1B: Approx. consistent spectral & spatial sampling, best for science studies using nadir spectra	Level 4: One each for CPF-VIIRS & CPF-CERES inter-cal. Merged data products including all required info for inter-cal analysis

CPRS Payload: LASP Leadership

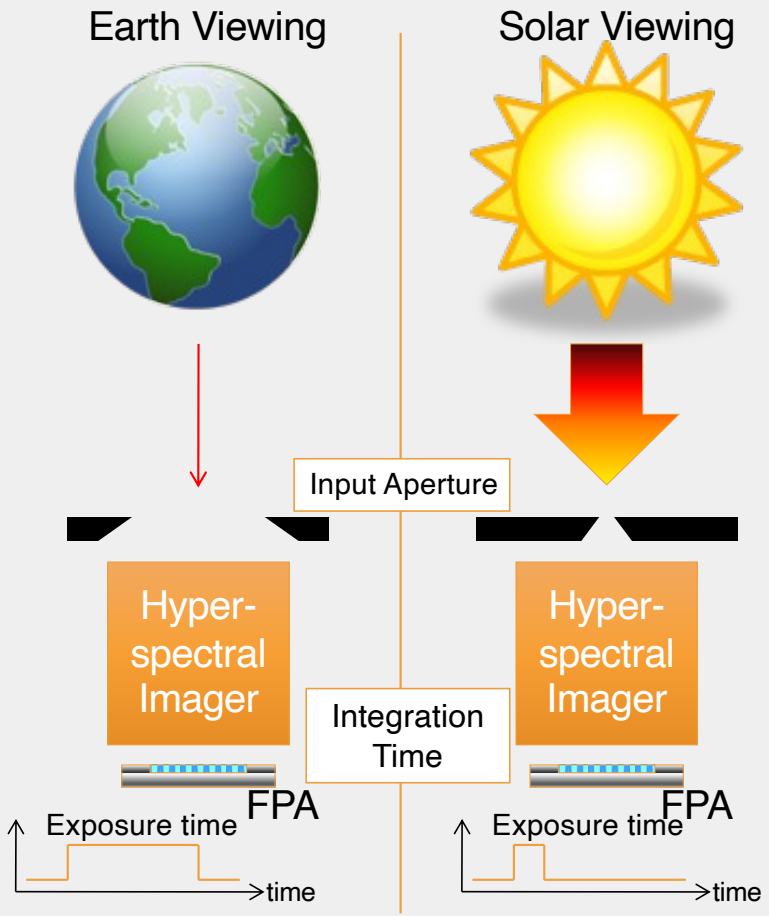
HYSICS: Hyperspectral Imager for Climate Science



Radiometric Uncertainty	0.3% (1-sigma)
Spectral Range	350 nm – 2300 nm
Spectral Resolution	6 nm
Swath Width	10° (70 km nadir)
Spatial Resolution	0.5 km
Sampling Rate	15 Hz

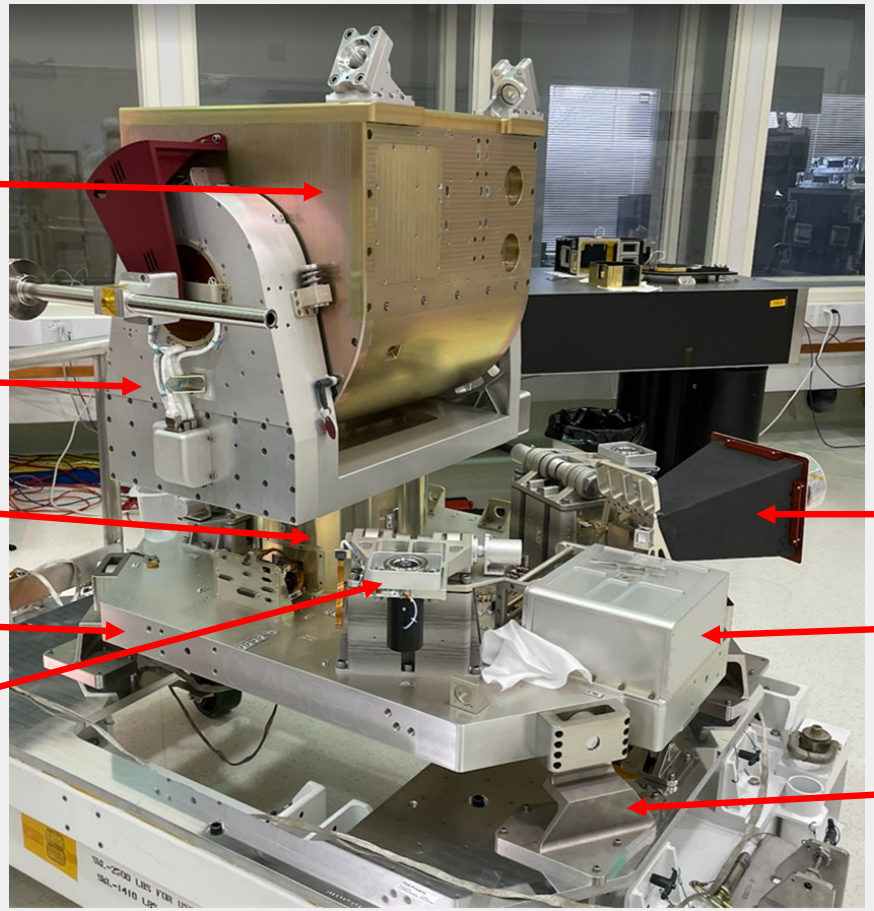
Calibration & Measurement Approach

- Earth reflectance will be obtained using a band-ratioing approach
- CPF will view both Sun & Earth with similar optical paths using
  - Aperture attenuation
    - Over 3 orders of magnitude (20 mm to 0.5 mm)
  - Integration time attenuation
    - Over 2 orders of magnitude (66 ms to 1.17 ms)
- Solar measurements & on-orbit calibration
  - Cross-slit scan
  - Flat fielding for both apertures – along-slit scan
  - Pen-ray lamp measurement



P. Smith (LASP)

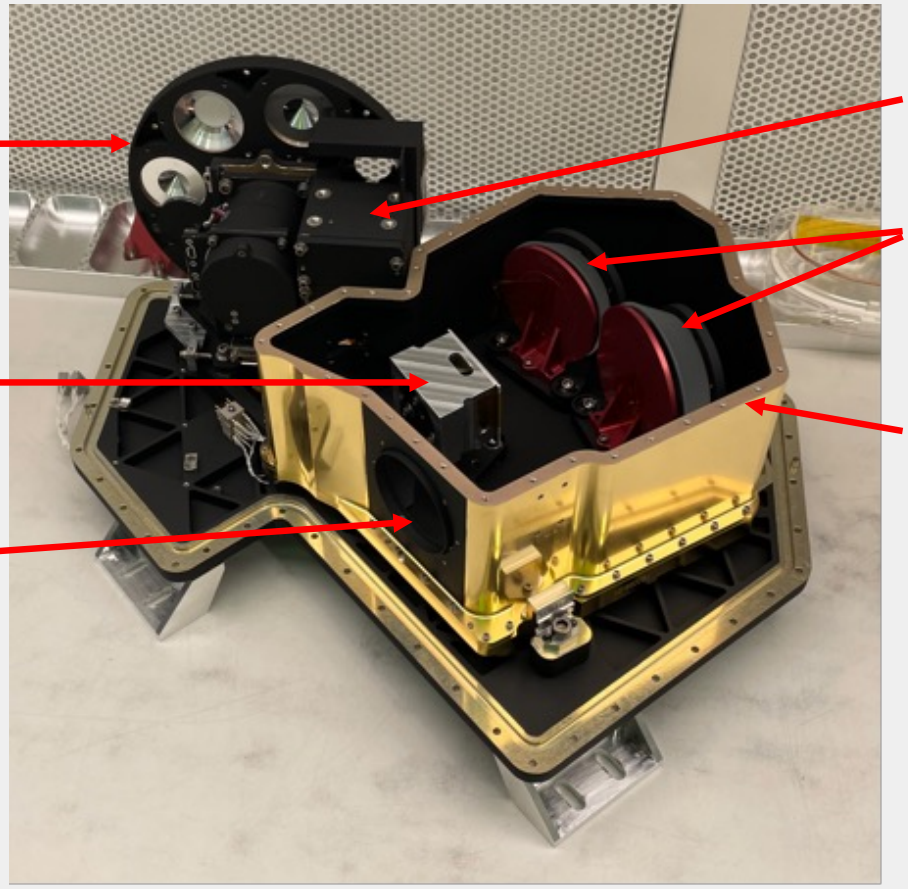
CLARREO Pathfinder



HySICS Pointing System (HPS) – the primary structure and two-axis pointing system of the CLARREO Pathfinder payload. The HySICS instrument and associated electronics reside within the tan-colored instrument cradle. The kinematic flexures serve as the payload attachment to the ISS-provided ExPRESS Pallet Adapter (ExPA) (ExPA not pictured).

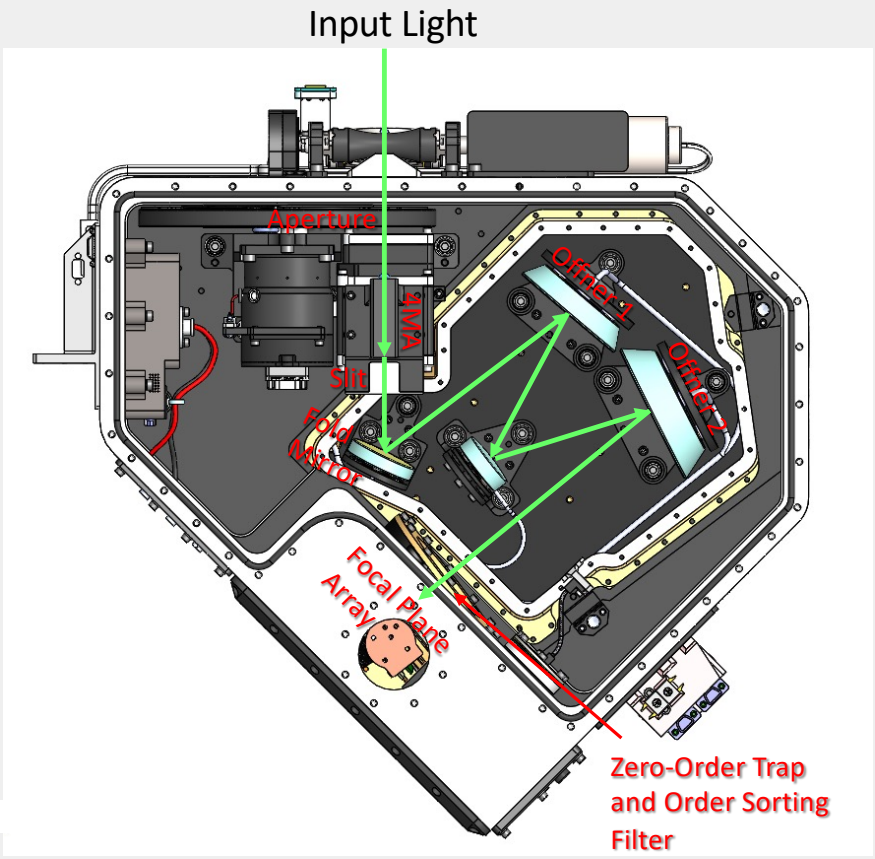
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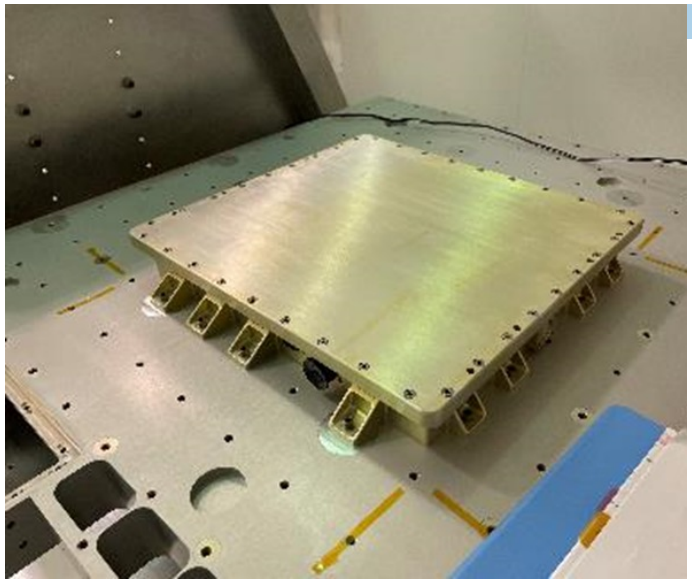
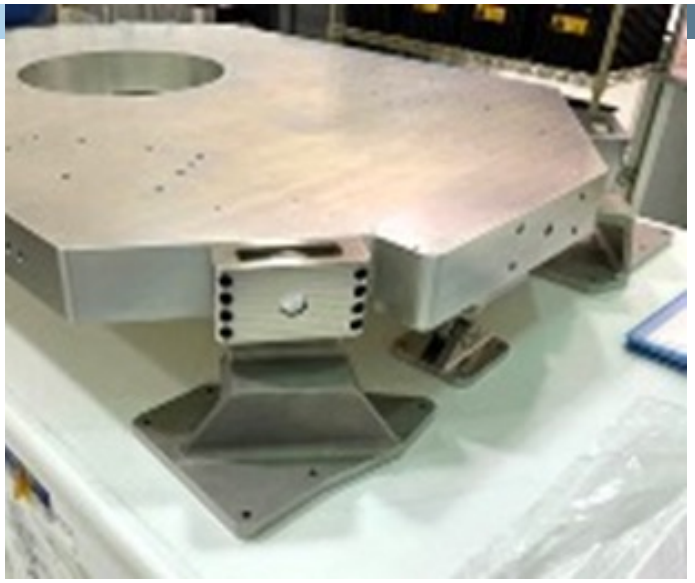
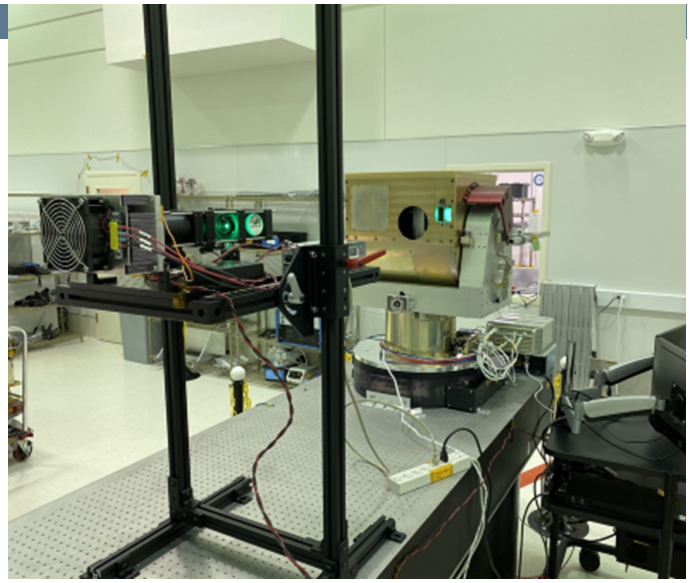
CLARREO Pathfinder

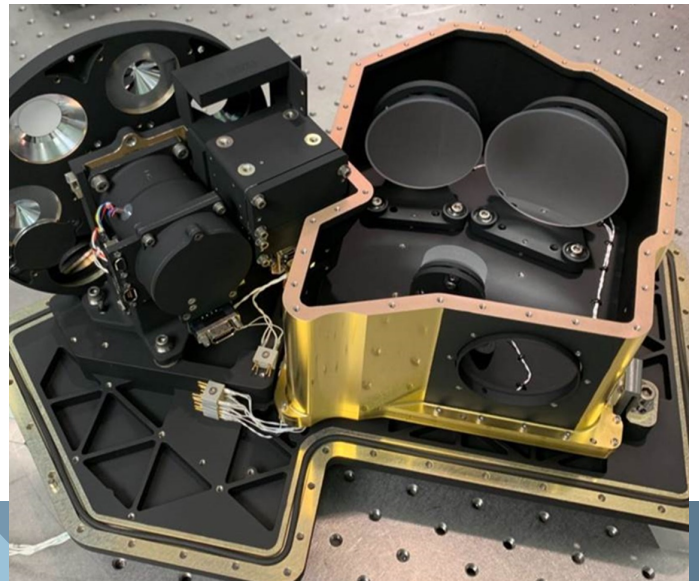
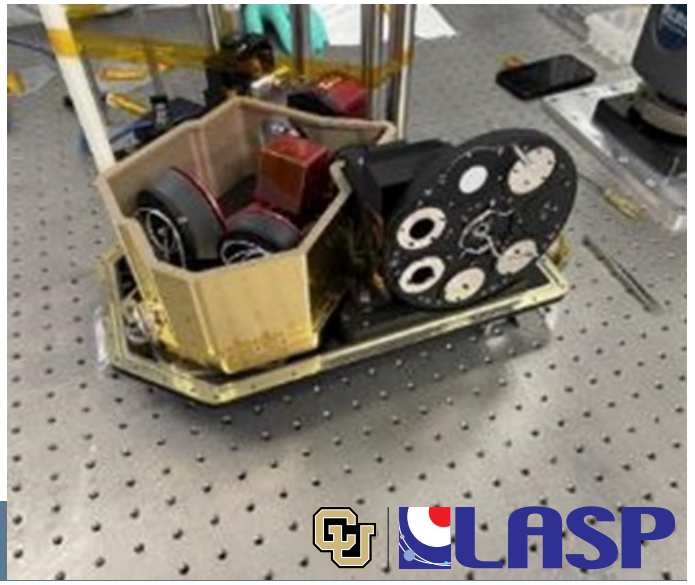


Internal view of the HyperSpectral Imager for Climate Science (HySICS) Instrument – the heart of the CLARREO Pathfinder Payload. Visible are the Aperture Wheel; 4-Mirror Anastigmat (4MA) Telescope; and spectrometer section with Offner mirrors and spectroscopic grating (with protective GSE covers installed); detector port.

HySICS Instrument: Light Path





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Versatility in CPF Observations

Launch-Ready: Late 2023 | Prime Mission Ops | Extended Mission Ops (TBD)

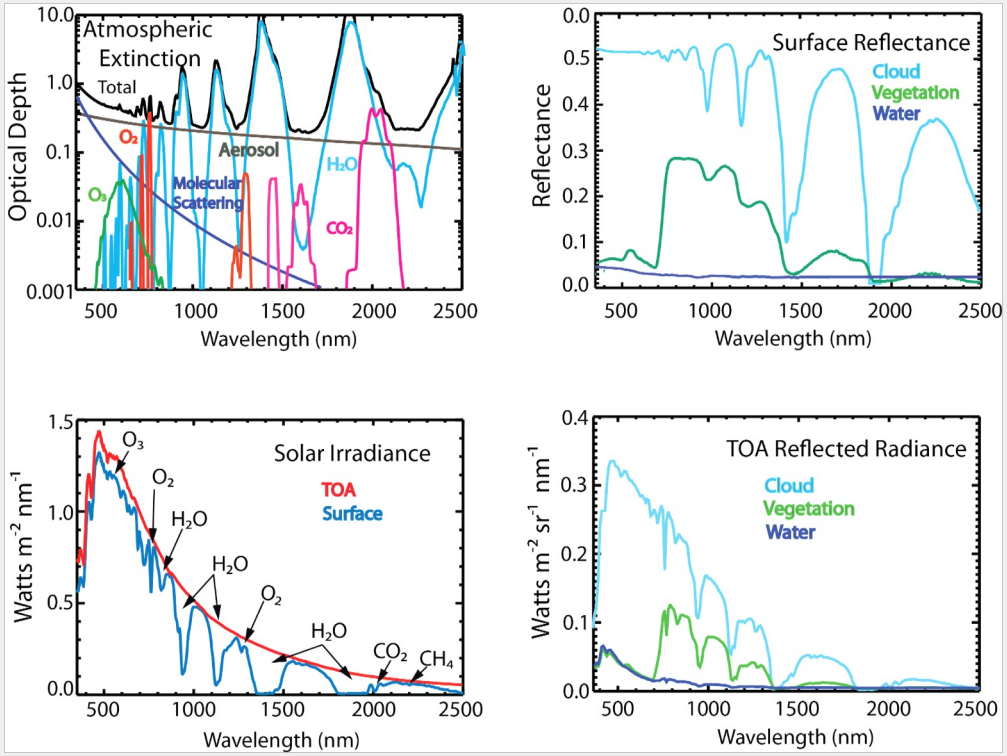
Observation Type	1-Year Prime Mission	2025—2030??
On-orbit Instrument Calibration	Confirm success of calibration approach over 1 year	
Earth Reflectance and Radiance Nadir Spectra	Will be used to confirm achieved calibration, geolocation, etc requirements	
LEO On-orbit Inter-calibration	Measurements and data analysis for CERES and VIIRS Only	
GEO On-orbit Inter-Calibration	Demonstration measurements with 1 GEO	
Enhanced Land/DCC Pseudo-Invariant Calibration Site (PICS) Characterization	Measurements over high priority PICS	
Improved characterization of the Moon	Leveraging existing ops mode to cover libration and phase angles available	

Core Mission Objectives

Addl Capabilities

Nadir CPF Hyperspectral Measurements

High accuracy, information-packed measurements are critical for both detecting climate change and identifying what is driving Earth's changing climate *(Shea et al., 2022 [In Press]).*



B. Kindel

CLARREO Pathfinder

Leveraging the CPF Spectrum

NASA

Predecessor & Complement to Several Missions	Decadal Survey Missions PACE TRUTHS/Libra
Cloud, aerosol, water vapor, and surface remote sensing studies and hyperspectral retrieval algorithm development	
Developing a Climate Benchmark Prototype	Critical for monitoring geophysical variable changes to provide climate model constraints
Development of Climate Change Attribution Techniques	
Evaluating temporal variability of spectral radiation	e.g. How has spectral reflectance changed in past 20 years?

CPF Intercalibration Benefits

Core Mission Direct Targets (CERES & VIIRS)	Earth Energy Imbalance Spectral Response Calibration evaluation across dynamic range
Independent Verification of Radiometric Consistency between multiple flight models (e.g. CERES, VIIRS)	
Climate Data Record Continued Development, Improved Quality	MODIS-VIIRS Dark Target & Deep Blue Aerosol, Cloud Continuity Products (20+ year records!) Landsat/Land Imagers
Lunar Reflectance Characterization	Complement to ARCSTONE & airLUSI Supplementing inputs to GIRO, ROLO, etc lunar char. models
Pseudo-Invariant Earth Targets	Deep Convective Clouds Hyperspectral, multi-angle land targets reflectance Improved PICS uncertainty characterization
Augmenting Existing Intercalibration Approaches	GSICS Standard? e.g. All-sky tropical ray matching, Surface PICS, DCCs, etc

Conclusions/Closing

- Science Education Opportunities Abound!
  - CPF NPP Opportunity – please share
  - CPF Internship Opportunities too
- Next CPF Science Workshop: ~Spring 2023
  - Contact me if you'd like to be added to the participant list
- CLARREO Pathfinder scheduled to Launch on SpaceX Launch 29 – December 2023
- CLARREO Pathfinder Science Team Solicitation anticipated in ROSES-24

https://clarreo-pathfinder.larc.nasa.gov/


REFERENCE INTER CALIBRATION
ADVANCING OBSERVATION ACCURACY
CLARREO PATHFINDER