National Aeronautics and
Space Administration

CLARREO Pathfinder Project Status

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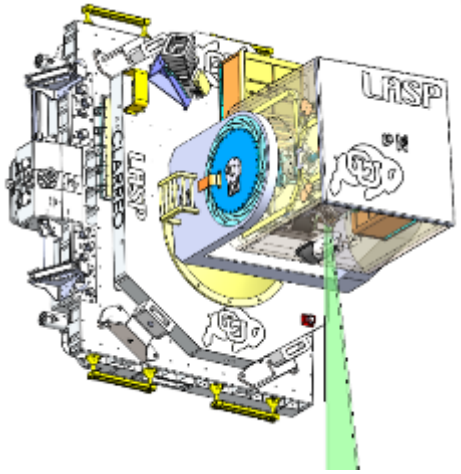
Langley Research Center

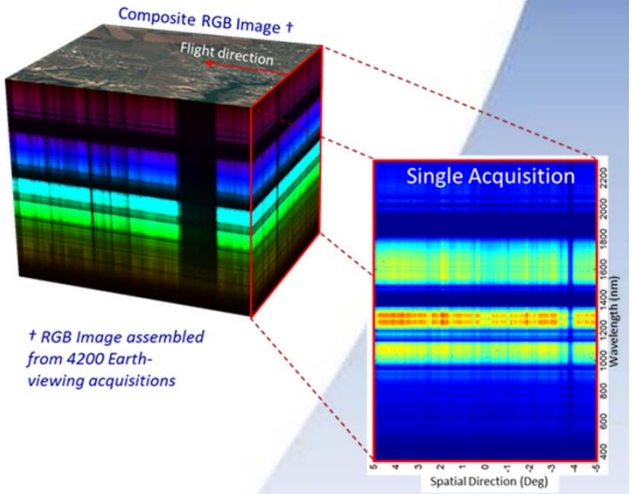
May 17, 2018

Project Description and Scope

- ***CLARREO Pathfinder will demonstrate essential measurement technologies for high accuracy radiance inter-calibration within the reflected solar spectral range***
  - Aligned with ESAS 2017 finding of radiance inter-calibration being a targeted observable, and ESAS 2007 Tier 1 CLARREO mission
  - Demonstrate on orbit, high accuracy, SI-Traceable calibration for measurement of Earth solar reflectance
    - ***4-8 times more accurate*** than current best available sensors on-orbit
  - Demonstrate ability to transfer this calibration to other on-orbit assets (VIIRS, CERES, and other assets as opportunities)
- **Formulation, implementation, launch, operation, and analysis of measurements from a Reflected Solar (RS) Spectrometer, launched to the International Space Station (ISS)**
- **Category 3 / Class D Mission, nominal 1-year mission life + 1 year science data analysis**
- **Project execution authority assigned to NASA LaRC**
- **Project is in extended Phase A**



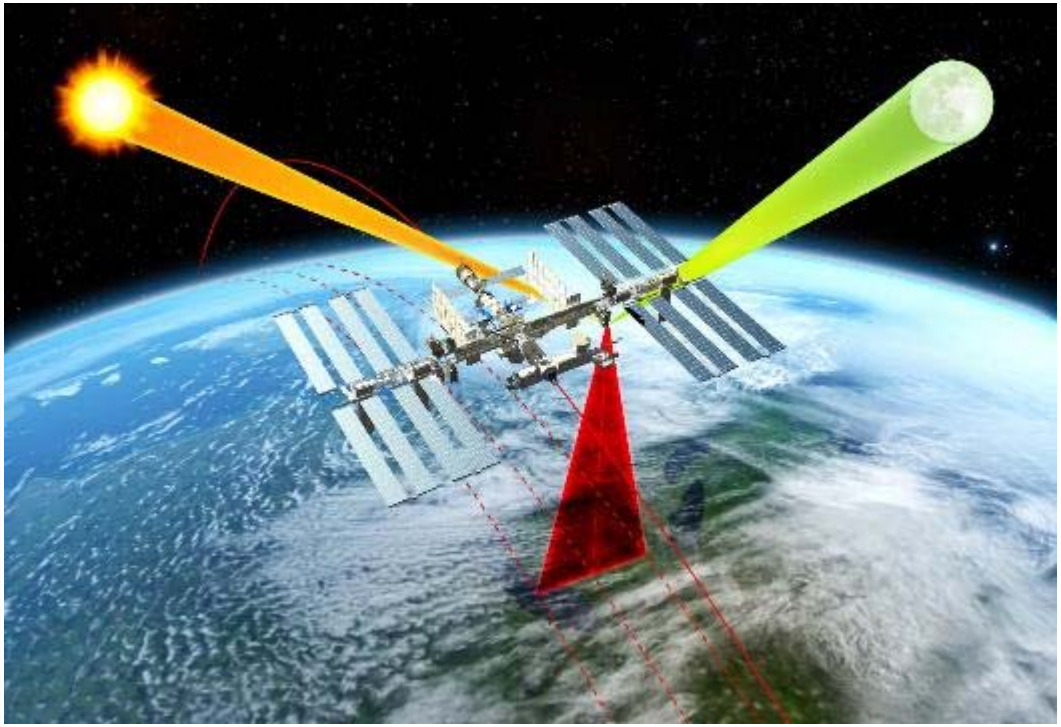
Instrument Payload



Spectrally-Resolved Earth Reflectance

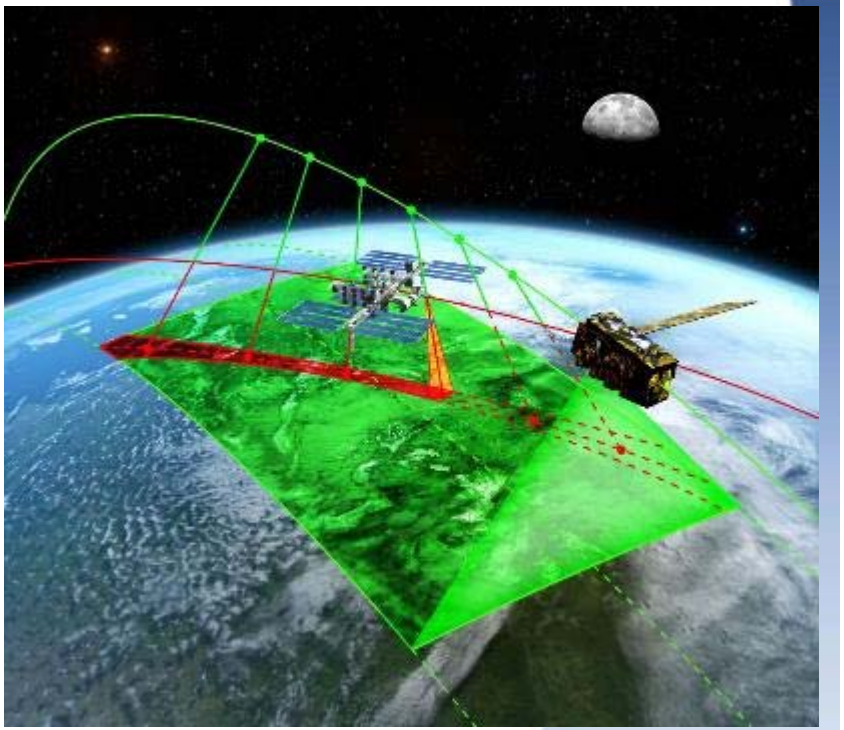
CLARREO Pathfinder Primary Mission Objectives

Demonstrate high accuracy SI-Traceable Calibration



Objective #1: Demonstrate the ability to conduct, on orbit, SI-Traceable calibration of measured scene spectral reflectance with an advanced accuracy over current on-orbit sensors using a reflected solar spectrometer flying on the International Space Station.

Demonstrate Inter-Calibration Capabilities



Objective #2: Demonstrate the ability to use that improved accuracy to serve as an in orbit reference spectrometer for advanced inter-calibration of other key satellite sensors across the reflected solar spectrum (350-2300 nm).

Project Purpose

- **<u>Project Purpose:</u> To advance and demonstrate on-orbit measurement capabilities that, when applied on future missions, will enable detection of climate change trends decades sooner, resulting in improved societal and economic decision making for the benefit of humanity.**

Science Observations

Requirements	
Solar and Lunar Views	Demonstrate On-Orbit SI-Traceable calibration accuracy
Nadir Data Collection	High accuracy, spectrally-resolved, geolocated data of Earth solar reflectance
Earth-views matched in time, space, viewing angle, and spectrum (visible) with CERES/RBI and VIIRS	Demonstrate inter-calibration with CERES/RBI and VIIRS Possibilities: SNPP, JPSS-1, JPSS-2

Additional Mission Opportunities	
Inter-Calibration of Geosynchronous Imagers	Examples: ABI on GOES-16, EUMETSAT's SEVIRI/GERB
Inter-Calibration of Low Earth Orbit Imagers	Example: Landsat imagers
Measurements of Surface Sites (i.e. Deserts) (instrumented and non-instrumented)	Spectrally-resolved reflectance that can be used as calibration references for current/future Earth Science instruments
Calibration of lunar irradiance	Potential ~10x improvement of current lunar irradiance standard, enabling the moon to be used as on-orbit calibration source for current / future Earth Science instruments

- *Instrument payload will have the capabilities to achieve the additional mission opportunities*
- *Priorities will be determined by a future CLARREO Pathfinder Science Team (anticipated FY20-21 start)*

Level 1 Requirements Summary

	Measurement Uncertainty	
Demonstration Parameter	**Baseline Requirement***	**Threshold Requirement****
Spectrally-Resolved Earth Reflectance (350 – 2300 nm): SI-Traceable, referenced to spectral solar irradiance	≤ 0.3% (k = 1)	≤ 0.6% (k = 1)
Spectrally-Integrated Earth Reflectance (350 – 2300 nm): SI-traceable broadband (350 - 2300 nm) spectrally-integrated Earth reflectance with spectral accuracy weighted using global average Earth spectrally reflected energy	≤ 0.3% (k = 1)	≤ 0.6% (k = 1)
On-Orbit Inter-Calibration*:** Demonstrate the ability to Inter-Calibrate with CERES/RBI short wave channel and VIIRS reflectance bands	≤ 0.3% (k = 1)	≤ 0.6% (k = 1)

**Baseline requirement is within a factor of 2 of full CLARREO Tier-1 Decadal Survey (2007) Mission Requirements*

***Threshold requirement is a factor of 2 (CERES) to 4 (VIIRS) better than current capabilities.*

****Inter-calibration uncertainty are contributions from data matching noise.*

CLARREO Pathfinder Reflected Solar Payload Design Concept

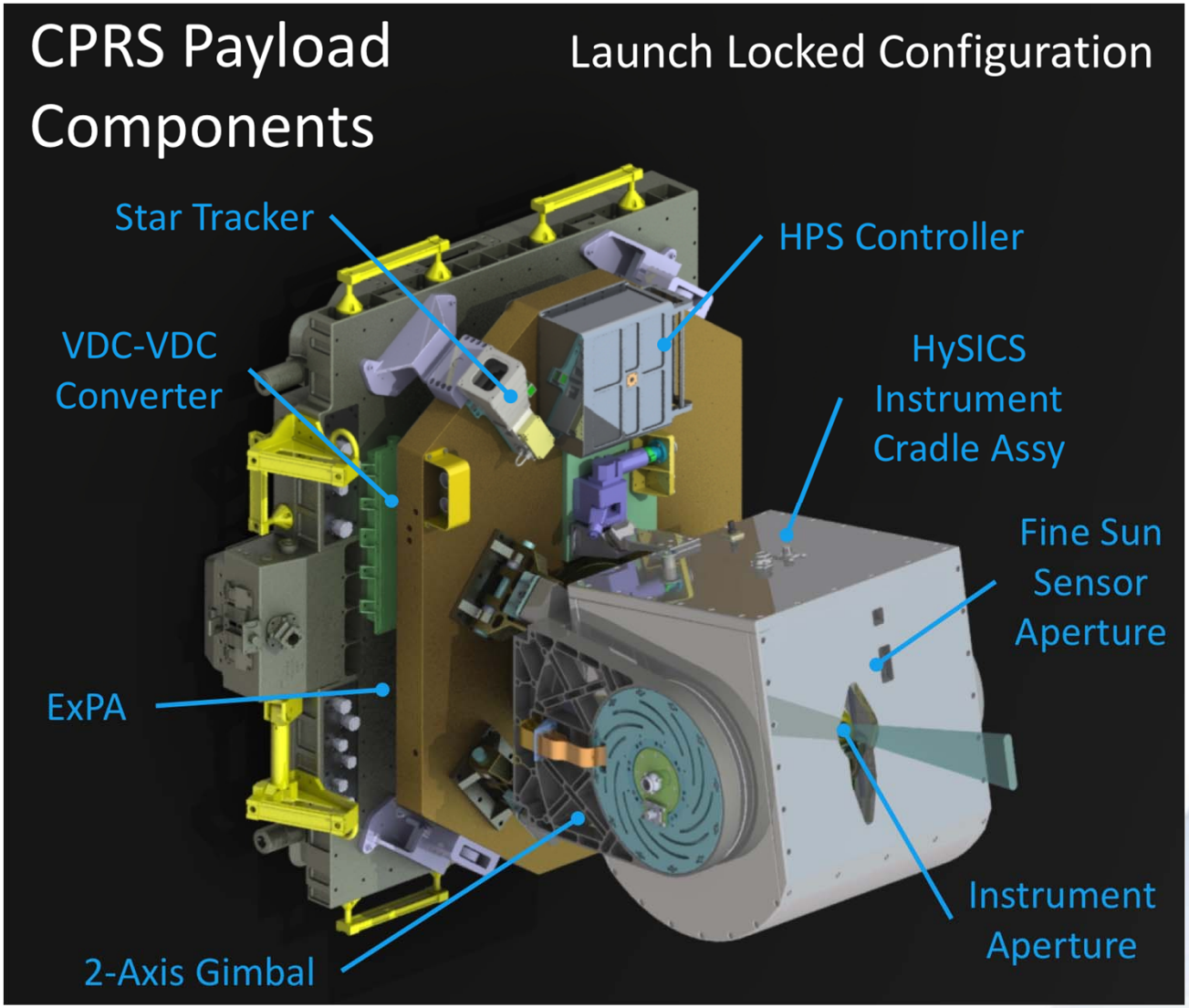
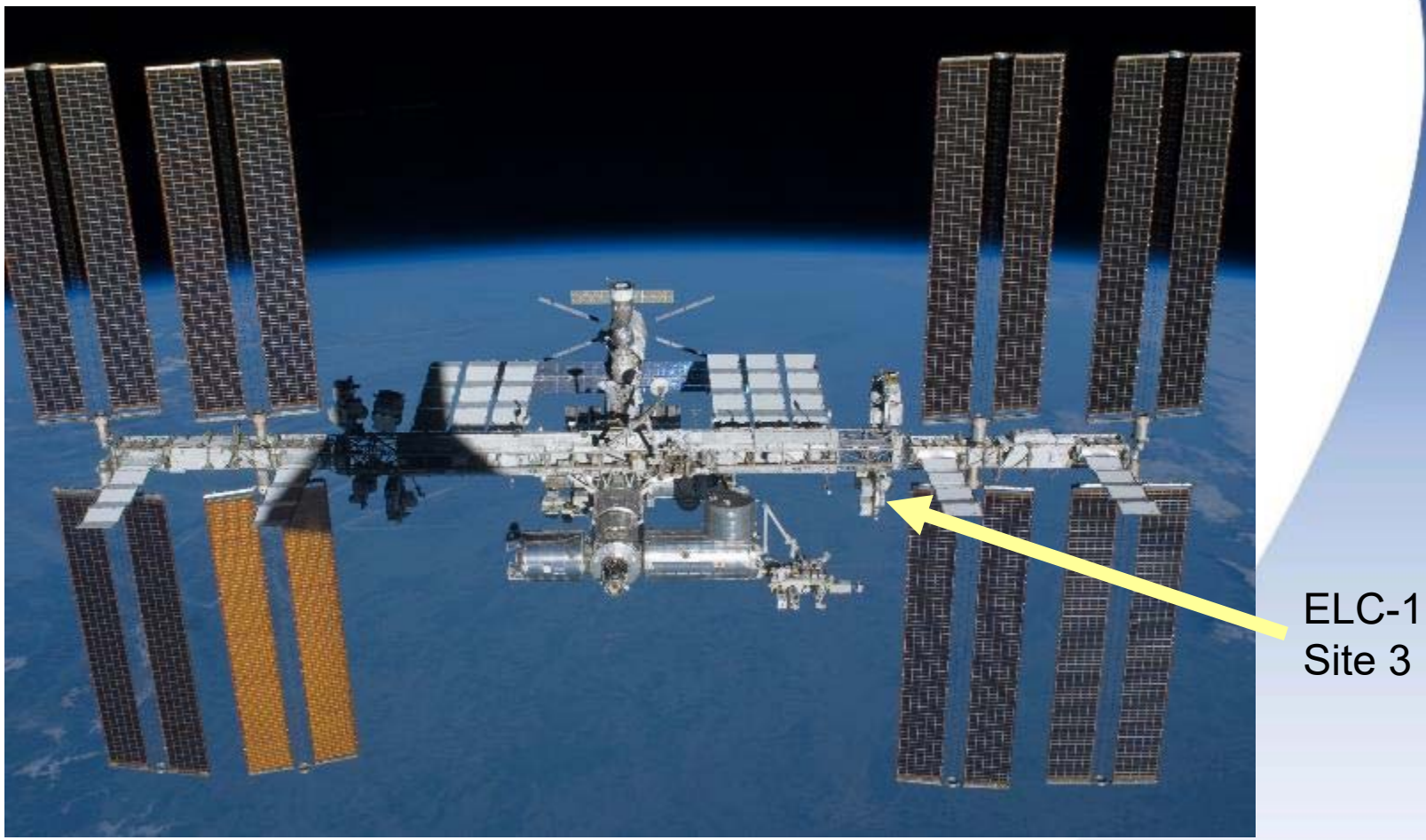


Image Credit: LASP

CLARREO Pathfinder:
Location on ISS: ELC-1 Site #3

- **CLARREO Pathfinder Payload will be installed on ExPRESS Logistics Carrier #1 (ELC-1) Site #3**



Orientation: ISS orbiting towards the reader

Project Status

CLARREO Pathfinder Project Status

as of May 17, 2018

- **CLARREO Pathfinder was included in the FY18 Appropriations passed by Congress on March 23, 2018!**
  - Project has continued to operate in FY18 while under Continuing Resolution
  - Currently in extended Phase A of Formulation
- **Request for Proposal for CLARREO Pathfinder Reflected Solar Payload and Operations prime contract released on April 17, 2018**
  - Sole source procurement to the University of Colorado Laboratory for Atmospheric and Space Physics (LASP)
  - Anticipate awarding prime contract prior to end of FY18 (September 30, 2018)
- **Project will conduct a delta-System Requirements Review with target date of early November, 2018**
  - Project successfully conducted SRR/MDR in July 2017, however programmatics could not be adequately assessed due to uncertainties resulting from the President's FY18 Budget Request
  - Anticipate proceeding into a short Phase B of Formulation after the d-SRR
- **Project has retained strong support and advocacy within NASA Science Mission Directorate – Earth Science Division, and the Earth Systematic Missions Program Office**

Still… A Few Challenges

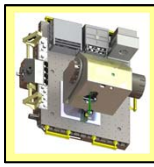
- ***Challenge:*** **The President's FY19 Budget Request retains the previous cancellation of CLARREO Pathfinder, and requests $0 for the project in FY19**
  - Although this is a significant concern it is not currently impacting project execution
  - We do not anticipate any roadblocks to proceeding with prime contract award
  - Stakeholders at NASA HQ have expressed reasonable confidence that CLARREO Pathfinder will continue to move forward
  - As in FY18, if CLARREO Pathfinder is to continue Congress will have to restore funding for it in the FY19 Appropriations
- **The project has incurred an approximate 18 month schedule delay due to the proposed cancellation of CLARREO Pathfinder in the President's FY18 Budget and responding NASA HQ direction to suspend all activities associated with prime contract award (5/26/17)**
  - Our work in FY18 has advanced the project and reduced risk, but has not shortened project schedule because of the inability to initiate long lead procurements

Project Life Cycle Schedule Milestones

Milestone	Date
Prime Contract Award	Sept. 2018
delta System Requirements Review (d-SRR)	Nov. 2018
Preliminary Design Review (PDR)	Feb. 2019
Critical Design Review (CDR)	Nov. 2019
Pre-Environmental Review (PER)	Q3 - CY2021
Pre-Ship Review (PSR)	Q2 - CY2022
Launch Readiness Date (LRD)	Late Q4-CY22 / Early Q1-CY23
End of Prime Operations	Q1 - CY24
End of Project	Q1 - CY25

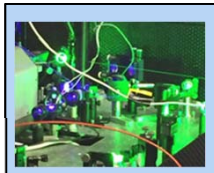
NASA

CLARREO Pathfinder Primary Work Elements



Payload Development

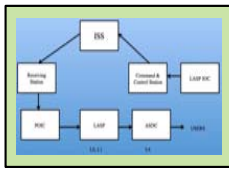
Project Management



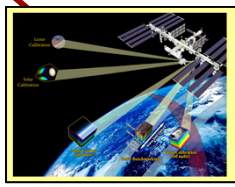
Independent Calibration

Science Data Analysis

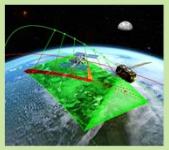
Launch and Accommodation on ISS



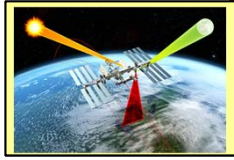
Science Data Management



On-orbit Operations



Demonstrate Inter-Calibration



Demonstrate High Accuracy Calibration

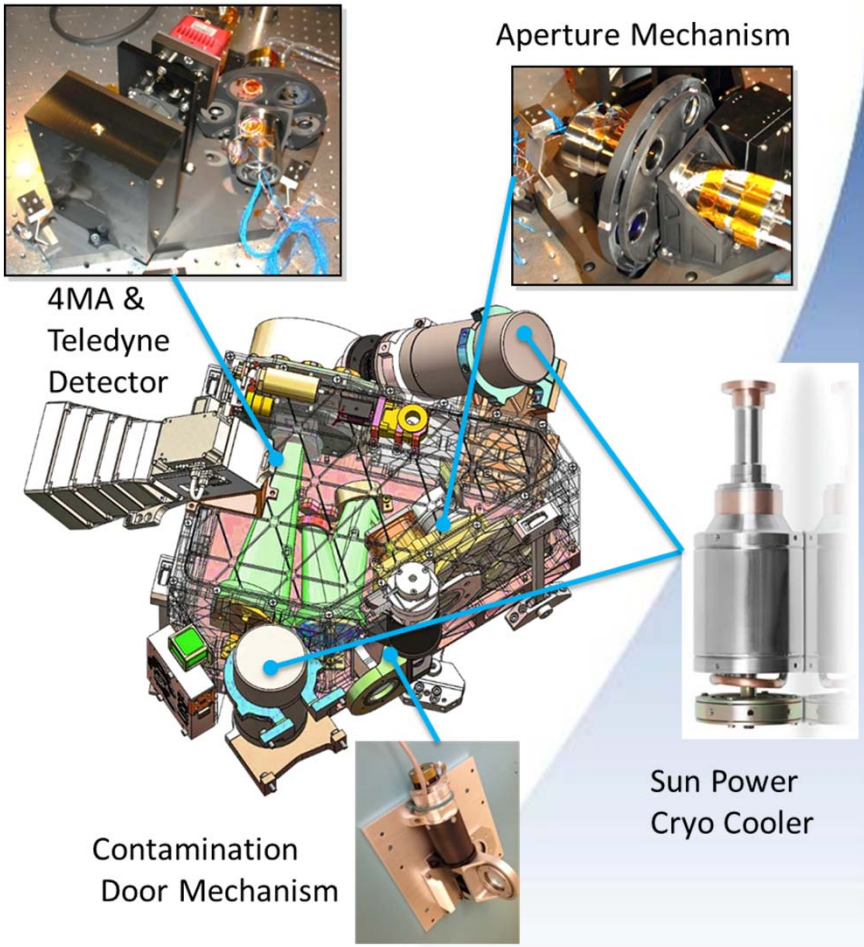
GSFC	LaRC
JSC / ISS	LASP

CLARREO Pathfinder Data Products

Data Product	Description	First Data Delivery after IOC	Maximum data latency after first release
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts (e.g., synchronization frames, communications headers, duplicate data) removed.	4 months	48 hours
Level 1b	Calibrated and geolocated observations at full resolution, annotated with ancillary information such as radiometric and geometric calibration coefficients and georeferencing parameters (e.g., platform ephemeris)	8 months	1 month
Level 4	Time/angle/space matched inter-calibration data for reference (CPF) and target sensors (CERES and VIIRS), scene information from target sensors (CERES and VIIRS), modeled parameters for estimated polarization and radiometric corrections	10 months	6 months

CLARREO Pathfinder
Reflected Solar (RS) Spectrometer Description

- **Based on Hyper-Spectral Imager for Climate Science (HySICS) instrument**
  - Developed by the ***University of Colorado Laboratory for Atmospheric and Space Physics (LASP)*** under NASA Earth Science Technology Office (ESTO) Instrument Incubator Program (IIP)
  - IIP Awards in 2007 and 2010
- **Push-broom Spectrometer**
  - 350-2300 nm spectral range
  - 70km cross-track swath width
  - Previously demonstrated to achieve accuracies approaching CLARREO requirements for climate data records
- **Two-Axis Pointing System enables solar / lunar / Earth viewing**
  - Pointing system will be developed by LASP
  - Active stabilization for use on ISS
  - Leverages significant design heritage from past programs – TSIS, GLORY, TIMED



HySICS instrument has been previously flown on two high altitude balloon flights: 2013 and 2014