CLARREO Pathfinder
Project Status

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Langley Research Center

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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
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.

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

➢ Project Purpose: 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

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

<table>
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<tr>
<th>Demonstration Parameter</th>
<th>Measurement Uncertainty</th>
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<td><strong>Baseline Requirement</strong></td>
<td><strong>Threshold Requirement</strong></td>
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</table>
| **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

CPRS Payload Components

Launch Locked Configuration

- Star Tracker
- VDC-VDC Converter
- ExPA
- 2-Axis Gimbal
- HPS Controller
- HySICS Instrument Cradle Assy
- Fine Sun Sensor Aperture
- Instrument Aperture

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 programmatic 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

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

- Science Data Analysis
- Project Management
- Payload Development
- Independent Calibration
- Launch and Accommodation on ISS
- On-orbit Operations
- Demonstrate Inter-Calibration
- Demonstrate High Accuracy Calibration

GSFC / LaRC / JSC / ISS / LASP
# CLARREO Pathfinder Data Products

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Description</th>
<th>First Data Delivery after IOC</th>
<th>Maximum data latency after first release</th>
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</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts (e.g., synchronization frames, communications headers, duplicate data) removed.</td>
<td>4 months</td>
<td>48 hours</td>
</tr>
<tr>
<td>Level 1b</td>
<td>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)</td>
<td>8 months</td>
<td>1 month</td>
</tr>
<tr>
<td>Level 4</td>
<td>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</td>
<td>10 months</td>
<td>6 months</td>
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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*