



# Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder Mission: Status Overview

**CALCON Technical Meeting  
Thursday, August 25, 2016**

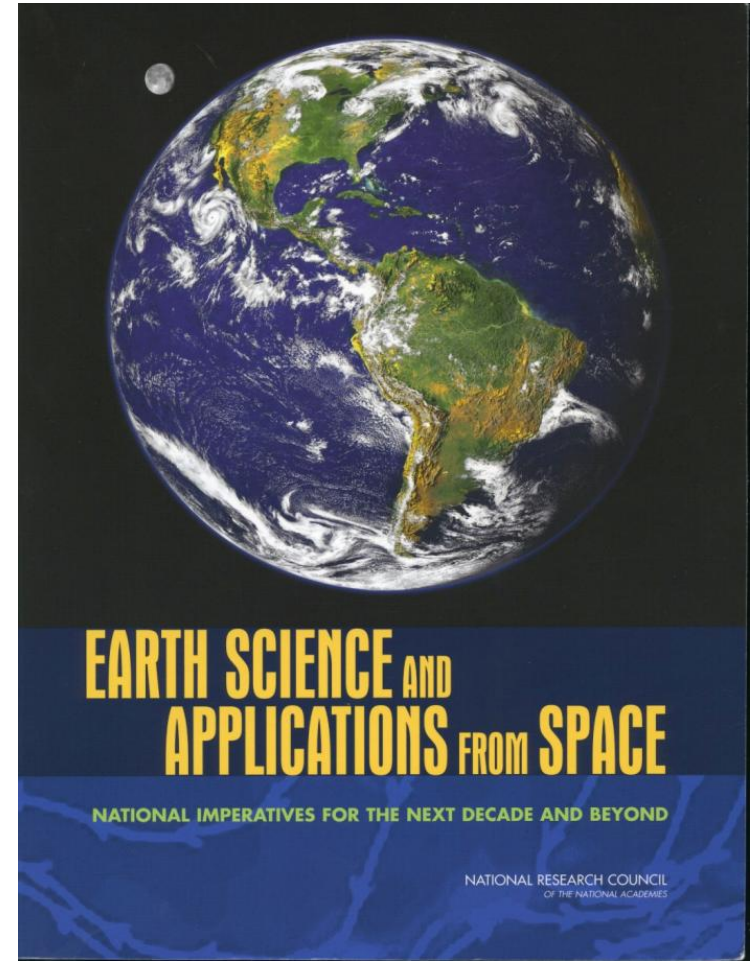
**Yolanda L Shea<sup>1</sup>, R.R. Baize<sup>1</sup>, G.A. Fleming<sup>1</sup>, D. Johnson<sup>1</sup>,  
C. Lukashin<sup>1</sup>, M.G. Mlynczak<sup>1</sup>, K.Thome<sup>2</sup>, and B.A. Wielicki<sup>1</sup>**

<sup>1</sup>NASA Langley Research Center

<sup>2</sup>NASA Goddard Space Flight Center

## CLARREO – Climate Absolute Radiance and Refractivity Observatory

- CLARREO was recommended as a top priority for NASA by the National Academy of Science
  - The [2007 Decadal Survey](#) concluded that the single most critical issue for current climate change observations was their [lack of accuracy](#) and low confidence in observing the small climate change signals over long decadal time scales.



**CLARREO will play an essential role in system of Earth-viewing sensors**



# Novel CLARREO Science Contributions



- **High-accuracy in-orbit standard:** A metrology laboratory in orbit to accurately quantify and attribute climate change.
- **Climate Benchmark (*Decadal Survey Tier 1 mission*):** Fill the critical need for unambiguous climate change measurements with a high level of accuracy (improved by factors of 5 to 10).
- **Climate Change Detection/Attribution:** Used to detect climate trends and to test, validate, and improve climate model predictions.
- **Inter-calibration Standard:** Inter-calibrate 30 to 40 Earth viewing sensors in LEO and GEO orbits to a higher accuracy.
- **Discovery Science:** Provide the first spectral observations of Earth's far-infrared, which includes 50% of Earth's energy emitted to space.



**Authority to Proceed** received April 11, 2016 stated **funds support:**

- Formulation, implementation, launch to ISS, and operation of a Reflected Solar (RS) Spectrometer
- Category 3 / Class D Mission
- Nominal 1-year mission life
- Additional 1 year science data analysis

**Purpose:** Demonstrate essential measurement technologies for the Reflected Solar portion of the full Tier 1 Decadal Survey-recommended CLARREO mission

1. Demonstrate on-orbit, high accuracy, SI-Traceable calibration
2. Demonstrate ability to transfer calibration to other operational satellite sensors by inter-calibrating CERES & VIIRS on JPSS

Target instrument [launch date late CY2020](#)

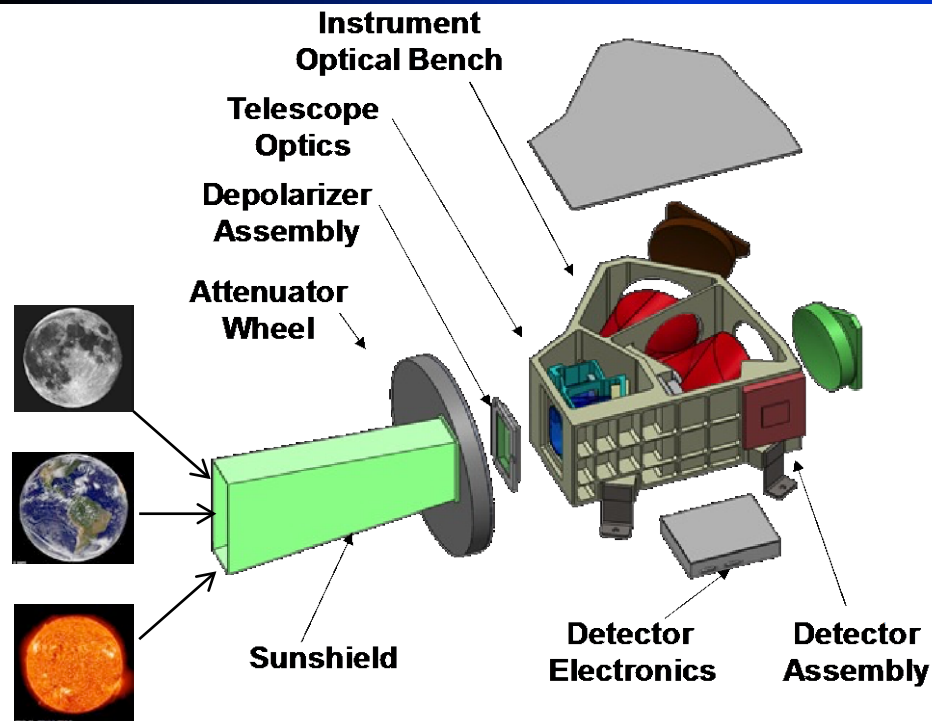
**CLARREO Pathfinder is a critical step toward the full CLARREO Mission.**



# CLARREO Pathfinder vs Full Mission



Parameter	Full CLARREO Mission	CLARREO Pathfinder
Science Objectives	<ul style="list-style-type: none"> <li>• Document climate changes</li> <li>• Make highly accurate and SI-traceable decadal change observations</li> <li>• Improve calibration traceability for EOS assets</li> </ul>	Demonstrate essential measurement technologies for CLARREO (RS only): <ol style="list-style-type: none"> <li>1. On-orbit, high accuracy, SI-Traceable calibration</li> <li>2. Transfer calibration to other operational assets</li> </ol>
Lifetime	5+ Years	1 Year
Data Products	L1-L4 (L2 GNSS-RO, L3 Benchmark)	L1 (L4 for CERES, VIIRS)
Orbit	2 satellites: P90	ISS 52° Inclination
Reflected Solar	2 Instruments: 1 Per Satellite	1 Instrument
Infrared	2 Instruments: 1 Per Satellite	None
GNSS-RO	2 Instruments: 1 Per Satellite	None
Reference Inter-calibration	<ul style="list-style-type: none"> <li>• Broadband CERES</li> <li>• Operational sounders (e.g. CrIS, IASI) &amp; imagers (e.g. VIIRS, AVHRR, Landsat)</li> <li>• Geo assets (all)</li> <li>• Vicarious calibration targets</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Broadband CERES on JPSS</b></li> <li>• <b>Operational imager (VIIRS on JPSS)</b></li> <li>• Lunar spectral reflectance</li> <li>• Geo and land imagers (data collection only)</li> <li>• Vicarious calibration targets (limited)</li> </ul>



Parameter	Requirement
Accuracy	<0.3% (k=1)
Spatial Resolution	- 0.5 km spatial samp. - 70 km swath
Spectral Range	350 nm – 2300 nm
Spectral Resolution	3 nm sampling 6 nm spectral res.

- RS Calibration Demonstration Breadboard developed and in test.
  - Successfully demonstrated the measurement approach.
  - Incorporated NIST calibration advancements
- Earth Science Technology Office investments
  - CU/LASP IIP
  - Successfully matured the required technologies to TRL=6.
  - ESTO investments have also benefited other existing missions

**CLARREO Pathfinder RS Instrument reaped benefits of CLARREO advances**

## EXPRESS Pallet Adapter (ExPA)

## RS Spectrometers

## Instrument Control and ISS Interface Electronics

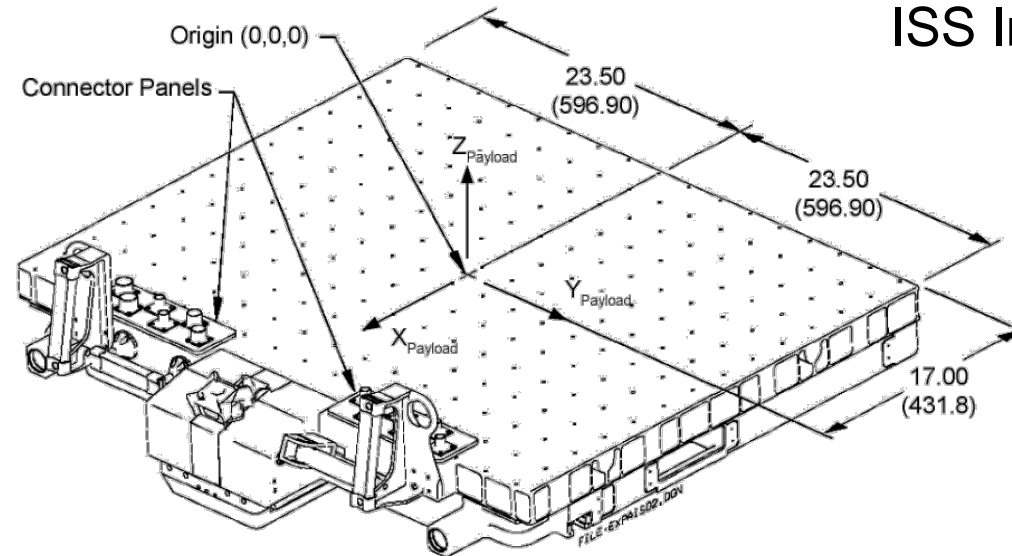
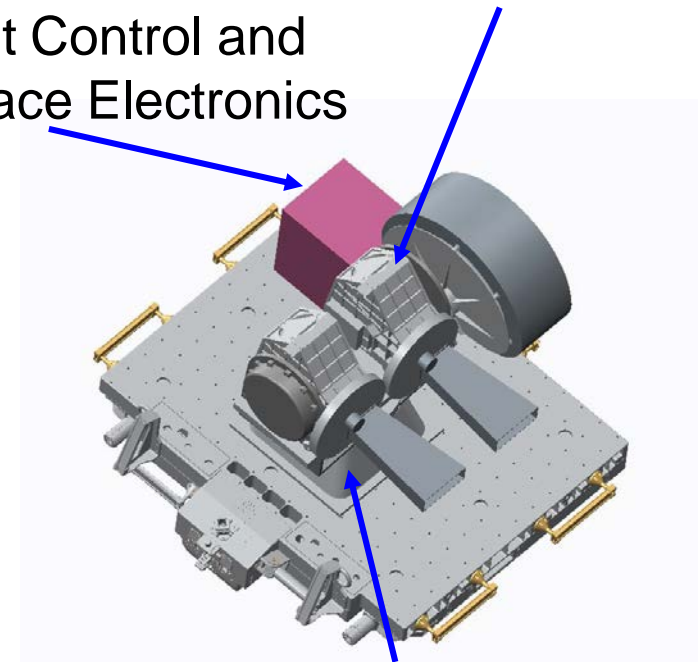
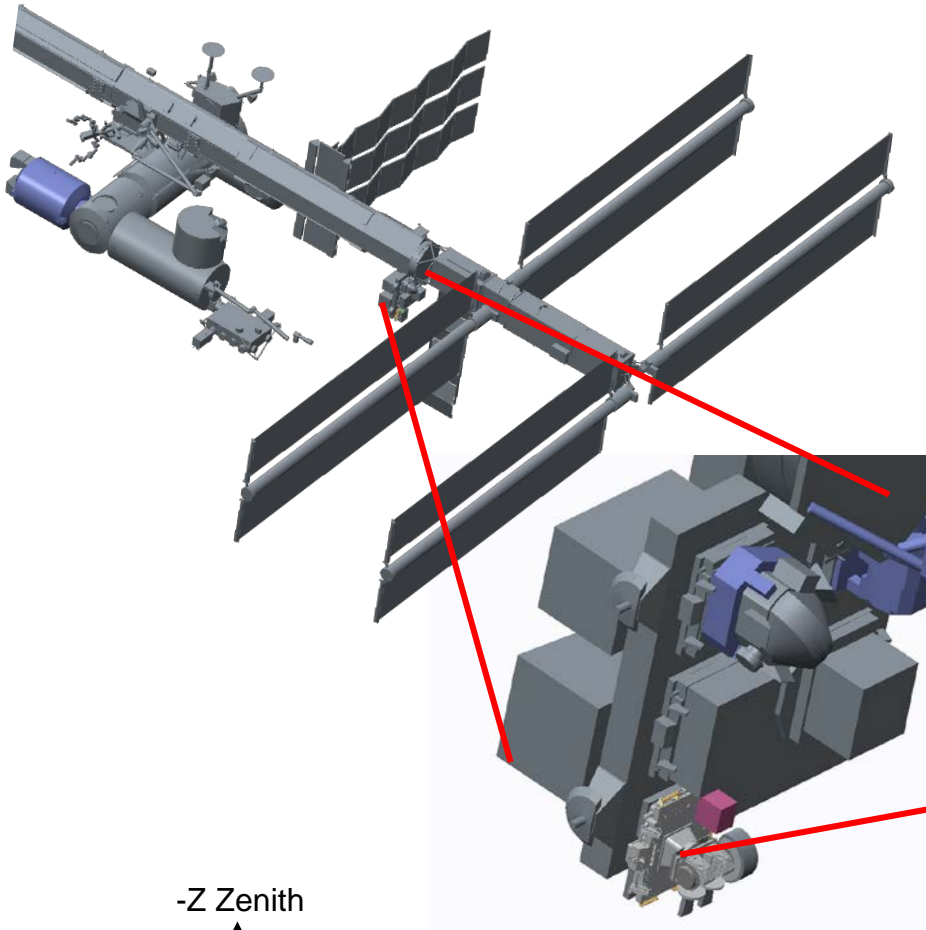


Figure 3.1.1-4. Generic ExPA payload coordinate system.

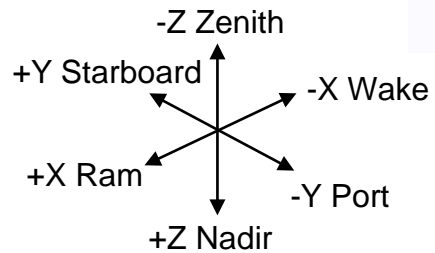
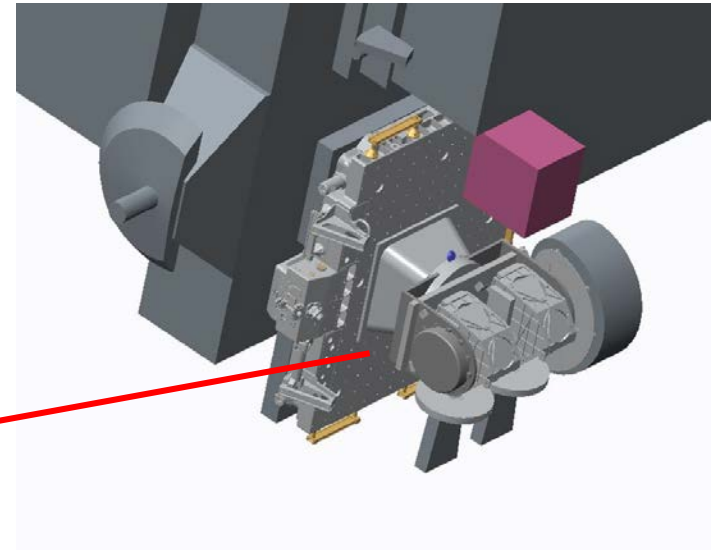


## Two-Axis Pointing System Pitch & Roll with gimbal

- Will make use of ISS wireless data transfer infrastructure for data transfer to ISS and subsequent telemetry downlink

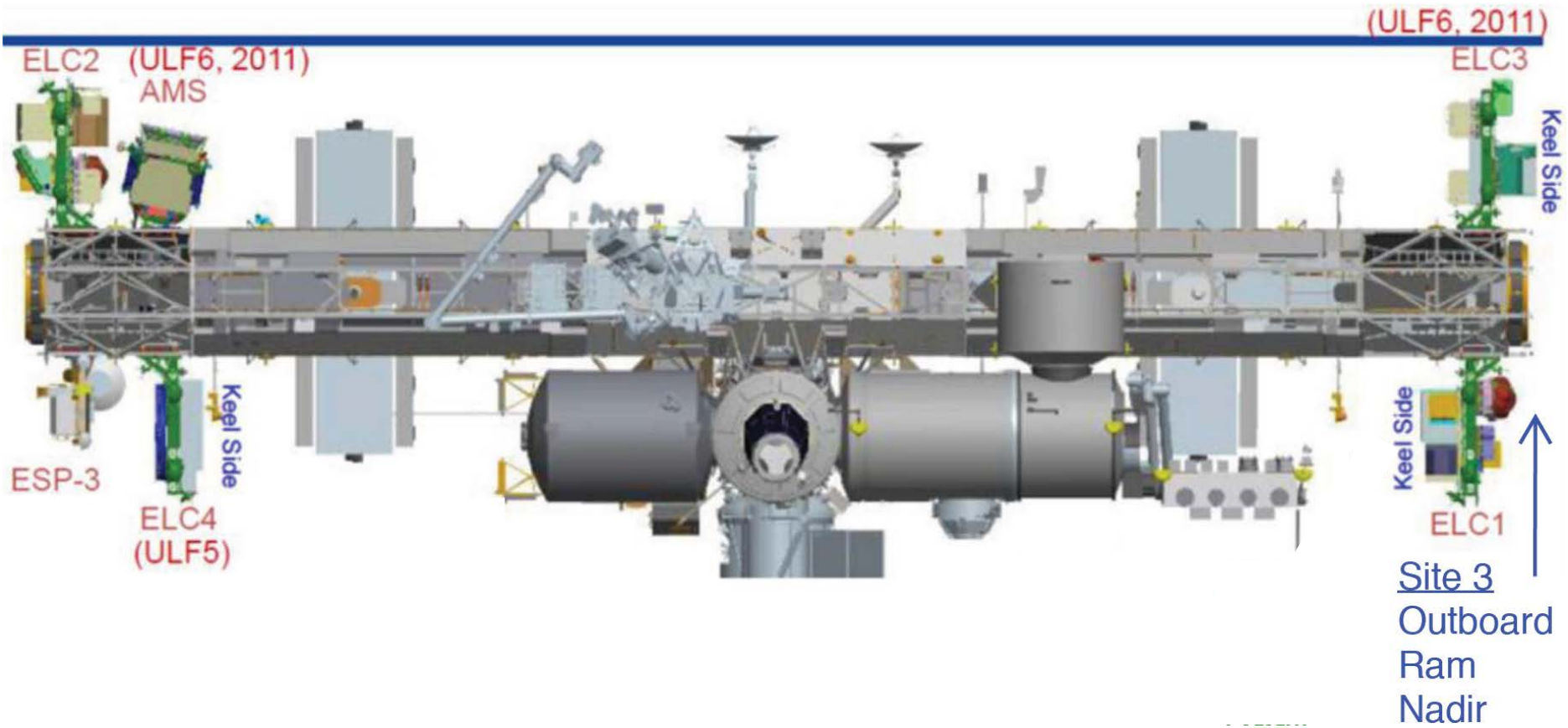


## ELC-1 (ExPRESS Logistics Carrier #1) Site 3





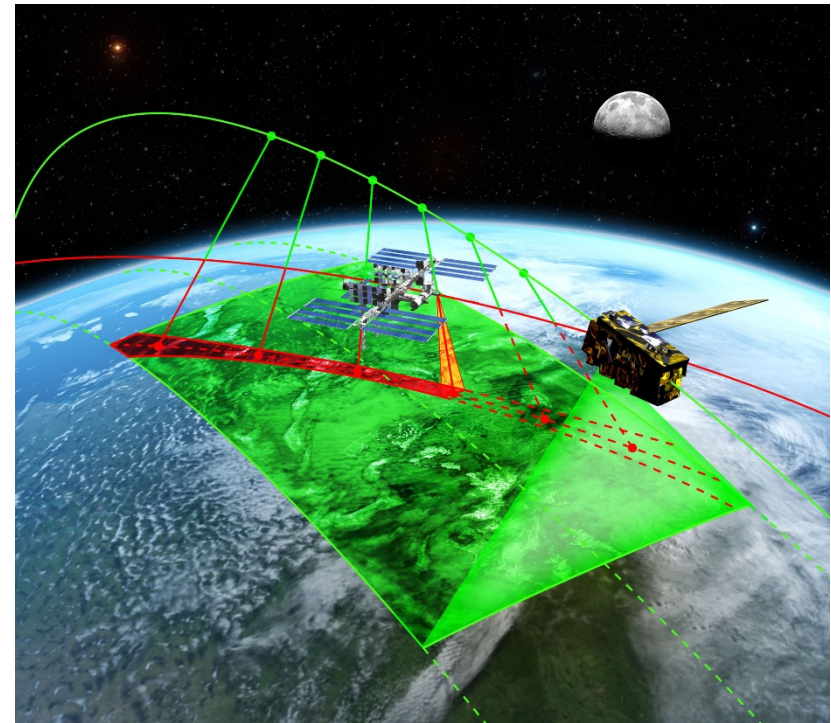
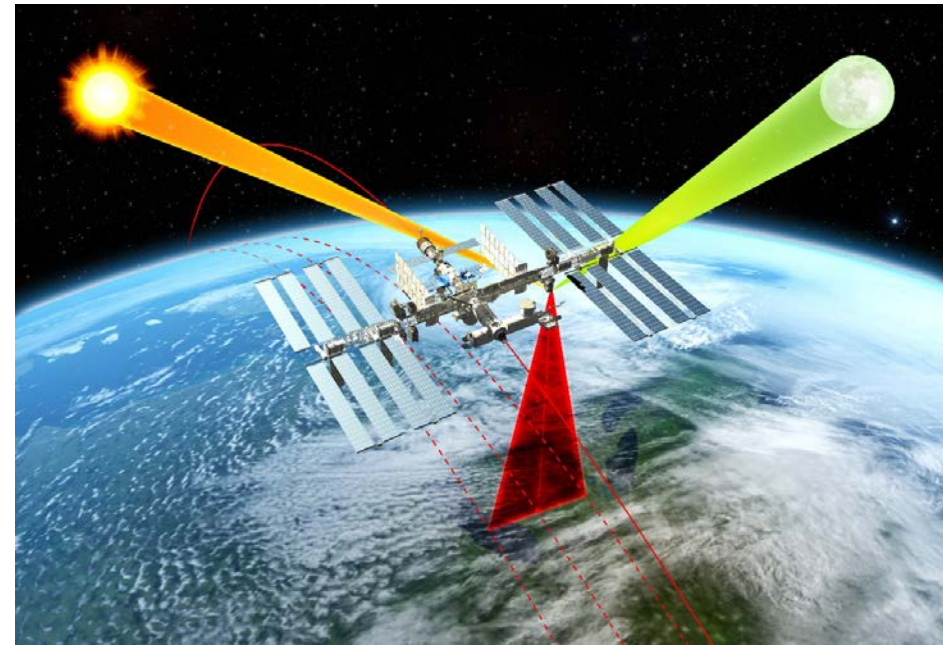
- CLARREO Pathfinder Payload will be installed on ExPRESS Logistics Carrier #1 (ELC-1) Site #3



Orientation: ISS flying out of the page towards the reader

## Demonstrate high accuracy SI-Traceable Calibration

## Demonstrate Inter-Calibration Capabilities

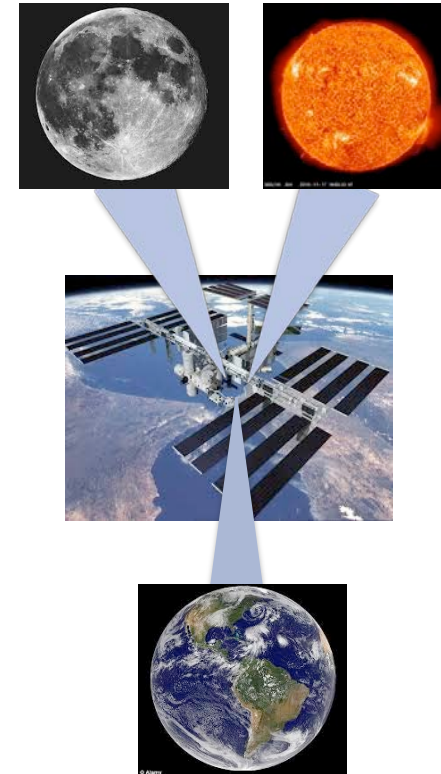


Objective #1: Demonstrate the ability to conduct, on orbit, SI-Traceable calibration of measured scene spectral reflectance, with an advance in accuracy over operational sensors.

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

**Calibration verified on-orbit *and* traceable to international standards**

- **Solar & lunar calibration** - performed intermittently (dependent on 6 minute accesses availability)
- **Inter-calibration**
  - CERES & VIIRS on JPSS
  - Other assets as feasible
- **Nadir observations** – daylight portion of every orbit
  - Scene selection and data compression maximize data capture during available science data downlinks
- **Full resolution Earth scenes** - periodically to:
  1. Demonstrate full capabilities of instrument
  2. Provide diagnostic capabilities for assessing performance
  3. Advance data analysis and data compression tools
- **Lower spatial resolution** scenes may be binned to higher spectral/spatial resolution to initiate climate benchmark-quality data series





# CLARREO Pathfinder: Data Products



- L0, Cal, L1 data products produced by instrument partner
- L4 Intercalibration products produced at LaRC

Data Product	Description
L0	<ul style="list-style-type: none"><li>○ All science telemetry, time-ordered, duplicate packets removed</li></ul>
Calibration	<ul style="list-style-type: none"><li>○ Solar (flat field and irradiance)</li><li>○ Lunar (flat field)</li></ul>
L1B Nadir Benchmark	<ul style="list-style-type: none"><li>○ Details TBD</li></ul>
L1B Inter-calibration	<ul style="list-style-type: none"><li>○ Full resolution (spatial and spectral)</li><li>○ LEO (CERES &amp; VIIRS on JPSS) &amp; GEO targets</li><li>○ Lunar spectral reflectance (USGS lunar model)</li><li>○ Surface Sites</li></ul>
L4 Inter-calibration	<ul style="list-style-type: none"><li>○ CERES-matched</li><li>○ VIIRS-matched</li></ul>

**Data Products align with science objectives directed in Authority to Proceed**

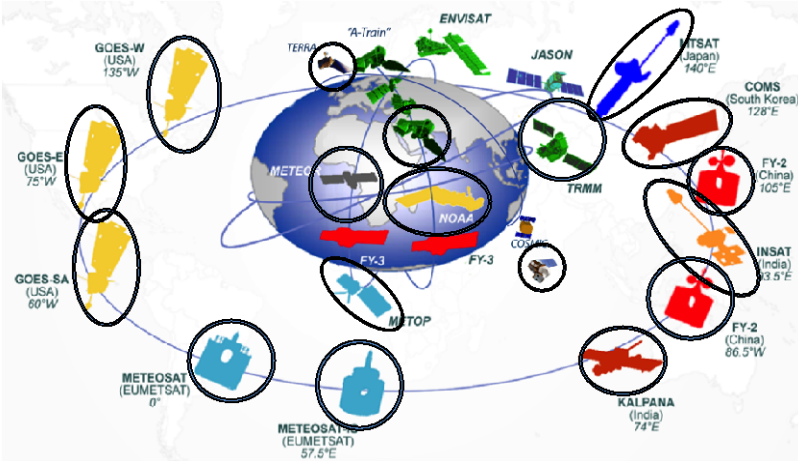


- Lessons learned from CLARREO Pathfinder will benefit a future CLARREO mission, reducing risk by
  - Demonstrating **SI-traceable** calibration approaches in orbit
  - Demonstrating that **SI-traceable inter-calibration** is achievable
- CLARREO Pathfinder will demonstrate highest accuracy reflectance measurements from orbit of any other operational Earth observing instrument
  - First on-orbit SI-traceable reflectance with **absolute accuracy <0.3% (k=1)**
- Lessons learned from CLARREO Pathfinder will produce benefits across many NASA Earth Science Missions and International Missions
  - Improved laboratory calibration approaches
  - Development and testing of innovative on-orbit SI-traceable methods
  - Transfer calibration to other operational sensors
  - Improved lunar reflectance standard

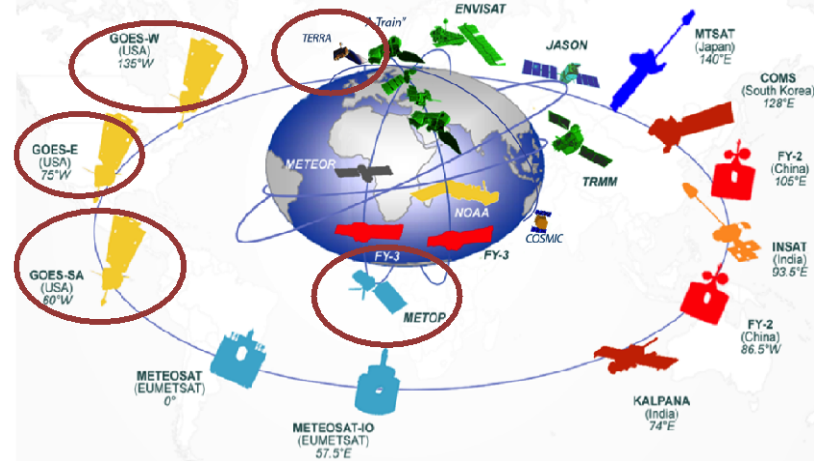
**CLARREO Pathfinder will improve accuracy across Earth Sciences**

- Potentially provide **one year of inter-calibration data** with Suomi-NPP, JPSS-1, MetOP, Terra, Aqua, and geostationary satellites.
  - CPF technology demonstration requires inter-calibration with CERES and VIIRS
- Demonstrate RS spectrometer as **inter-calibration reference on orbit**
  - Potential to benefit to GSICS (Global Space Based Inter-Calibration System)
- Provide accurate measurements of **lunar spectral reflectance**
- Potential **characterization of surface sites** (e.g. Libyan desert) for Landsat inter-calibration and demonstration of capability of accurate surface BRDF spectral product for the full CLARREO mission.

## Full CLARREO Mission



## CLARREO Pathfinder



**CLARREO Pathfinder will improve accuracy across RS Earth Science observations**



# CLARREO Pathfinder: Upcoming Milestones



## Progress to date

- ✓ Authority to Proceed Received April 2016
- ✓ LaRC 60-Day Project Review June 2016
- ✓ ISS Accommodations Review/Site Selection July 2016

## Planned Major Life Cycle Reviews and Dates (all dates TBR)

- Mission Concept Review August 25, 2016
- System Requirements Review Feb/Mar 2017
- Preliminary Design Review September 2017
- Critical Design Review April 2018
- Pre-Ship / Integration Review April 2020
- Operations Readiness Review June 2020

CLARREO website: <http://clarreo.larc.nasa.gov>

Approximately 3 <sup>3</sup>/<sub>4</sub> years from Project Confirmation (KDP-A) to Launch



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### Job Overview

#### Summary

[About the Agency](#)

The Climate Science Branch within the Science Directorate (SD) is seeking a Physical Scientist with expertise in the conception, development, implementation, and validation of passive and active remote sensing instruments to measure the Earth's radiation balance and advance understanding of climate change.

How to Apply

+

Required Documents

+