Libera Mission Status Update

P. Pilewskie & Libera Team

Libera, NASA Earth Venture Continuity-1 Mission

'Li-be-ra, named for the daughter of Ceres in ancient Roman mythology

JPSS-4 Instruments

***Libera* – Earth Radiation Budget**

ATMS - Advanced Technology Microwave Sounder

CrIS - Cross-track Infrared Sounder

VIIRS – Visible Infrared Imaging Radiometer Suite

OMPS – Ozone Mapping and Profiler Suite

Critical Design Review 27-29 June 2023

Provides continuity of the Clouds and the Earth's Radiant Energy System (CERES) Earth radiation budget (ERB).

- Measures integrated shortwave (0.3–5 µm), longwave (5–50 µm), total (0.3–100+ µm) and ***(new) split-shortwave (0.7–5 µm) radiance*** over 24 km nadir footprint; ***uncertainty ~ 0.3%***
- ***Includes a wide FOV camera for scene ID and simple ADM generation to pave way for future free-flyer ERB observing system***

Innovative technology:

- ***Electrical substitution radiometers (ESRs) using vertically-aligned carbon nanotube (VACNT) detectors***

Primary operational modes:

- Cross-track and azimuthal scanning; on-board calibrators; solar and lunar viewing.

Flight:

- **JPSS-4, 2027 launch; 5-year mission**

Partners:

- LASP, Ball Aerospace, NIST Boulder, Space Dynamics Lab; CU, JPL, CSU, UA, UM, LBL

Libera Major Reviews and Key Milestones

Milestone	Acronym	Date	Convening Authority
Authorization to Proceed	ATP	6 Jul 20	-
System Requirements Review	SRR	22 Feb 21	SRB
Key Decision Point - B	KDP-B	30 Apr 21	SMD PMC
Preliminary Design Review	**PDR**	**8-10 Feb 22**	**SRB**
Key Decision Point - C	**KDP-C**	**Apr 22**	**SMD PMC**
Critical Design Review	CDR	27-29 Jun 23	SRB
Pre-Environmental Review	PER	Mar 24	SRB
Pre-Ship Review	PSR	Sep 25	SRB
Delivery to Spacecraft		Sep 25	-
Key Decision Point D	KDP-D	Nov 25	SMD PMC
Launch		2027	-
Key Decision Point E	KDP-E	2027	SMD PMC
Post Launch Assessment Review	PLAR	L+90d	SRB
Operational Transition Review	OTR	PLAR + 9mo	TBD

Engineering Peer Reviews in Preparation for Critical Design Review

- 38 of 51 completed as of last week.

Date	Topic
4/3/2023	Science Data System
4/3/2023	Operations
4/4/2023	PE Power PWBA Schematic
4/5/2023	Ball Wide Field of View Camera, 1-5pm
4/6/2023	ICIE AZ schematic
4/7/2023	Radiometer Calibration Module Overview
4/7/2023	ICIE Mechanical
4/11/2023	PE ATOMS PWBA schematic
4/12/2023	Azimuth Launch Locks
4/12/2023	Ball Long Wave Calibrator 1-5
4/13/2023	ICIE Backplane schematic and layout
4/14/2023	SE: process, interfaces, requirements
4/14/2023	Electrical Interconnects
4/17/2023	AZ platform assembly overview, RCM support, PE mechanical
4/19/2023	Integration and Test
4/19/2023	Ball Telescope assembly, 1-5
4/20/2023	PE Backplane PWBA schematic
4/25/2023	FSW, science data taking and processing
4/26/2023	FSW, ICIE and PE motor control software
4/26/2023	Ball Short Wave Calibrator, 1-5

Date	Topic
4/27/2023	RSM, Shutter, Diffuser mechanisms
4/28/2023	ITDC
4/28/2023	FSW ICIE/ATOMS topics not covered in another review
5/1/2023	Detector Peer Review
5/1/2023	Pointing Controls AM-13
5/2/2023	Ground calibration plans and radiometric performance
5/3/2023	On orbit calibration and long term stability
5/4/2023	WFOV camera system
5/4/2023	FPGA and FSW roll in processing the WFOV science
5/5/2023	Contamination control and purge
5/8/2023	Solar avoidance system
5/8/2023	El scan mechanism, and El launch lock
5/9/2023	Reliability analysis
5/9/2023	FEM/structures
5/10/2023	Thermal
5/10/2023	Electronics Overview
5/11/2023	SSIM
5/11/2023	Pointing Knowledge Budget
5/12/2023	FPGA logic design for ICIE CPU/FPGA and FSW interfaces

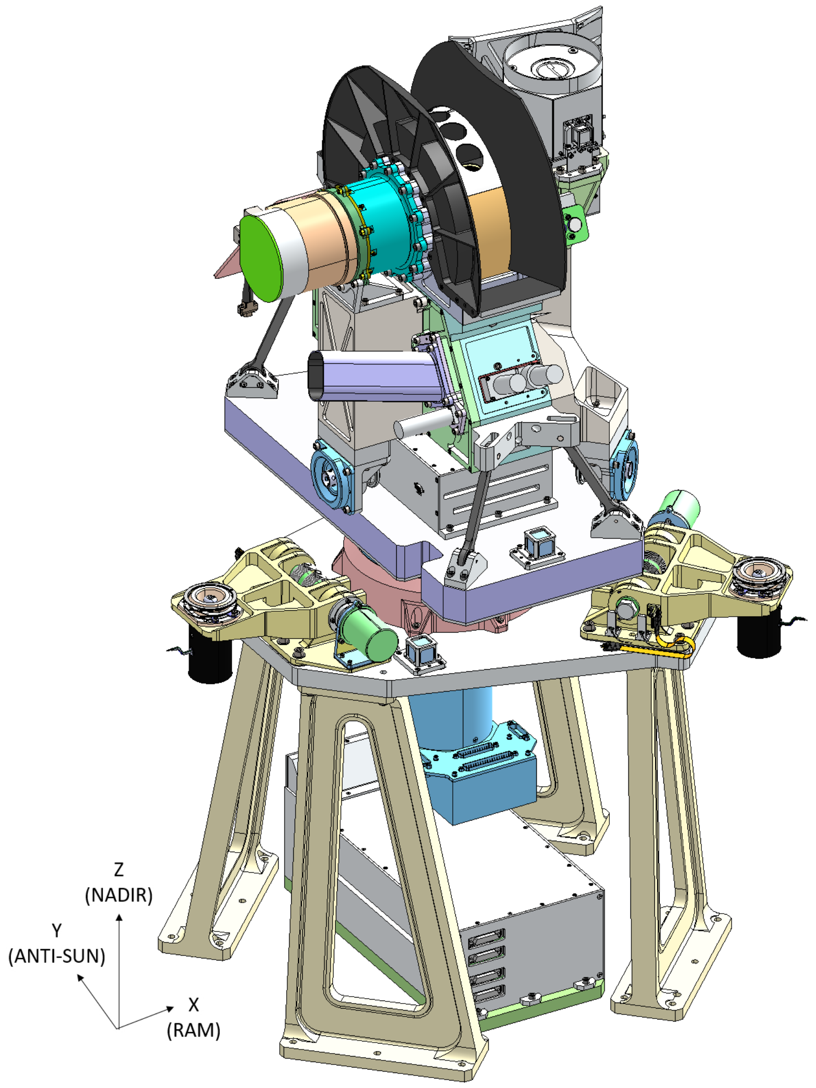
Decision to Integrate Libera onto JPSS-4 and Launch JPSS-4 Prior to JPSS-3

- Libera will be integrated onto JPSS-4.
  - ➢ Trade study performed by JPSS address risk for having a replacement JPSS spacecraft available, and in consideration of the delivery date of Libera
- JPSS-4 will be launched prior to JPSS-3.
  - ➢ There is no change to the Libera delivery date.
- Integration of Libera onto JPSS-3 involved removing JPSS-3 from storage, integrating Libera, conducting regression testing and returning the spacecraft to storage until the target JPSS-3 launch date.
- The current Libera delivery date of Aug. 2025 aligns with the planned flow of integration and testing of JPSS-4
- Reduces risk for Libera because design completion and analyses of the spacecraft will now include Libera in process of development and requires no special testing post storage.

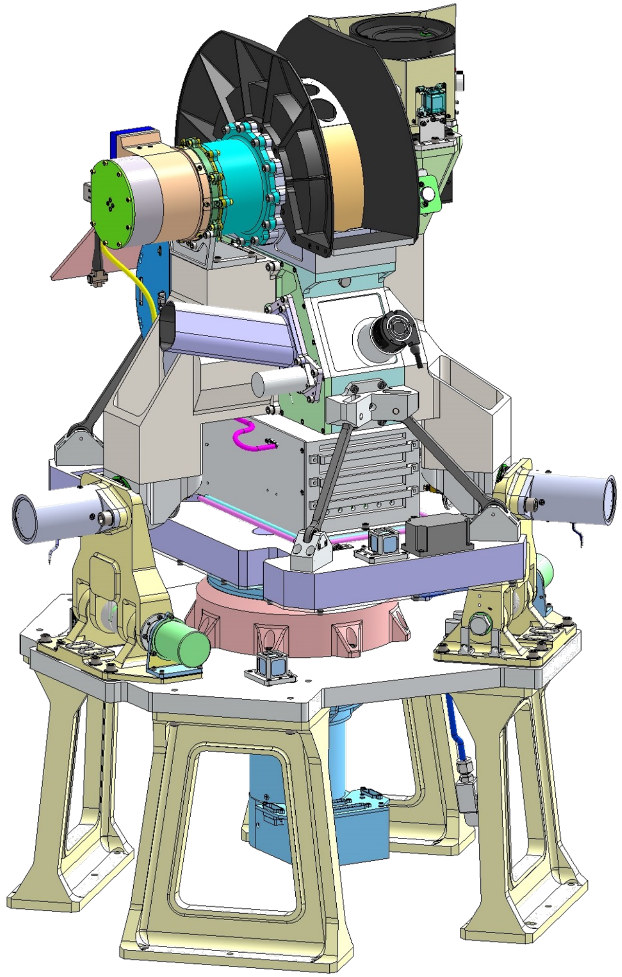
Design Change Driving Delay of CDR

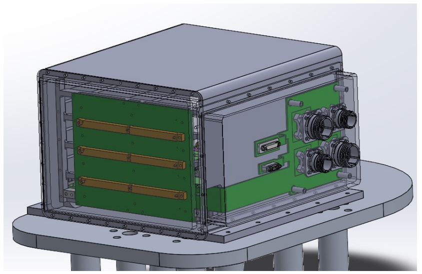
- The PDR version of the Libera envelope did not account for an additional ATMS EMI keep-out zone
  - This was missed by JPSS
- Design changes and additional work were required to meet the new keep-in volume
  - Libera Sensor Stand shortened by 4.1” to avoid ATMS keep-out
  - New ICIE, location, volume and harness accommodations
  - ICIE Form factor change to support existing SC harness routing
  - Additional analysis required
    - Finite elemental analysis
    - Thermal analysis, and possible thermal design changes
    - Disturbance torques and forces for new design
  - Resulting updated requirements (thermal, mechanical environment, etc.) flowed to sub-contractors impacting their designs
- CDR moved by 4 months

Re-design Comparison



PDR Design

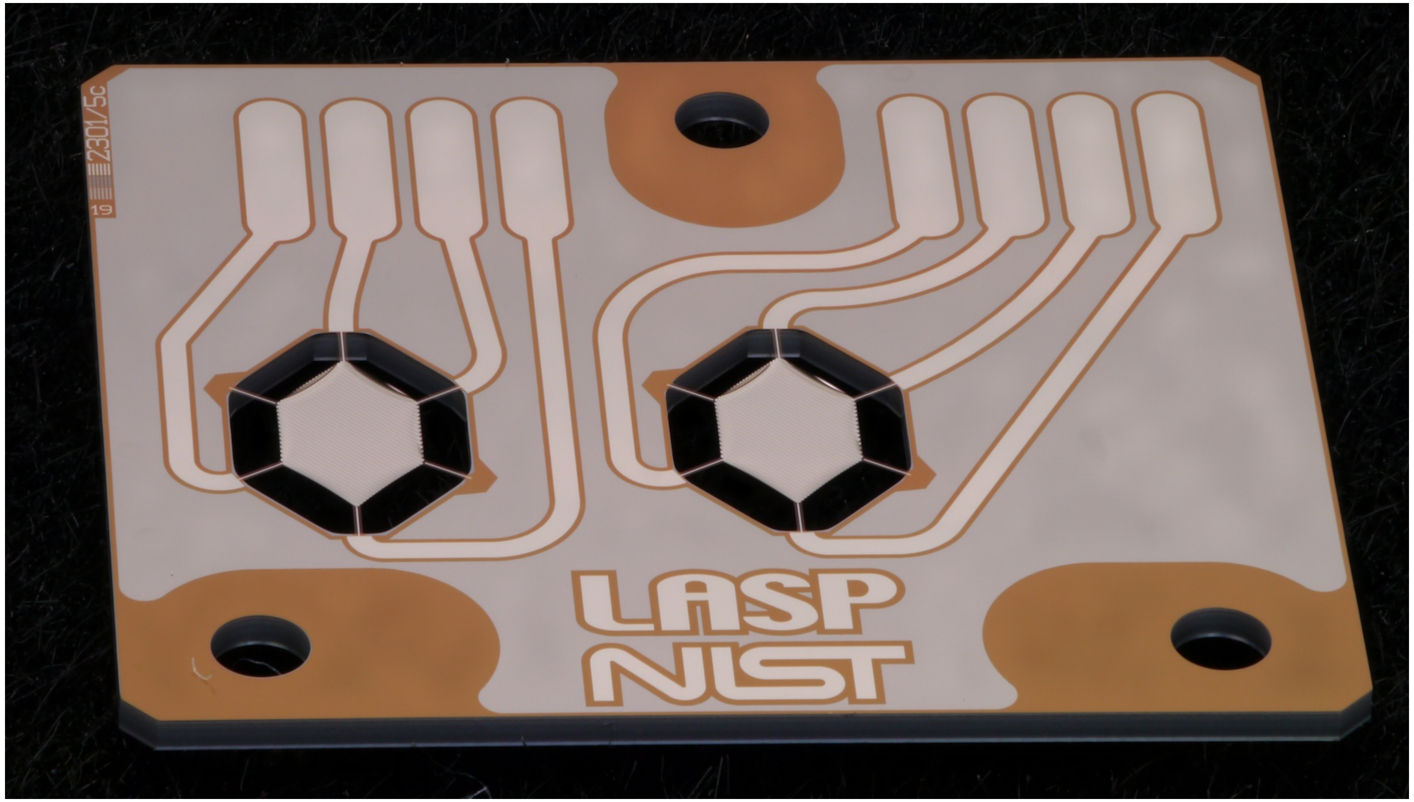




CDR Design

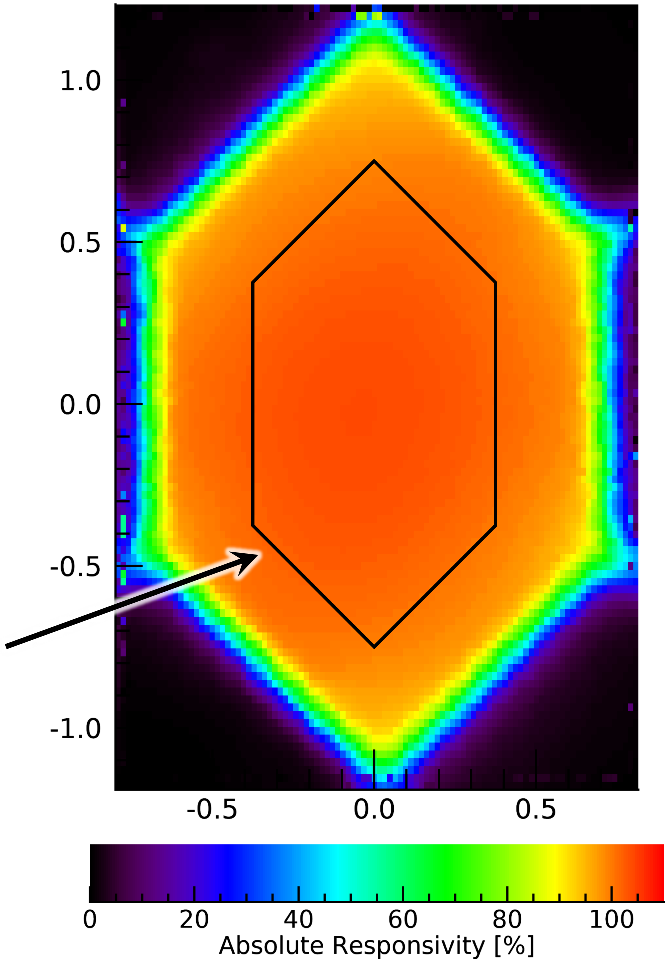
Flight Detector Design

Final Flight Prototype Detector



Flight detector fabrication has started using this same design

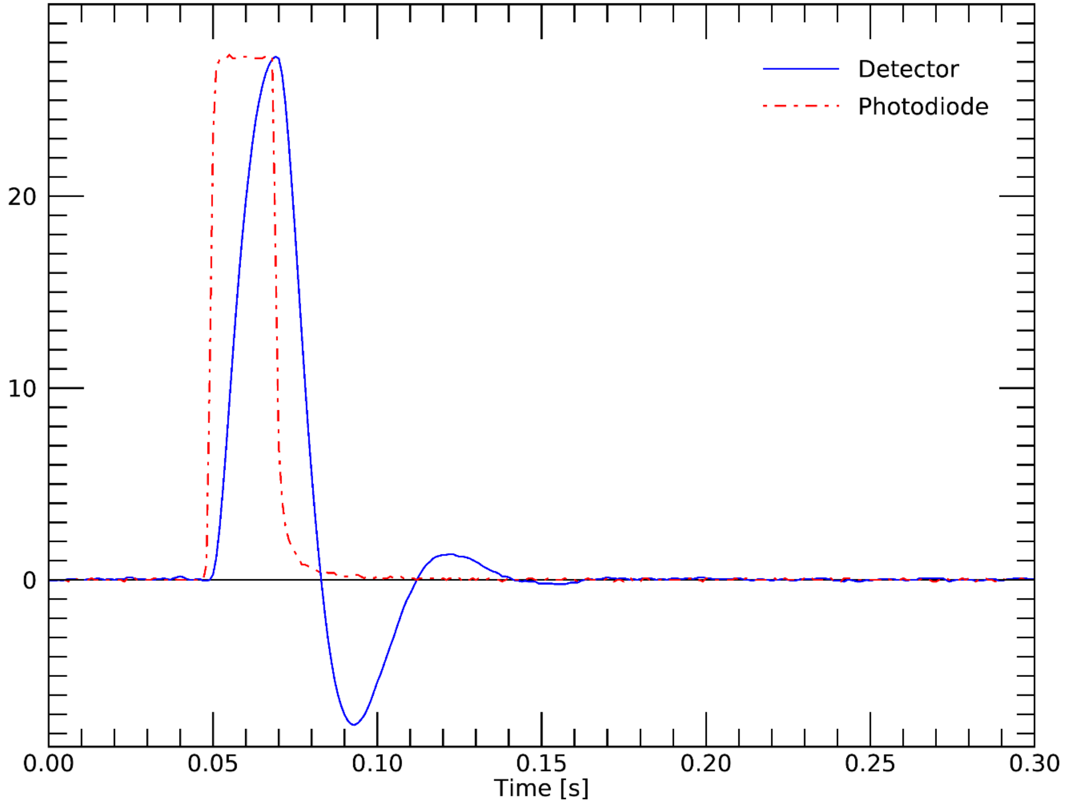
Detector Uniformity Map



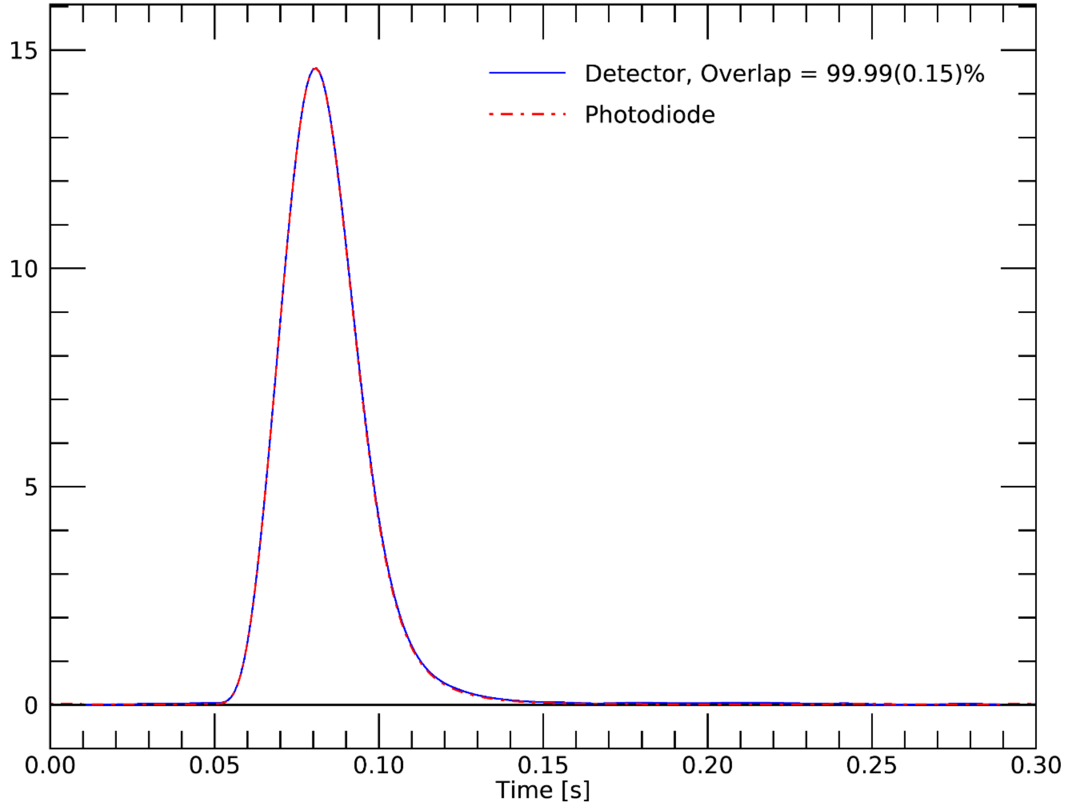
Detector Time Response Testing

- Photodiode response filtered by CERES time response
- Detector filtered with digital filter designed to match CERES response
- Resulting PRFs match

21 ms duration optical pulse (dashed red) applied to detector (blue)



Digital Filtering

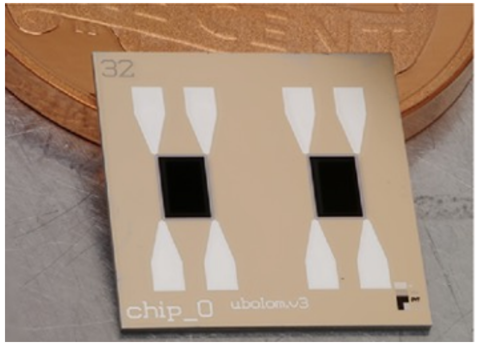


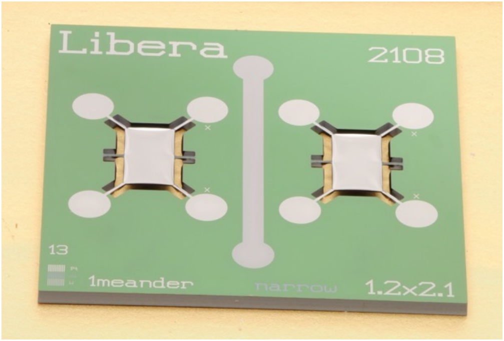
Detector Requirement Status

Requirement	Baseline Value	Prototype 5 Performance
Spectral Ranges	0.3 μm - 5 μm 0.7 μm - 5 μm 5 μm - 50 μm 0.3 μm - >100 μm	Confirmed from reflectivity measurements
Channel Accuracies (k=1)	SW: 0.17% Split SW: 0.17% LW: 0.24% Total: 0.22%	Supported by analysis
Channel Precision	0.11 $W/m^2/sr$	Confirmed
Dynamic Range	0 - 500 $W/m^2/sr$	0 - 500 $W/m^2/sr$
Linearity	0.1%	Confirmed
Response Time	Match CERES	Confirmed
Survival Temperature Range	-20˚C to +50˚C	Verified

Pre-launch Calibration and Characterization

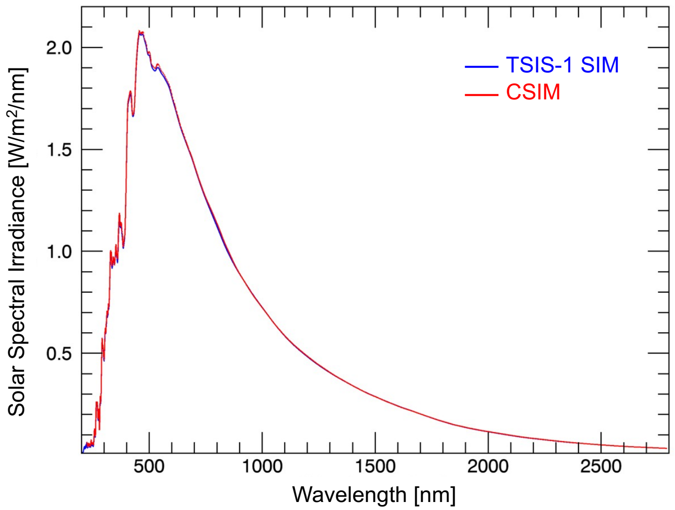
- Component-Level Characterizations
  - Properties of all optical surfaces (mirrors, filters, detectors) measured at NIST and PTB, Germany
  - Used in instrument model to generate expected spectral response functions
- Radiometer Calibrations
  - End-to-end channel calibration at LASP against NIST-traceable absolute radiance standard detector
  - Uses laser tie-points from 300 nm to 16 µm and broadband blackbody sources.
- System Level Validation
  - Integrated system transported to SDL for independent validation using SW & LW targets at a facility developed for RBI





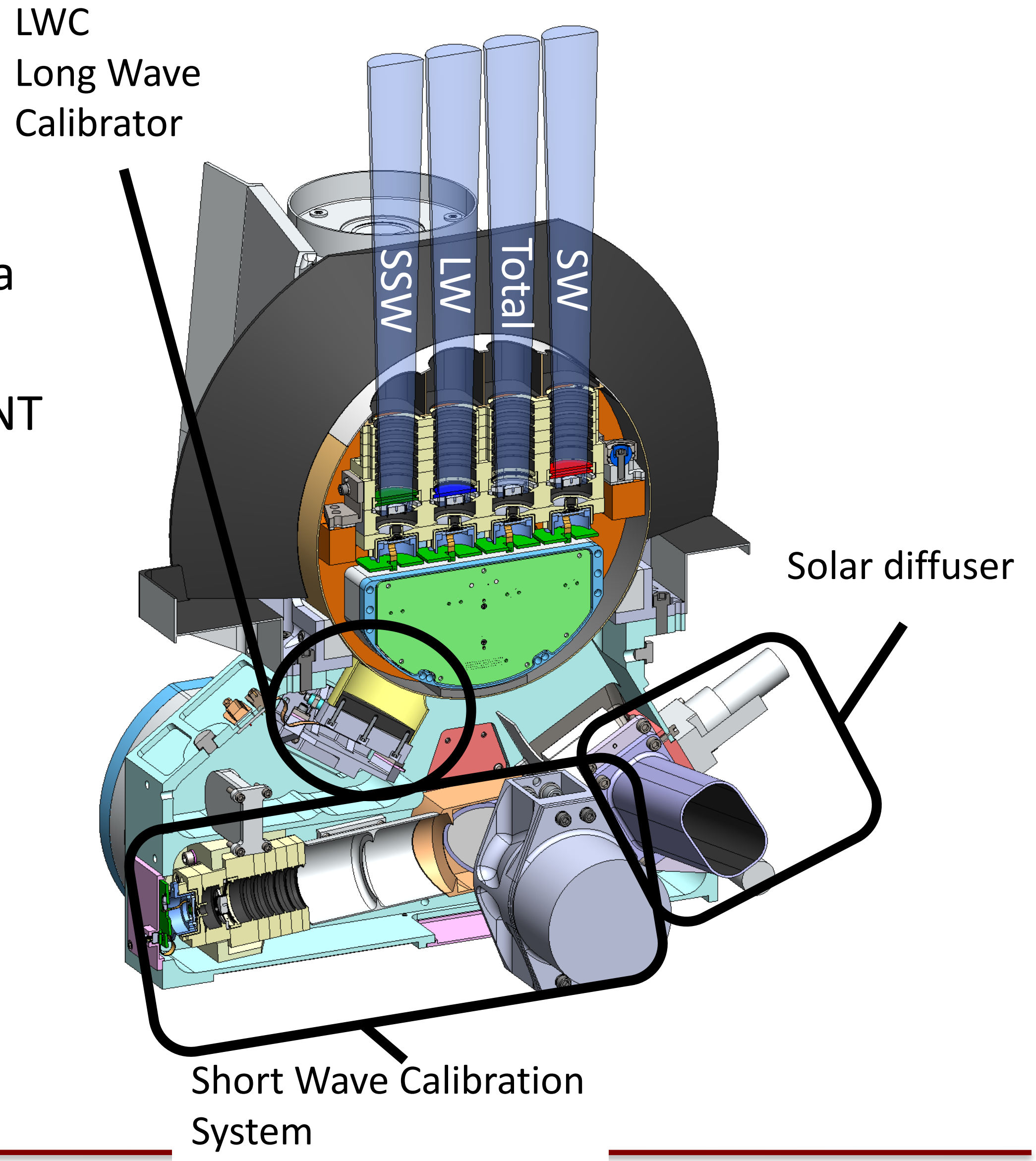
Libera utilizes advanced carbon nanotube detector technology developed by LASP and NIST over a number of ESTO projects: BABAR ACT, CTIM-FD, CAESR, and CSIM-FD.

On-Orbit Demonstration of ESRs Using VACNTs

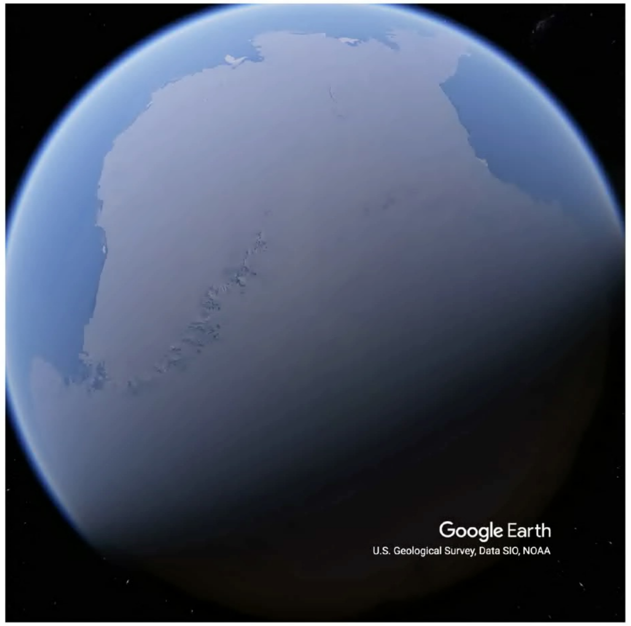


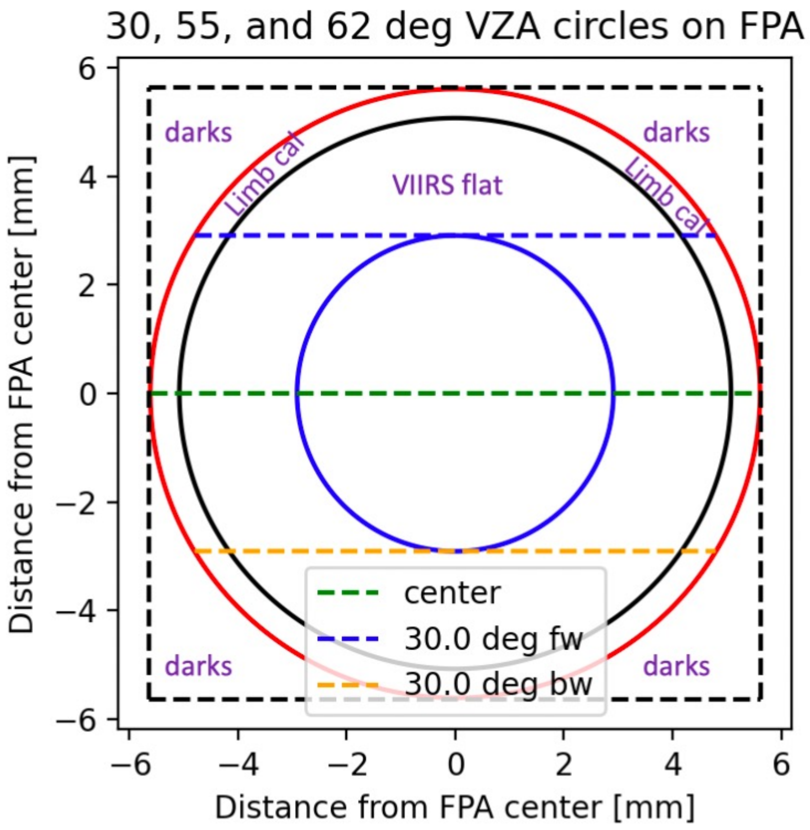
On-Orbit Calibration and Validation

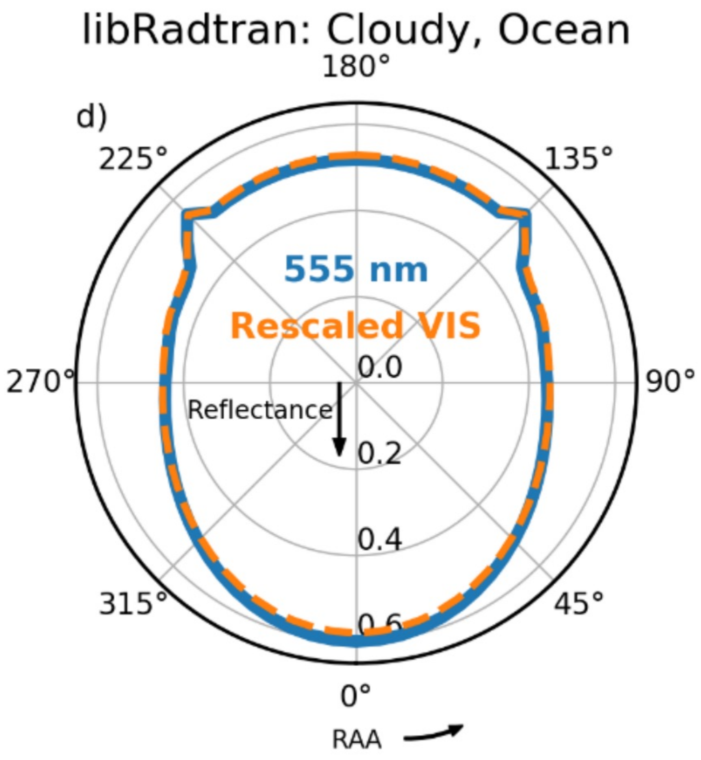
- Onboard calibration targets (daily)
  - Shortwave calibrator using LED sources (365, 410, 520, 625, 810, 1550 nm) and engineered diffuser; stability tracked via a SW calibration radiometer
  - Longwave calibrator: flat-plate blackbody (310-330K) with CNT coating, Si-traceable PRTs to NIST standards.
- Solar calibrations (bi-monthly)
  - Three Spectralon diffusive panels viewed bi-monthly/monthly/semi-annually for degradation tracking
- Lunar calibrations (~ 8-12 per year)



Libera Limb-to-Limb Camera





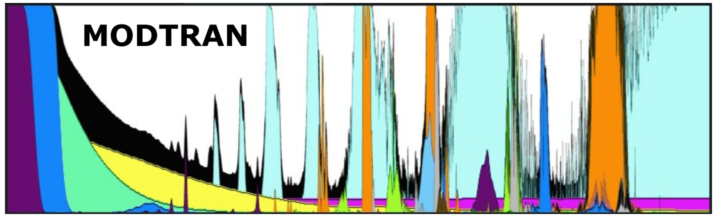


- Collect hemispherical monochromatic radiance
- Provide cloud fraction measurements for simple scene identification
- Accelerate split shortwave ADM development

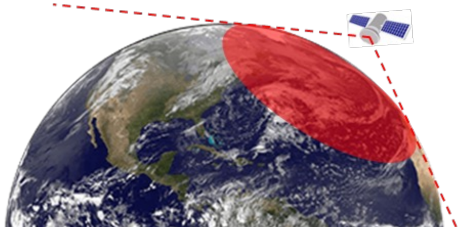
Libera Split-shortwave ADM Approach

Split-SW ADMs do not exist; *how will Libera split-shortwave radiance be converted to irradiance?*

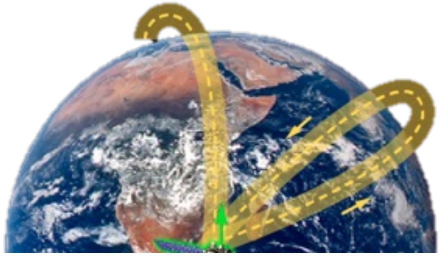
1. OSSE *"prior"* ADMs *[pre-launch]*



2. Wide-field-of-view camera ADMs *[shortly after launch]*



3. Primary split-SW radiometer RAP ADMs *[later in mission]*



Imager independent / Libera only

VIIRS / best available

Note: General approach is to develop new VIS ADMs and obtain NIR irradiance via subtraction

Libera Algorithm Theoretical Basis Document (ATBD)

Section#	Product or Processing	ATBD content	Lead
1	L1b Radiometer radiances	Instrument calibration and operations	D. Harber
2	Geolocation	Radiometer and camera	S. Beland
3	L1c Unfiltered radiometer radiances	VIS and NIR	P. Pilewskie
4	L1b Camera radiances	Instrument, calibration and operations	S. Schmidt
5	L2x Cloud fraction	Adaptive thresholding + camera	S. Schmidt
6	ADMs for split channel	ADM formulation & binning	J. Gristey
7	L2x TOA SW, VIS, NIR irradiance	Instantaneous foot print (limited regions); Scene ID with camera/VIIRS CF VIIRS & (new) ERBE ADMs	M. Hakuba
8	L2 TOA Far-IR irradiance	Instantaneous foot print; includes ADMs	X. Huang
9	L2 SUR fluxes SW, NIR, VIS	Computed TOA and SUR fluxes SSF; validation approach	X. Dong

ERB Continuity: Gap Risk Analysis

- By late 2027, there is a 38% probability of a gap
- Gap-filling methods using imagery data have uncertainty on the order of current decadal trends, 0.4 Wm^{-2}.
- The current ERB data record depends on continuity and overlap