Libera, NASA Earth Venture Continuity-1 Mission
’Li-be-ra, named for the daughter of Ceres in ancient Roman mythology

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

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
**Libera Major Reviews and Key Milestones**

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Acronym</th>
<th>Date</th>
<th>Convening Authority</th>
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<tbody>
<tr>
<td>Authorization to Proceed</td>
<td>ATP</td>
<td>6 Jul 20</td>
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<tr>
<td>System Requirements Review</td>
<td>SRR</td>
<td>22 Feb 21</td>
<td>SRB</td>
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<td>Key Decision Point - B</td>
<td>KDP-B</td>
<td>30 Apr 21</td>
<td>SMD PMC</td>
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<td>Preliminary Design Review</td>
<td>PDR</td>
<td>8-10 Feb 22</td>
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<td>KDP-C</td>
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<td>CDR</td>
<td>27-29 Jun 23</td>
<td>SRB</td>
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<td>Pre-Environmental Review</td>
<td>PER</td>
<td>Mar 24</td>
<td>SRB</td>
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<td>Pre-Ship Review</td>
<td>PSR</td>
<td>Sep 25</td>
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<td>Nov 25</td>
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<td>Launch</td>
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<td>Key Decision Point E</td>
<td>KDP-E</td>
<td>2027</td>
<td>SMD PMC</td>
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<td>Post Launch Assessment Review</td>
<td>PLAR</td>
<td>L+90d</td>
<td>SRB</td>
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<td>Operational Transition Review</td>
<td>OTR</td>
<td>PLAR + 9mo</td>
<td>TBD</td>
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## Engineering Peer Reviews in Preparation for Critical Design Review

- **38 of 51 completed as of last week.**

<table>
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<tr>
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<th>Topic</th>
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<tbody>
<tr>
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<td>Science Data System</td>
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<td>4/3/2023</td>
<td>Operations</td>
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<tr>
<td>4/4/2023</td>
<td>PE Power PWBA Schematic</td>
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<tr>
<td>4/5/2023</td>
<td>Ball Wide Field of View Camera, 1-5pm</td>
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<td>4/6/2023</td>
<td>ICIE AZ schematic</td>
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<tr>
<td>4/7/2023</td>
<td>Radiometer Calibration Module Overview</td>
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<tr>
<td>4/7/2023</td>
<td>ICIE Mechanical</td>
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<td>4/11/2023</td>
<td>PE ATOMS PWBA schematic</td>
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<tr>
<td>4/12/2023</td>
<td>Azimuth Launch Locks</td>
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<td>4/12/2023</td>
<td>Ball Long Wave Calibrator 1-5</td>
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<tr>
<td>4/13/2023</td>
<td>ICIE Backplane schematic and layout</td>
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<tr>
<td>4/14/2023</td>
<td>SE: process, interfaces, requirements</td>
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<tr>
<td>4/14/2023</td>
<td>Electrical Interconnects</td>
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<tr>
<td>4/17/2023</td>
<td>AZ platform assembly overview, RCM support, PE mechanical</td>
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<tr>
<td>4/19/2023</td>
<td>Integration and Test</td>
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<tr>
<td>4/19/2023</td>
<td>Ball Telescope assembly, 1-5</td>
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<tr>
<td>4/20/2023</td>
<td>PE Backplane PWBA schematic</td>
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<td>4/25/2023</td>
<td>FSW, science data taking and processing</td>
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<td>4/26/2023</td>
<td>FSW, ICIE and PE motor control software</td>
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<td>4/26/2023</td>
<td>Ball Short Wave Calibrator, 1-5</td>
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<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
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<tbody>
<tr>
<td>4/27/2023</td>
<td>RSM, Shutter, Diffuser mechanisms</td>
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<td>4/28/2023</td>
<td>ITDC</td>
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<td>4/28/2023</td>
<td>FSW ICIE/ATOMS topics not covered in another review</td>
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<td>5/1/2023</td>
<td>Detector Peer Review</td>
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<tr>
<td>5/1/2023</td>
<td>Pointing Controls AM-13</td>
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<tr>
<td>5/2/2023</td>
<td>Ground calibration plans and radiometric performance</td>
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<tr>
<td>5/3/2023</td>
<td>On orbit calibration and long term stability</td>
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<td>5/4/2023</td>
<td>WFOV camera system</td>
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<td>5/4/2023</td>
<td>FPGA and FSW roll in processing the WFOV science</td>
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<td>5/5/2023</td>
<td>Contamination control and purge</td>
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<td>5/8/2023</td>
<td>Solar avoidance system</td>
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<td>5/8/2023</td>
<td>EL scan mechanism, and EL launch lock</td>
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<tr>
<td>5/9/2023</td>
<td>Reliability analysis</td>
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<tr>
<td>5/9/2023</td>
<td>FEM/structures</td>
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<td>5/10/2023</td>
<td>Thermal</td>
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<tr>
<td>5/10/2023</td>
<td>Electronics Overview</td>
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<tr>
<td>5/11/2023</td>
<td>SSIM</td>
</tr>
<tr>
<td>5/11/2023</td>
<td>Pointing Knowledge Budget</td>
</tr>
<tr>
<td>5/12/2023</td>
<td>FPGA logic design for ICIE CPU/FPGA and FSW interfaces</td>
</tr>
</tbody>
</table>
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

Field Stop Dimensions

Absolute Responsivity [%]
Detector Time Response Testing

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

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

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Baseline Value</th>
<th>Prototype 5 Performance</th>
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<tbody>
<tr>
<td><strong>Spectral Ranges</strong></td>
<td>0.3 µm - 5 µm</td>
<td>Confirmed from reflectivity measurements</td>
</tr>
<tr>
<td></td>
<td>0.7 µm - 5 µm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 µm - 50 µm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.3 µm - &gt;100 µm</td>
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</tr>
<tr>
<td><strong>Channel Accuracies (k=1)</strong></td>
<td>SW: 0.17%</td>
<td>Supported by analysis</td>
</tr>
<tr>
<td></td>
<td>Split SW: 0.17%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LW: 0.24%</td>
<td></td>
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<tr>
<td></td>
<td>Total: 0.22%</td>
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<tr>
<td><strong>Channel Precision</strong></td>
<td>0.11 W/m²/sr</td>
<td>Confirmed</td>
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<tr>
<td><strong>Dynamic Range</strong></td>
<td>0 - 500 W/m²/sr</td>
<td>0 - 500 W/m²/sr</td>
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<tr>
<td><strong>Linearity</strong></td>
<td>0.1%</td>
<td>Confirmed</td>
</tr>
<tr>
<td><strong>Response Time</strong></td>
<td>Match CERES</td>
<td>Confirmed</td>
</tr>
<tr>
<td><strong>Survival Temperature Range</strong></td>
<td>-20°C to +50°C</td>
<td>Verified</td>
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</table>
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 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]

Note: General approach is to develop new VIS ADMs and obtain NIR irradiance via subtraction
# Libera Algorithm Theoretical Basis Document (ATBD)

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