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Program: AIST-18

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Recent composition changes in the UTLS have significant implications for climate change, but are not understood.

- Combined effects resulted in a negative (cooling) radiative forcing of ~80% of the positive CO$_2$ forcing (warming) during the 2000-2009 period.
- The cause of these changes is not well understood: indicative of importance of UTLS transport because the distribution of radiatively active constituents in the UTLS is mainly controlled by stratosphere/troposphere exchange.

### H$_2$O Radiative Forcing:
- **1980-1998:** +0.24 Wm$^{-2}$
- **1996-2005:** -0.098 Wm$^{-2}$

### CO$_2$ Forcing:
- **1996-2005:** +0.26 Wm$^{-2}$

### Lower Stratosphere Aerosol Trends:
- **2000-2010:** 4-7% per year increase

(Hoffman et al., 2009)

Aerosol radiative forcing: 2000-2010: ~-0.19Wm$^{-2}$
45% of forcing between trop and 15 km (Ridley et al., 2014)
The GLO Instrument Uses Broadband Radiometer and GFCR Channels to Achieve High Vertical Resolution and Precision Solar Occultation Measurements

Top system-level requirements (subset):
- 0.5 km vertical resolution from 600 km orbit
- SNR: 300,000:1 above the atmosphere
- SWaP: 29x16x16 cm (O), 5.25 kg (O), 28.2 W (O)

Top level derived requirements (subset):
- Image full sun for pointing knowledge - automated edge detection
- Solar diameter of 211 pixels for signal aggregation (supports SNR and vertical resolution requirements)

<table>
<thead>
<tr>
<th>Channel</th>
<th>$\lambda_0$ ($\mu$m)</th>
<th>$\Delta\lambda$</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$O</td>
<td>2.503</td>
<td>0.0626</td>
</tr>
<tr>
<td>O$_3$</td>
<td>2.475</td>
<td>0.0371</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>2.305</td>
<td>0.0461</td>
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<tr>
<td>N$_2$O</td>
<td>3.905</td>
<td>0.0976</td>
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<tr>
<td>CO</td>
<td>2.335</td>
<td>0.0537</td>
</tr>
<tr>
<td>HDO</td>
<td>3.710</td>
<td>0.1113</td>
</tr>
<tr>
<td>HCN</td>
<td>3.005</td>
<td>0.0601</td>
</tr>
<tr>
<td>HCl</td>
<td>3.380</td>
<td>0.1014</td>
</tr>
<tr>
<td>HF</td>
<td>2.455</td>
<td>0.0491</td>
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</table>

9 GFCR Channels

<table>
<thead>
<tr>
<th>Channel</th>
<th>$\lambda_0$ ($\mu$m)</th>
<th>$\Delta\lambda$</th>
</tr>
</thead>
<tbody>
<tr>
<td>aerosol</td>
<td>0.45</td>
<td>0.0045</td>
</tr>
<tr>
<td>aerosol</td>
<td>1.02</td>
<td>0.0102</td>
</tr>
<tr>
<td>aerosol</td>
<td>1.556</td>
<td>0.0156</td>
</tr>
<tr>
<td>H$_2$O</td>
<td>2.60</td>
<td>0.052</td>
</tr>
<tr>
<td>CO$_2$ (T)</td>
<td>2.80</td>
<td>0.056</td>
</tr>
</tbody>
</table>

5 Single (broadband) Radiometer Channels

Highlighted wavelengths are also used for aerosol composition & particle properties.
GLO Design is Complete and Utilizes Heritage Components

- OB1-OB3 (TRL 6)
- Front plate ND filters holder
- Connecting plate for OBs
- OB2-OB4
- Frames
- Baseplate
- Cryocoolers (TRL 9)
- QuIDCA (TRL 5)
- FPA electronics (TRL 9/5)
- Cryocoolers electronics (TRL 6)
- QuIDCA and electronics mounting frame
- Radiator
- Mounting plate for bus

<table>
<thead>
<tr>
<th>Item</th>
<th>Heritage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optics</td>
<td>COTS</td>
</tr>
<tr>
<td>Focal Plane Array</td>
<td>Lockheed Martin nbn SBF207 FPA</td>
</tr>
<tr>
<td>Cryo Coolers</td>
<td>Ricor K508N</td>
</tr>
<tr>
<td>Electronics</td>
<td>Xiphos Q7S</td>
</tr>
</tbody>
</table>
GLO is Designed to be Compact for Constellation Missions and for Straightforward Assembly

Front end assembly exploded and collapsed

OB1/OB3

Front plate/ND filter holder (High emissivity outside low emissivity inside)

Joining bracket (OB1/OB3 → OB2/OB4)

Base plate

Radiator plate (IDCA and electronics enclosure mounts directly to it)

IDCA

Back frame

Processing boards (x4)

Enclosure

Cryooler electronics (x2)

Location of high precision guide pins matching OB walls and back support plate to base plate

Frame (panels support)

OB2/OB4

OB1/OB3

OB1/OB3 wall

Location for thermal insulation spacers

Small focusing Optics OB3

N2O Gas cell

Kinematic Mounts (fold and BSC)

BS cube

CH4 Gas cell

Reference cell (empty cell)

Joining bracket points (OB1/OB3 → OB2/OB4)

333.3 mm

318.0 mm

159.1 mm

318.0 mm

333.3 mm

Bus mounting brackets

Location of high precision guide pins matching OB’s walls

Front plate/ND filter holder (High emissivity outside low emissivity inside)

Joining bracket (OB1/OB3 → OB2/OB4)

Base plate

Front end assembly exploded and collapsed

June 23, 2020
GLO Fabrication is nearly complete and lab testing is underway.

- The NRL team is starting back to work.
- Completion of fabrication should be complete in coming weeks.
- Lab testing will occur this summer to confirm optical performance, SNR, scattered light etc.
- Environmental testing will also be done.
- TRL 6 will be achieved by Fall 2020.
- Ground based occultation column measurements will be obtained, aerosol optical depth compared to Aeronet results.
- A stratospheric balloon flight originally planned for all 2020, but delayed due to COVID-19 is now planned for fall 2021.
Back Up Slides
### GLO Enabling Technology

**Lockheed Martin nbn SBF207 Focal Plane Array**

**Ricor K508N sterile cycle micro cryocooler**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>1280 x 1024 pixels</td>
</tr>
<tr>
<td><strong>Pixel pitch</strong></td>
<td>12 microns</td>
</tr>
<tr>
<td><strong>A/D</strong></td>
<td>13 or 14 bit</td>
</tr>
<tr>
<td><strong>Frame Rate</strong></td>
<td>99 Hz full frame and 14 bit</td>
</tr>
<tr>
<td><strong>Well Depth</strong></td>
<td>2.05 million electrons</td>
</tr>
<tr>
<td><strong>ROIC noise</strong></td>
<td>300 electrons (max)</td>
</tr>
<tr>
<td><strong>Responsivity</strong></td>
<td>125 electrons/bit</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>160 mWatts</td>
</tr>
<tr>
<td><strong>Integration modes</strong></td>
<td>Snapshot- integrate while or then read</td>
</tr>
<tr>
<td><strong>Windowing</strong></td>
<td>608 x 8 in 1 x 4 increments</td>
</tr>
<tr>
<td><strong>QE</strong></td>
<td>&gt;80%</td>
</tr>
<tr>
<td><strong>Operability</strong></td>
<td>&gt;99.5%</td>
</tr>
<tr>
<td><strong>Readout</strong></td>
<td>Direct injection</td>
</tr>
</tbody>
</table>

GLO uses 4 FPAs: 3 with 1.7-4.2 µm, 1 with 0.5-4.2 µm sensitivity (substrate removed)

- Ricor K508N has space heritage
  - Prototype uses the (mechanically identical) non-space qualified version of this cooler
- GLO uses 2 coolers (each unit cools 2 FPAs) as components of the Integrated Detector and Cooling Assembly (IDCA): operating temperature ~ 150K

June 23, 2020
GLO Assembly

Assembly and alignment

• Step 1: Mount IDCA to baseplate
• Step 2: OB4 is the first unit assembled and aligned (Interior OB)
• Step 3: Connecting plate is added
• Step 4: OB1 assembled and aligned (second interior OB).
• Step 5: Continue with OB3
• Step 6: Follow by OB2
• Step 7: Add frames and enclosures
• Step 8: Add ND filter plate
• Step 9: Mount to pan/tilt unit (IIP Instrument)

- The design allows for the OBs to be aligned horizontally with alignment adjustments from top
- Once all parts are assembled, there is access to kinematic components (including through OBs) for fine tuning prior to locking components
GLO Data Acquisition

In the GLO orbital configuration the sensor does not scan, rather the MicroSat inertially points the sensor optics toward the sun (~0.1° pointing accuracy required).

- GLO uses the solar edge detection algorithm developed and used operationally on SOFIE for 10 years.
- This allows for downlinking only a small subset of the image data and placing only modest communications requirements on the spacecraft.

- 1024x1280 FPA.
- 6 images of the sun on each FPA.
- Solar diameter subtends 211 pixels:
  - From orbit ~125m/pixel
  - From balloon ~21m/pixel
- SOFIE demonstrated solar edge detection to ~1 m (on the limb) from orbit.