Expected Performance of the GeoCarb Integrated Instrument from Thermal Vacuum Measurements During a Limited Performance Test

Sean Crowell[1,3], Eric Burgh[2], Máté Ádámkovics[2], Timothy Miller[3], Peter Somkuti[3,4], Alex Webb[3,4], Eric Mentzell[4], Chris O'Dell[5], Berrien Moore III[3]
[1]LumenUs Scientific, LLC [2]Lockheed Martin Advanced Technology Center [3]University of Oklahoma [4]NASA GSFC [5]Colorado State University

GeoCarb Overview and Path to Delivery

GeoCarb was selected in 2016 by NASA as the second Earth Venture Mission with the University of Oklahoma as the prime contractor, Lockheed Martin Advanced Technology Center as the instrument contractor, and SES Government Solutions as the commercial host for the instrument as part of a ridesharing agreement.

In December 2019, OU requested that NASA Goddard take over programmatic management of Lockheed Martin to rein in cost and schedule overruns, which they did in January of 2020. Two years later in spring of 2022, NASA issued a request for proposals to get GeoCarb a dedicated bus and launch vehicle due to GeoCarb's status as a "national priority". In September 2022, the RFP was canceled and GeoCarb's path to space was left in limbo.

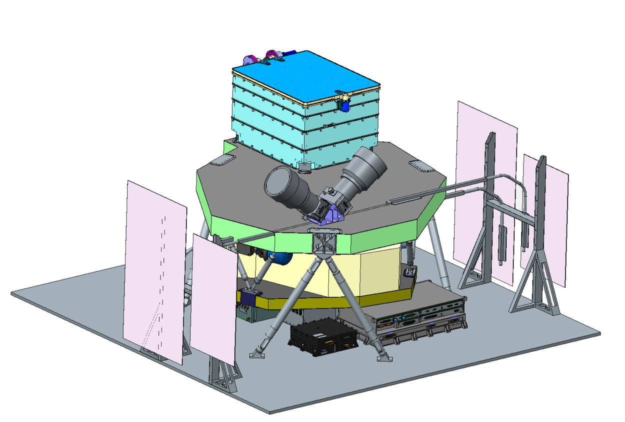
In November 2022, GeoCarb's cancelation was announced due to cost and schedule overruns, and the University of Oklahoma was instructed to use the remainder of the funds available under the original cost cap to complete the instrument to the degree possible and deliver it to NASA. The FY23 budget specified that should the GeoCarb instrument be completed, NASA should endeavor to find a path to space for the GeoCarb instrument.

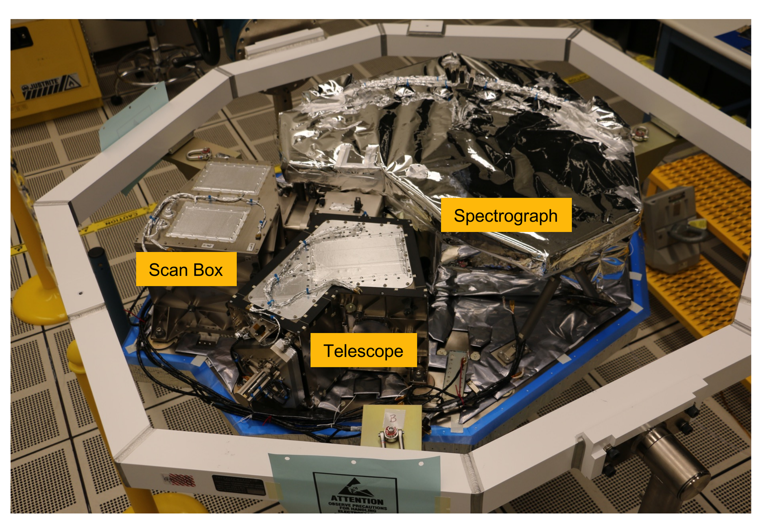
In the year since the cancelation, the GeoCarb spectrograph alignment and focus were confirmed in thermal vacuum. In parallel, the telescope, scan box, and door/baffle were assembled and integrated to the main structure. The Instrument Optics Package (IOP) and electronics were integrated to a nadir deck simulation plate in late summer 2023 and functionally tested prior to entering the engineering performance test in mid-September 2023.

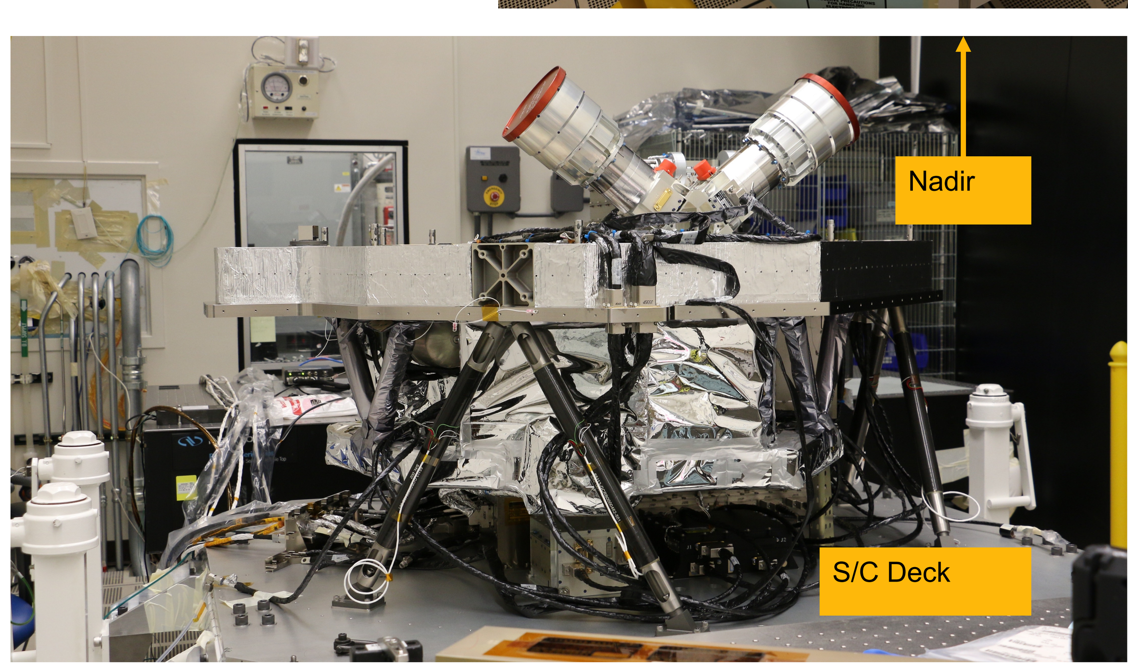
The instrument was successfully delivered to NASA on November 6, 2023 and a formal NASA assessment was begun on November 27, 2023.

GeoCarb Instrument Details

GeoCarb is a 4-channel grating spectrometer that measures spectra in the 0.76um, 1.6um, 2.05um, and 2.3um channels with resolving power ≥ 14000 in order to retrieve XCO_2, XCH_4, XCO, and SIF at 3km N-S vs. 6km E-W spatial resolution from geostationary orbit. The expected observations will be derived from 10s time integration with approximately 1000 samples N-S each integration ("step and stare").







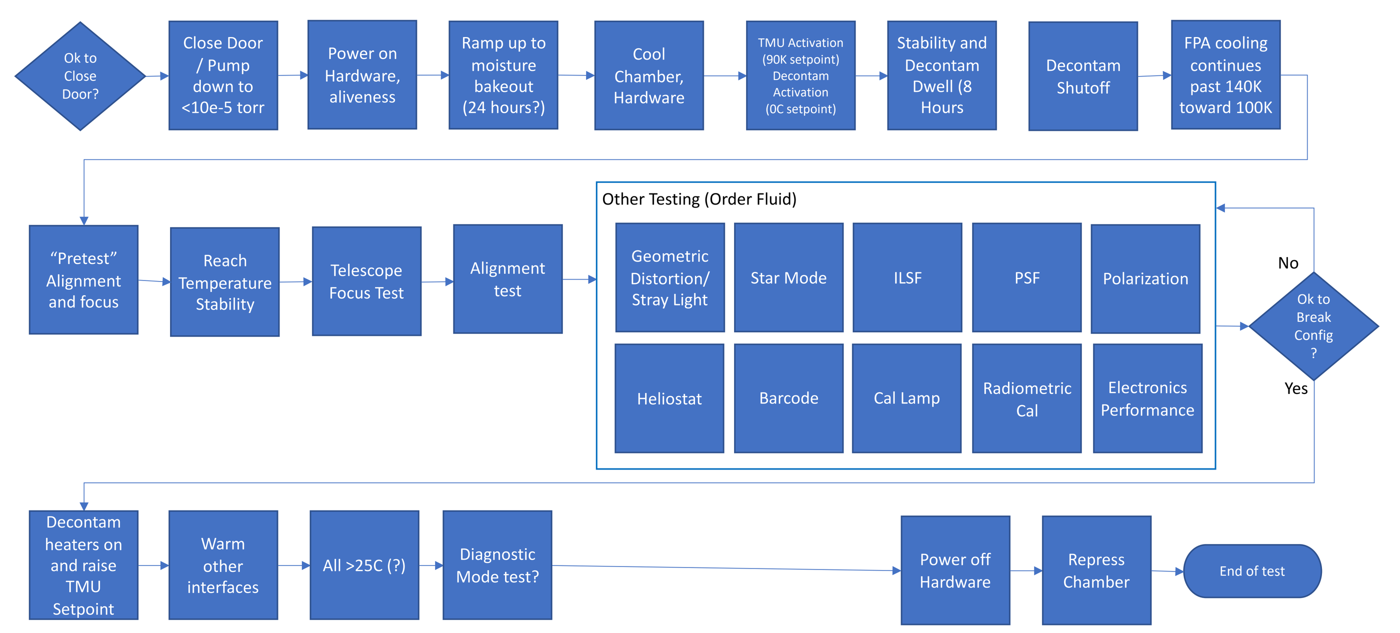
Engineering Performance Test Design

The Engineering Performance Test (EPT) was designed to assess the performance of the GeoCarb instrument relative to the key science requirements:

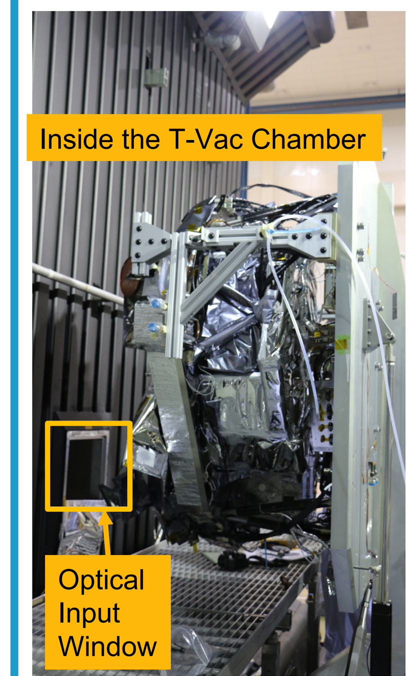
- Focus
- Alignment
- Spectral resolution
- Spatial image quality
- Signal-to-Noise Ratio
- Stray Light
- Polarization response

Reductions in Testing Relative to C&C

- Reduced OGSE characterization
- Most tests at a single temperature
- Fewer wavelengths and slit positions than a full calibration



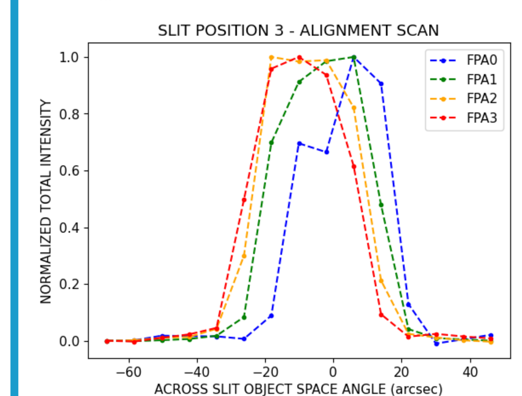
Test Details



OGSE

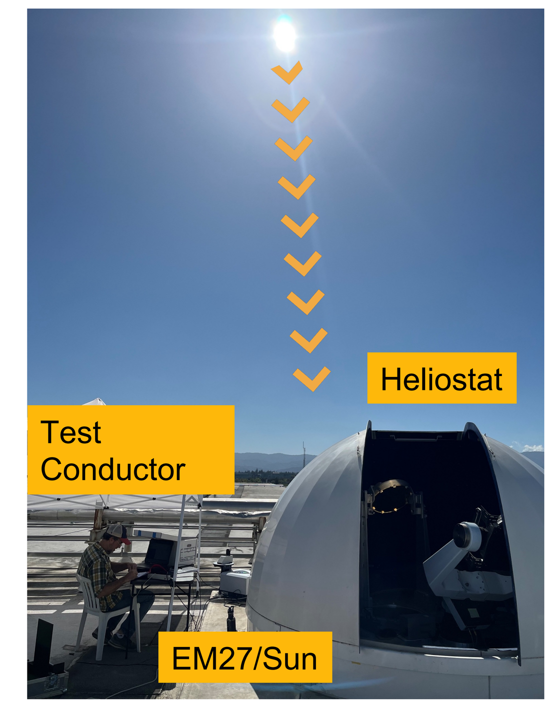
- Tunable Diode Lasers
- NIST-traceable radiometric sphere
- Heliostat
- Bar target with variable reflection
- Spectroradiometer
- EM27/Sun

Alignment



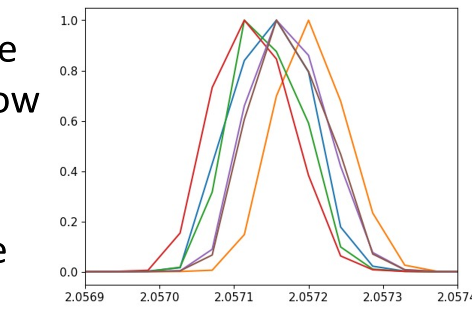
Scan mirror position

Heliostat



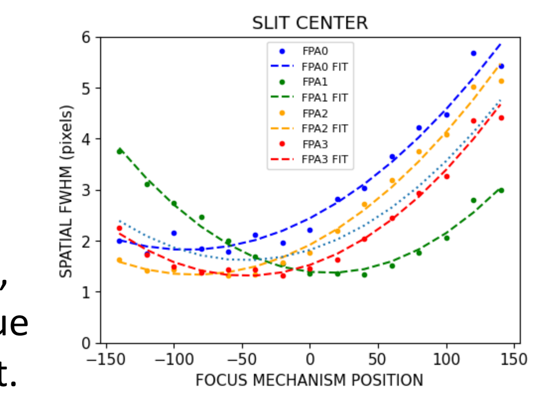
Instrument Line Shape

Following Lee et al. (2017), we oversample the ILS with narrow scans across a central wavelength. Coarse scans are recentered to oversample the average ILSF at multiple wavelength settings.



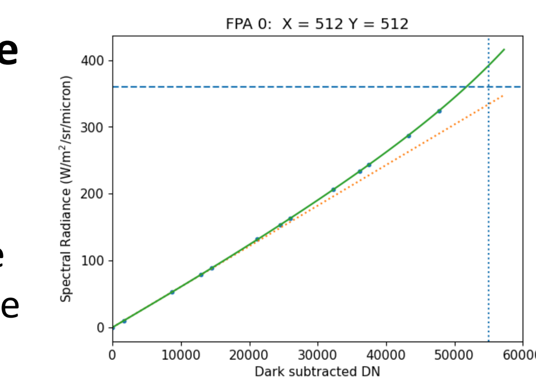
Focus

Operate the instrument focus mechanism over a sufficient range to locate the position of best focus, which is a compromise due to variations along the slit.



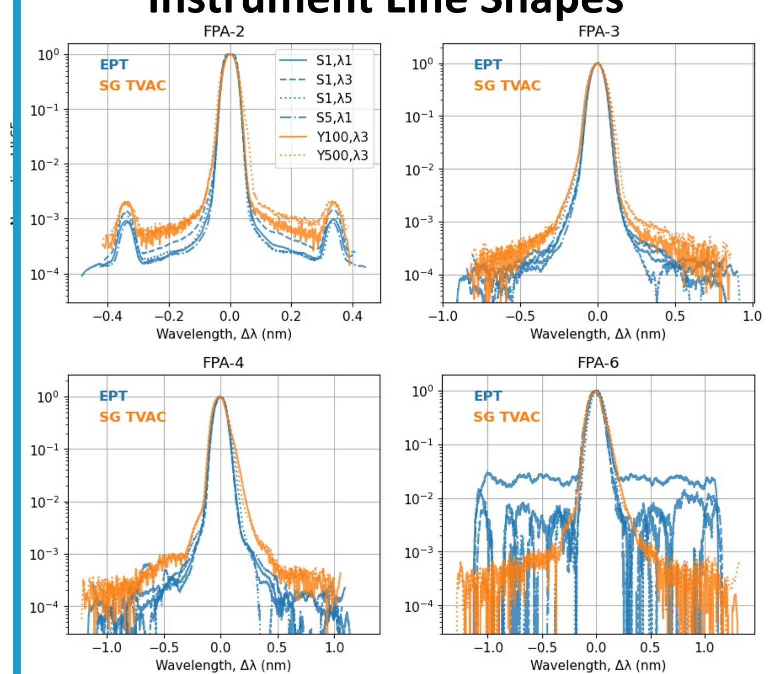
Radiometric Response

Operate the radiometric sphere with varying brightness levels from different lamps. Measure the absolute level with the ASD.

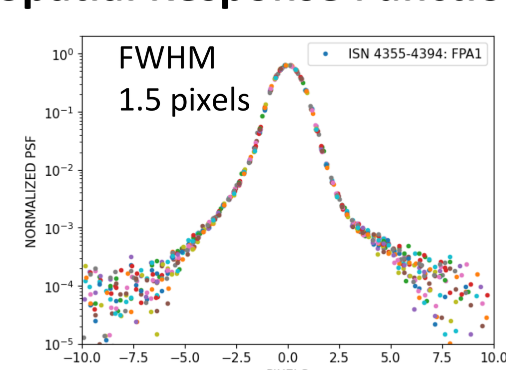


Preliminary Test Results

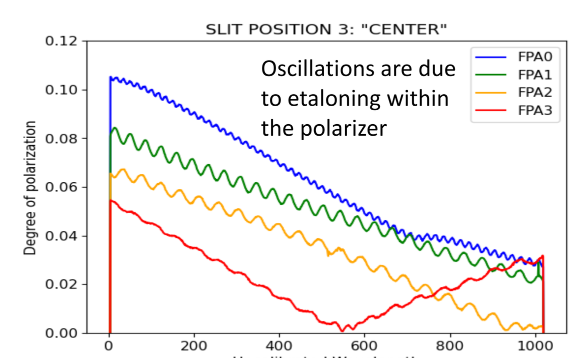
Instrument Line Shapes



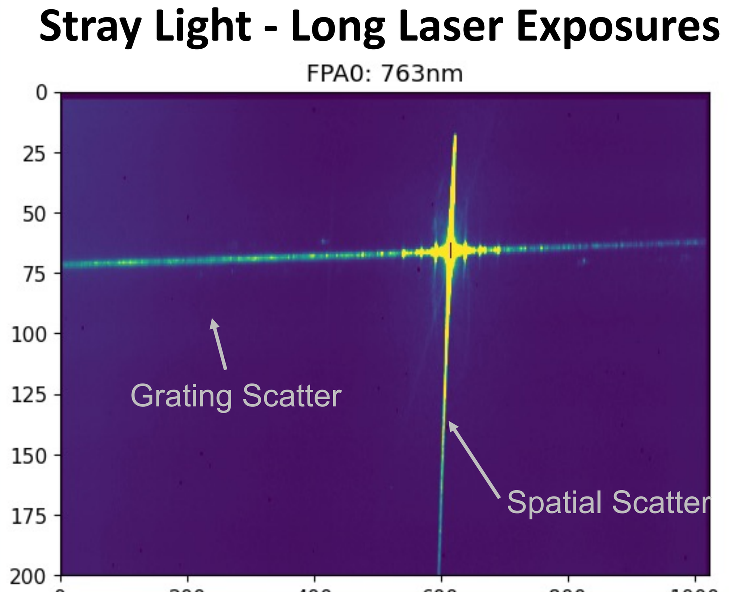
Spatial Response Function



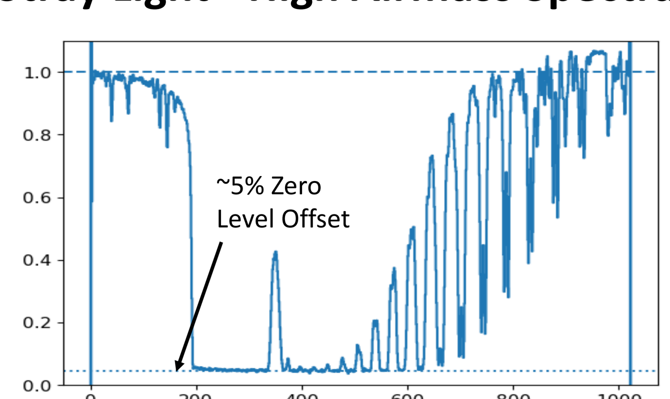
Degree of Linear Polarization



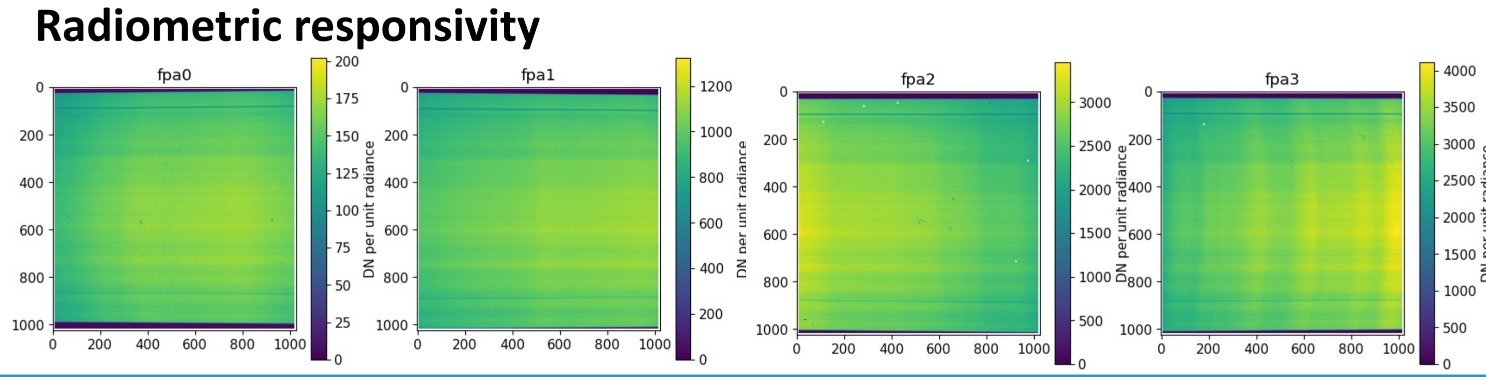
Stray Light - Long Laser Exposures



Stray Light - High Airmass Spectra

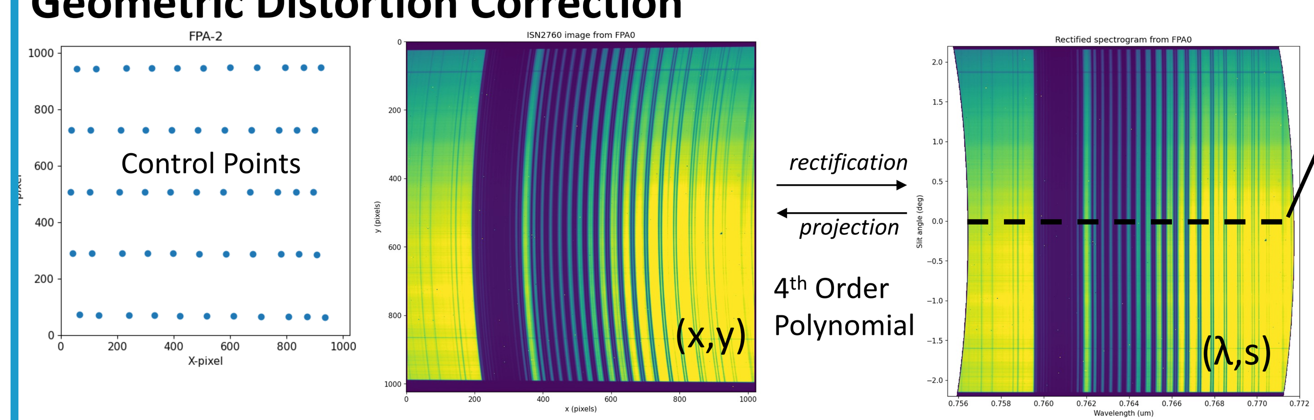


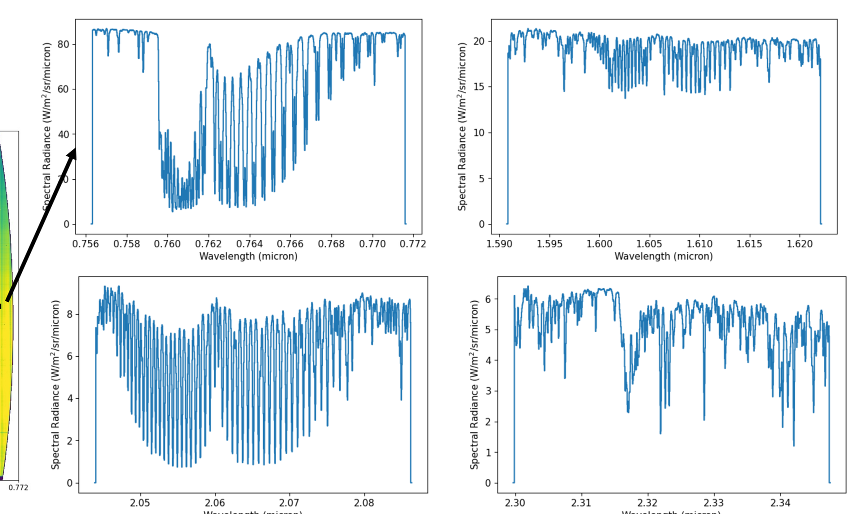
Radiometric responsivity



Further Preliminary Analyses

Geometric Distortion Correction





Preliminary Conclusions

The GeoCarb instrument has sufficient

- SNR
- Spectral Resolution
- Spatial Image Quality

to deliver on the science goals of the mission.

The tall poles that remain are

- Sufficient stray light correction
- Accurate geometric distortion correction that preserves energy flux
- Residual image

These ingredients will be tested with retrievals on heliostat observations and validated against the coincident spectra and retrievals from the co-deployed EM27/Sun.

Implications and Next Steps

The EPT demonstrate the essential performance of the GeoCarb instrument without serving as a sufficient dataset for characterizing and calibrating the instrument fully. A rigorously defined and more complete characterization and calibration effort must be completed alongside the traditional environmental testing to make GeoCarb flight-ready.

In the near term, the EPT analysis team will continue to improve analyses and refine algorithms to transform the solar observations into science data via the standard ACOS and GNG retrievals. Additionally, we will incorporate the lessons learned from these analyses to develop a plan for the full C&C.

A full final report will be delivered to NASA in late summer of 2024.