# The Goddard Laser for Absolute Measurement of Radiance (GLAMR) Facility

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# Outline

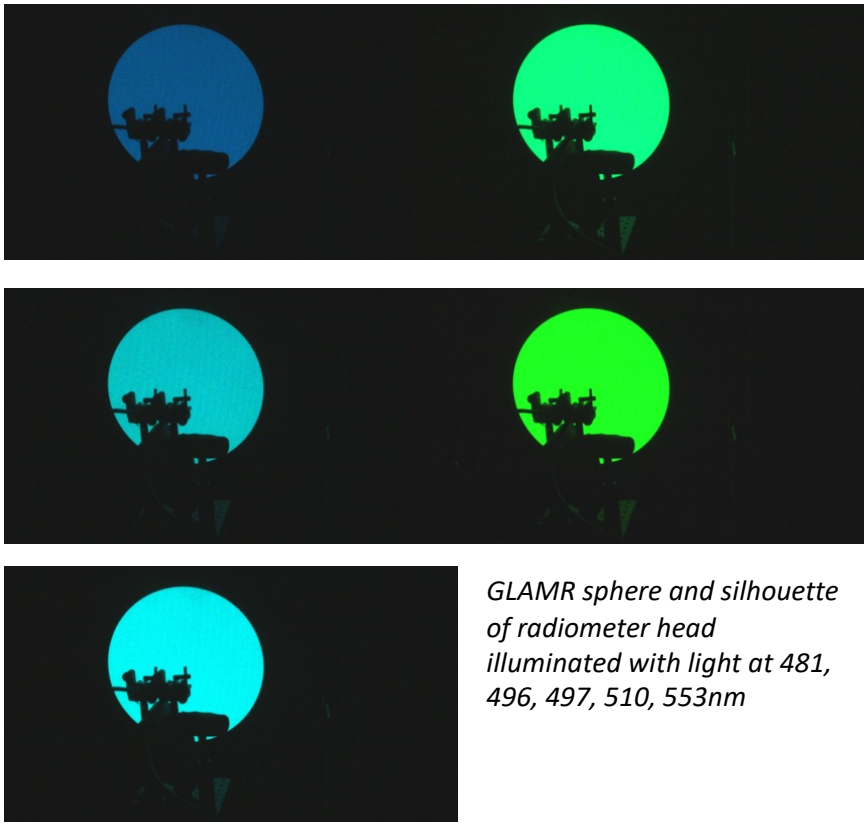

- Calibration/characterization opportunities
- Uncertainty
- References
- Sample datasets from flight instruments
- Testing logistics
  - Sample deployments to instrument site
  - In-house in the GLAMR lab
  - Planning questions to start the conversation

# GLAMR Measurements

**Operates between 310 and 2500nm**

Enables:

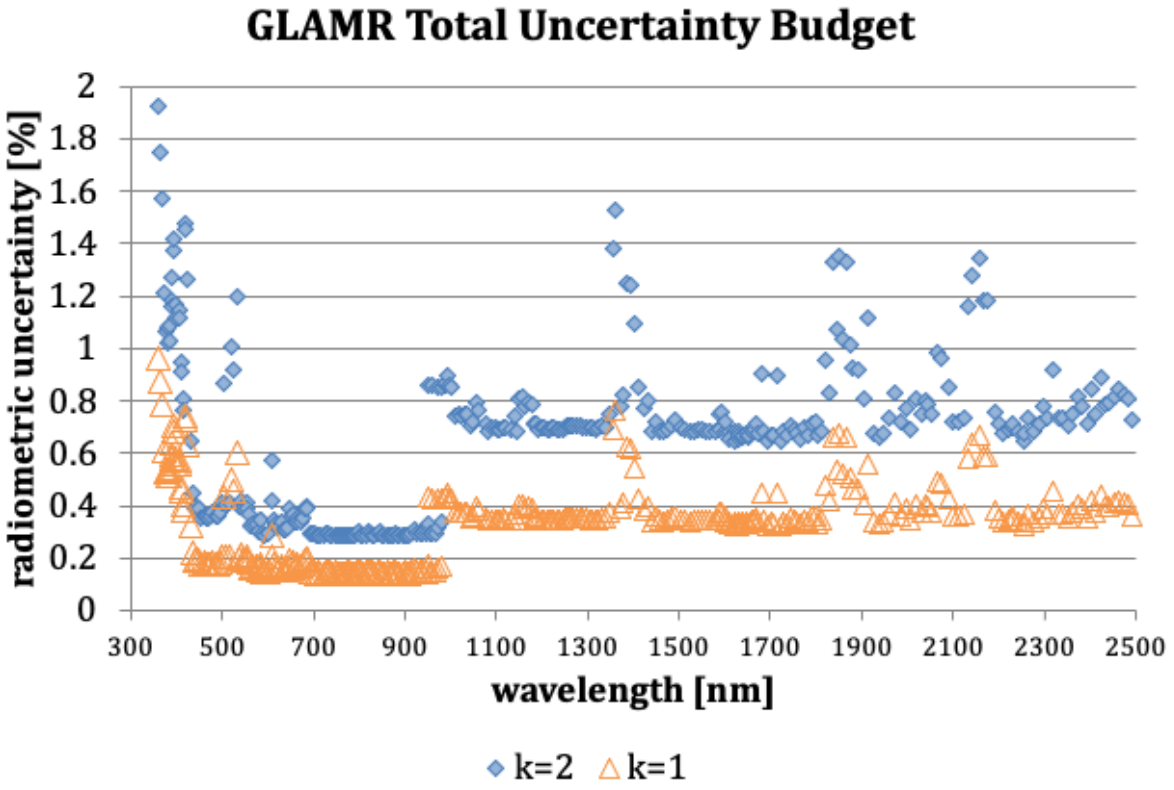
- Calibration of absolute spectral response (ASR)
- Characterization of relative spectral response (RSR)
  - In-band
  - Out-of-band
  - Characterization of stray light and crosstalk effects
- Characterization of linearity



*GLAMR sphere and silhouette of radiometer head illuminated with light at 481, 496, 497, 510, 553nm*

# GLAMR Total Uncertainty

As of Oct 2021



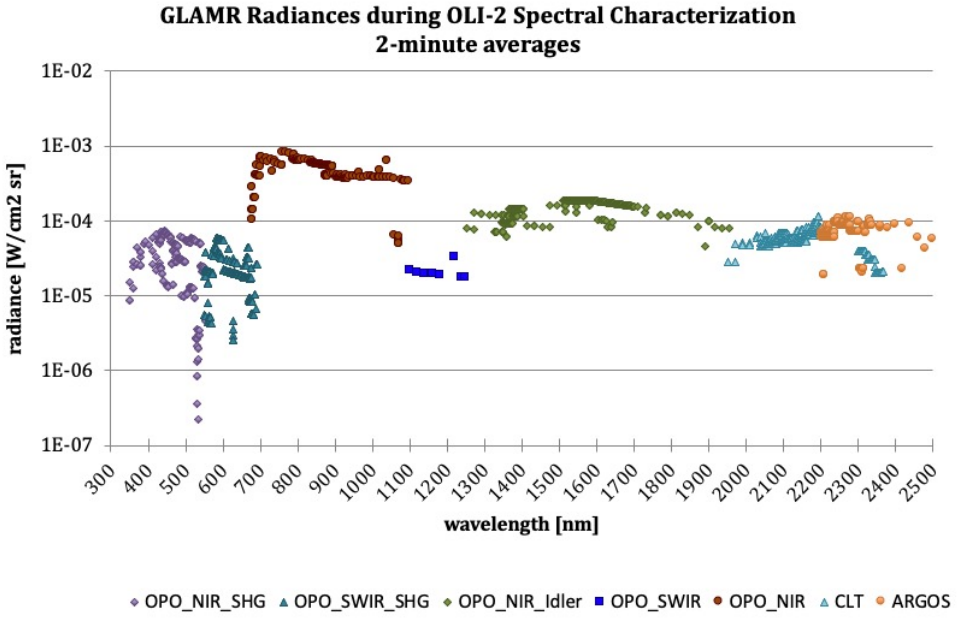
# References

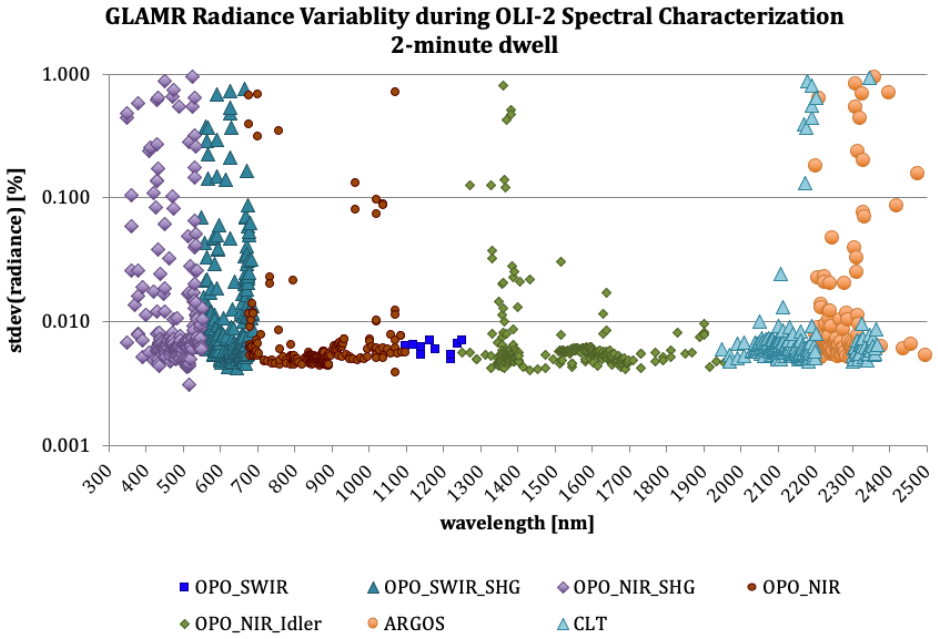

- Wang Z., J. Barsi, K. Thome, et al. 2024. "Uncertainty budget for detector-based absolute radiometric calibration with GLAMR." Applied Optics 63 (12): 3015 [10.1364/ao.519586]
- Barsi, J.A.; Donley, E.; Goldman, M.; Kampe, T.; Markham, B.L.; McAndrew, B.; McCorkel, J.; Morland, E.; Pedelty, J.A.; Pharr, J.; et al. Prelaunch Spectral Characterization of the Operational Land Imager-2. Remote Sens. 2024, 16, 981. https://doi.org/10.3390/rs16060981
- McIntire, J.; Meister, G.; Barsi, J.A.; Gliese, U.; Jepsen, K.; Kitchen-McKinley, S.; Lee, S. Linearity Assessment from the Plankton, Aerosol, Cloud, and Ocean Ecosystem Ocean Color Instrument Pre-Launch Testing and On-Orbit Operations. RemoteSens.2024,16,4032. https://doi.org/10.3390/rs16214032
- S. Kitchen-McKinley *et al*., "Pace OCI Flight Unit Pre-Launch Spectral Characterization," *IGARSS 2023 - 2023 IEEE International Geoscience and Remote Sensing Symposium*, Pasadena, CA, USA, 2023, pp. 1349-1352, doi: 10.1109/IGARSS52108.2023.10283202.
- McAndrew, B., Barsi, J., Sushkov, A., McCorkel, J., CalCon 2023, Radiometric Uncertainty Analysis of the GLAMR Calibration Facility. https://digitalcommons.usu.edu/calcon/calcon2023/All2023Content/5/
- R. A. Barnes, S. W. Brown, K. R. Lykke, *et al.*, "Comparison of two methodologies for calibrating satellite instruments in the visible and near-infrared," Appl. Opt. **54**, 10376–10396 (2015).

# Sample Data Sets

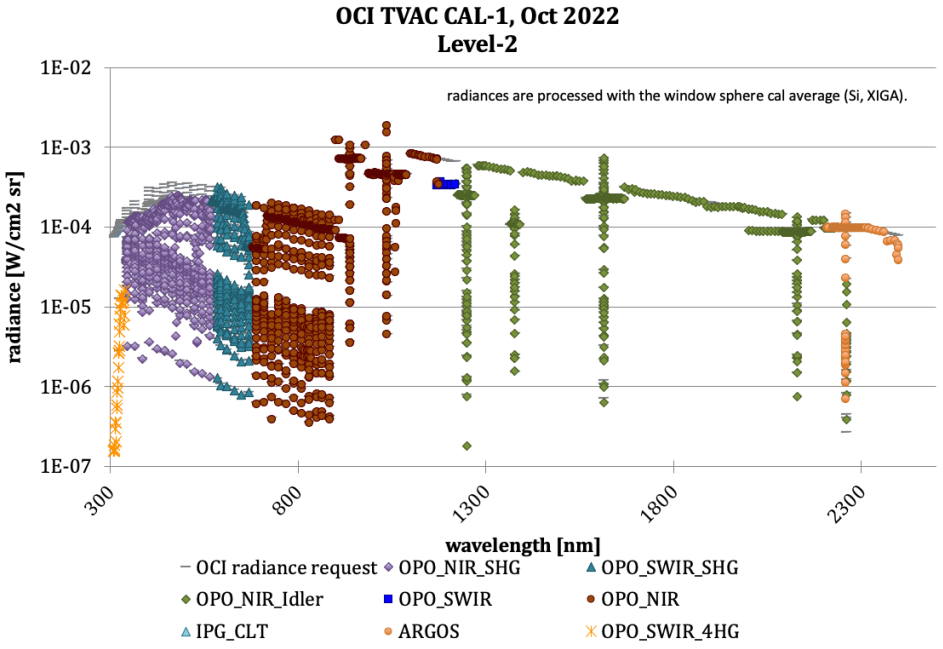
- OLI2_GLAMR_Scans.Nov2018.xlsx
  - Used for OLI2 vendor for instrument-level characterization of RSR
- OCI_TVAC_CAL1_radiances.L2.xlsx
  - Used for OCI radiometric calibration and spectral characterization
  - Level-2 indicates GLAMR data were post-processed with an updated GLAMR calibration
  - Available on the GLAMR website
    - https://glamr.gsfc.nasa.gov/performance

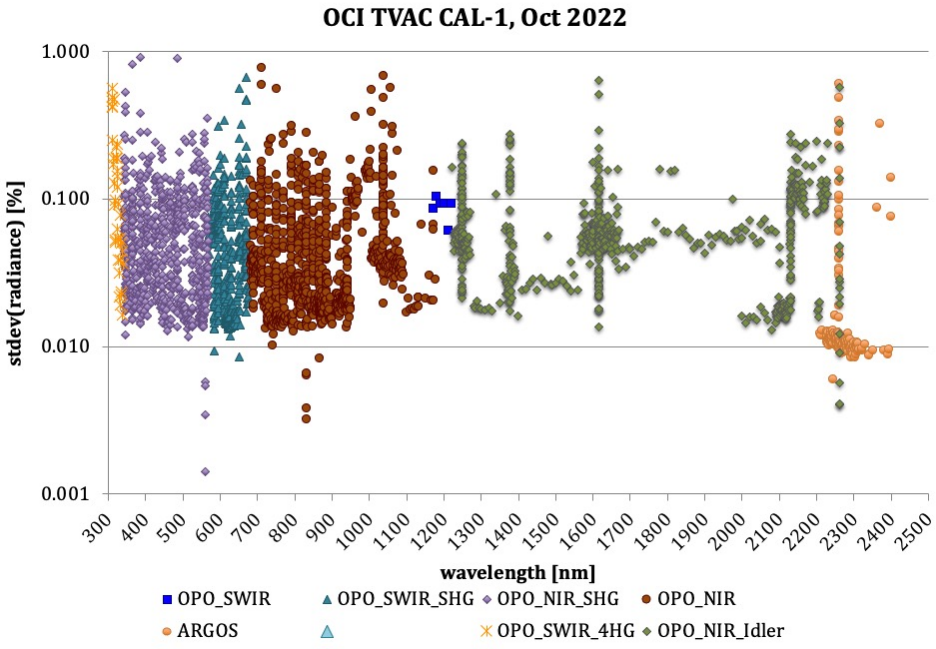
# OLI-2


GLAMR Radiances during OLI-2 Spectral Characterization
2-minute averages
radiance [W/cm2 sr]
1E-02
1E-03
1E-04
1E-05
1E-06
1E-07
300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500
wavelength [nm]
OPO_NIR_SHG
OPO_SWIR_SHG
OPO_NIR_Idler
OPO_SWIR
OPO_NIR
CLT
ARGOS


GLAMR Radiance Variablity during OLI-2 Spectral Characterization
2-minute dwell
stdev(radiance) [%]
1.000
0.100
0.010
0.001
300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500
wavelength [nm]
OPO_SWIR
OPO_SWIR_SHG
OPO_NIR_SHG
OPO_NIR
OPO_NIR_Idler
ARGOS
CLT

# OCI


OCI TVAC CAL-1, Oct 2022
Level-2
radiances are processed with the window sphere cal average (Si, XIGA).
radiance [W/cm2 sr]
1E-02
1E-03
1E-04
1E-05
1E-06
1E-07
300
800
1300
1800
2300
wavelength [nm]
OCI radiance request
OPO_NIR_SHG
OPO_SWIR_SHG
OPO_NIR_Idler
OPO_SWIR
OPO_NIR
IPG_CLT
ARGOS
OPO_SWIR_4HG


OCI TVAC CAL-1, Oct 2022
stdev(radiance) [%]
1.000
0.100
0.010
0.001
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
wavelength [nm]
OPO_SWIR
OPO_SWIR_SHG
OPO_NIR_SHG
OPO_NIR
ARGOS
OPO_SWIR_4HG
OPO_NIR_Idler

# GLAMR Test Location

- GLAMR facility is fully mobile, but test facilities are available at Goddard
- Considerations for which system travels:
  - System portability, including GSE and associated environmental requirements (i.e. clean room or TVAC)
    - Note that GLAMR does **NOT** require a clean environment. See later slides for requirements
  - System schedule limitations
- Deployed test information: see slides deployment slides
- In-house test information: see slides in-house slides

# Notional Diagram

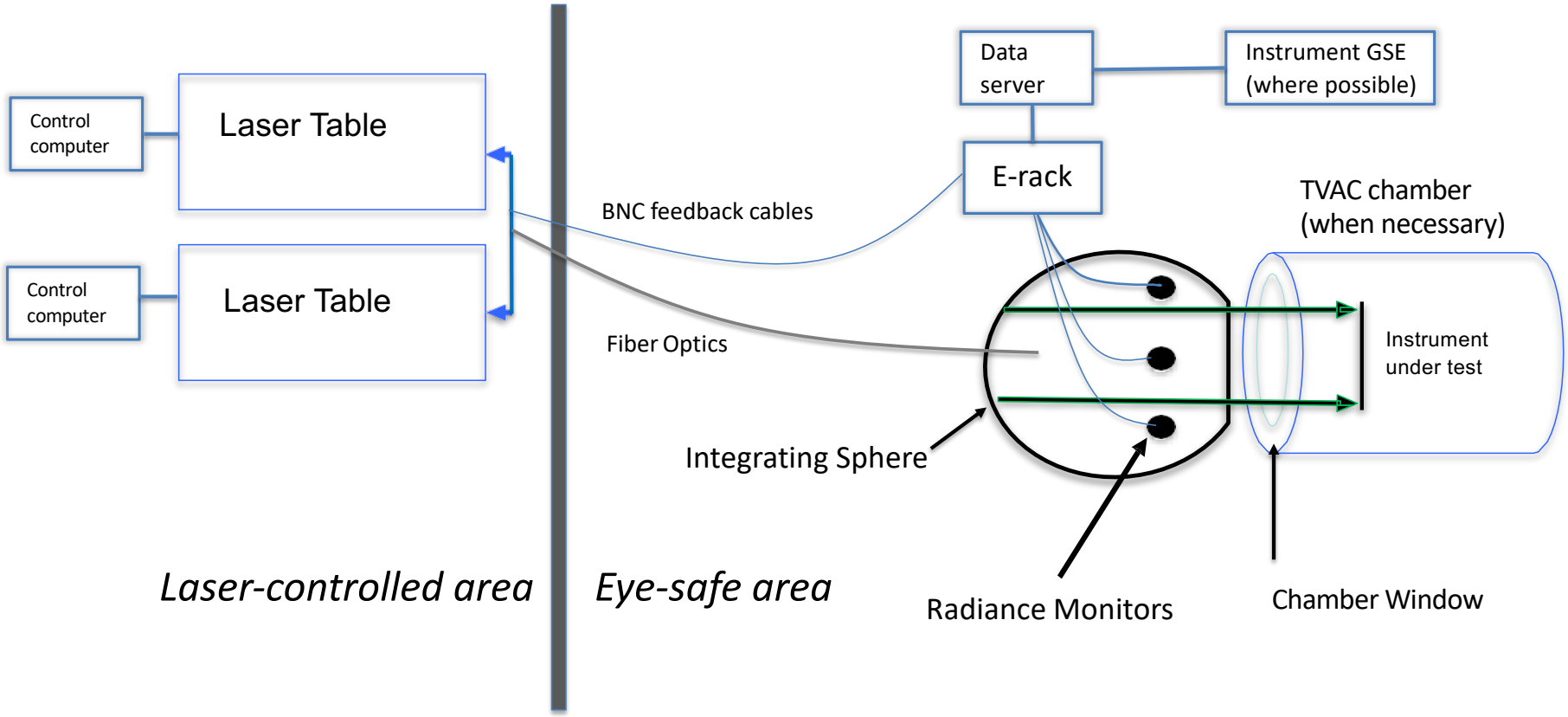
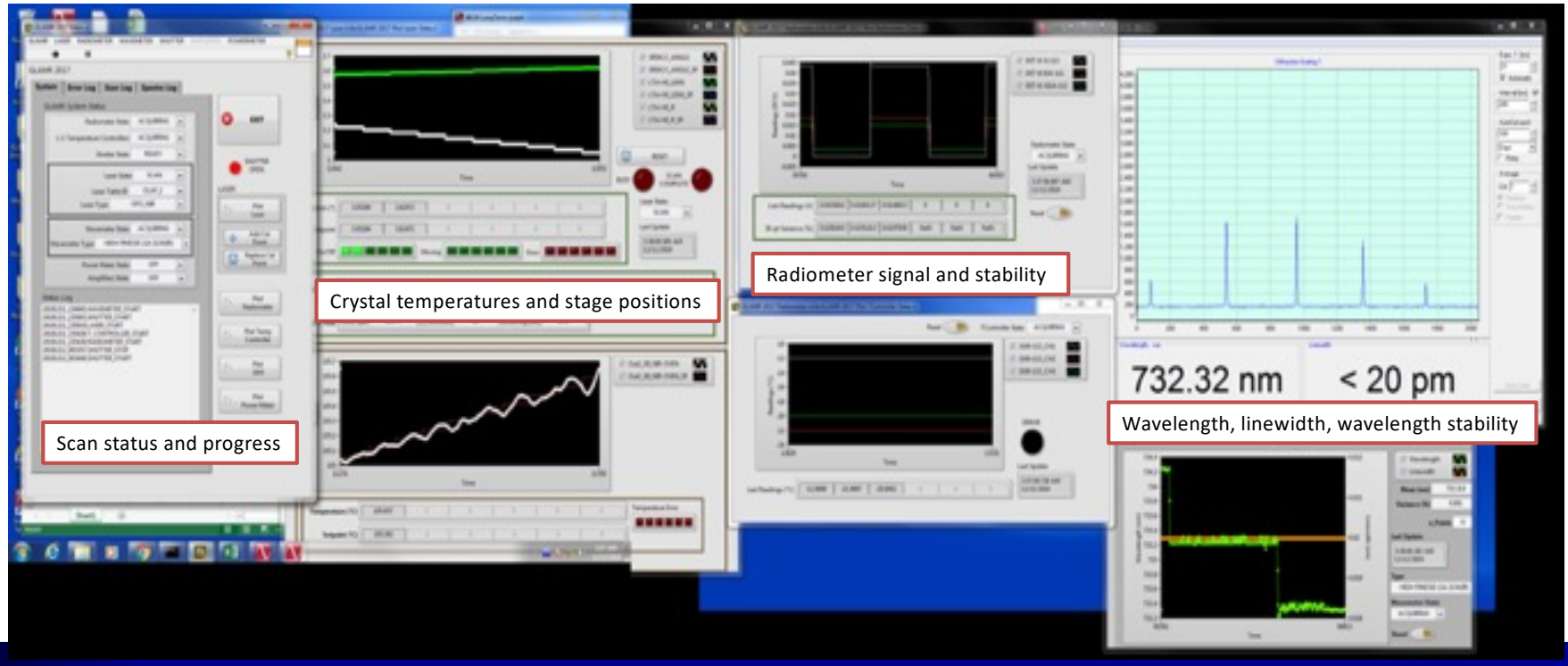



*Diagram is not to scale*

# Control System

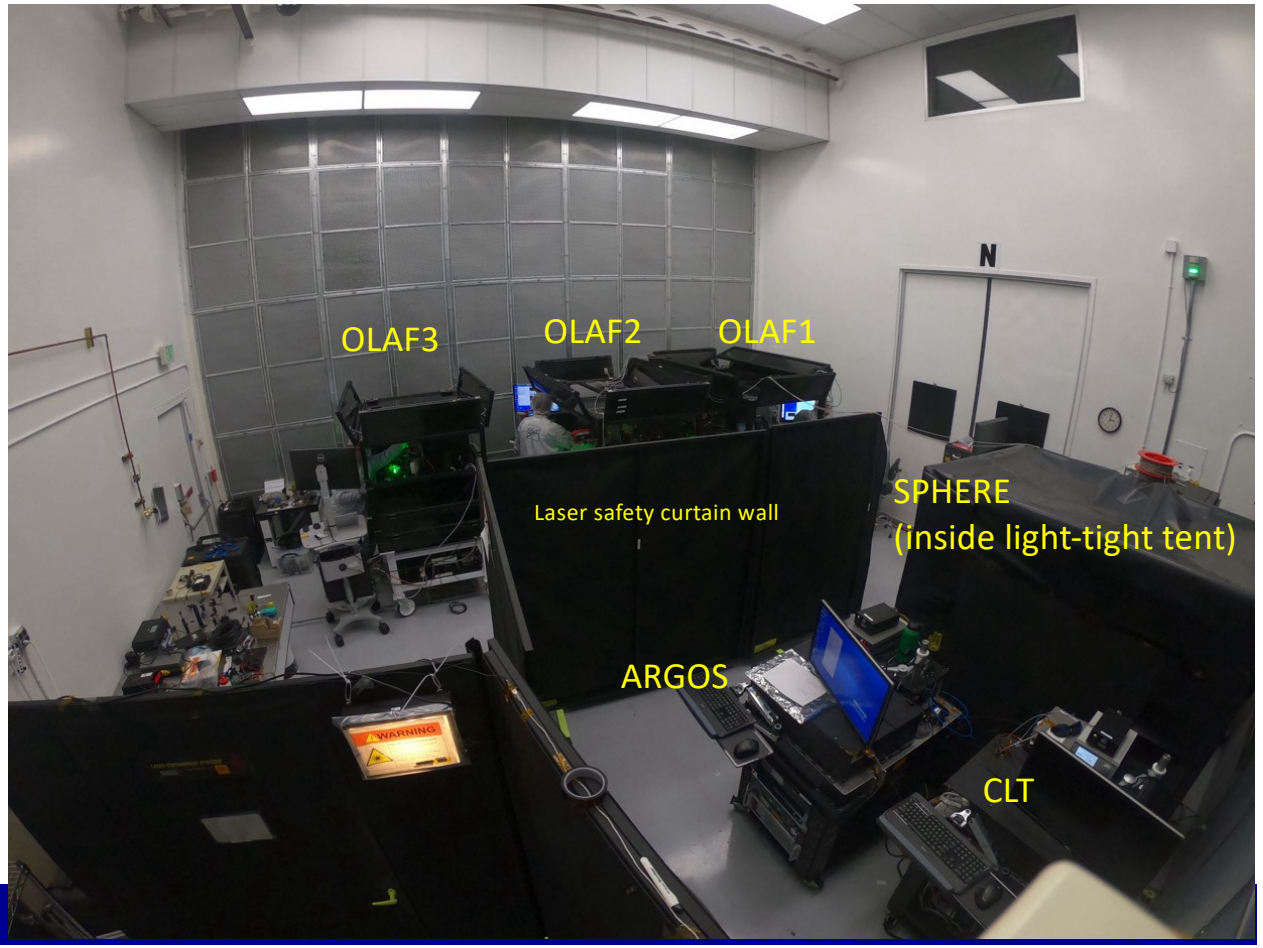
Extensive software backend for laser control and performance monitoring, data acquisition, instrument interface



# DEPLOYMENT DETAILS

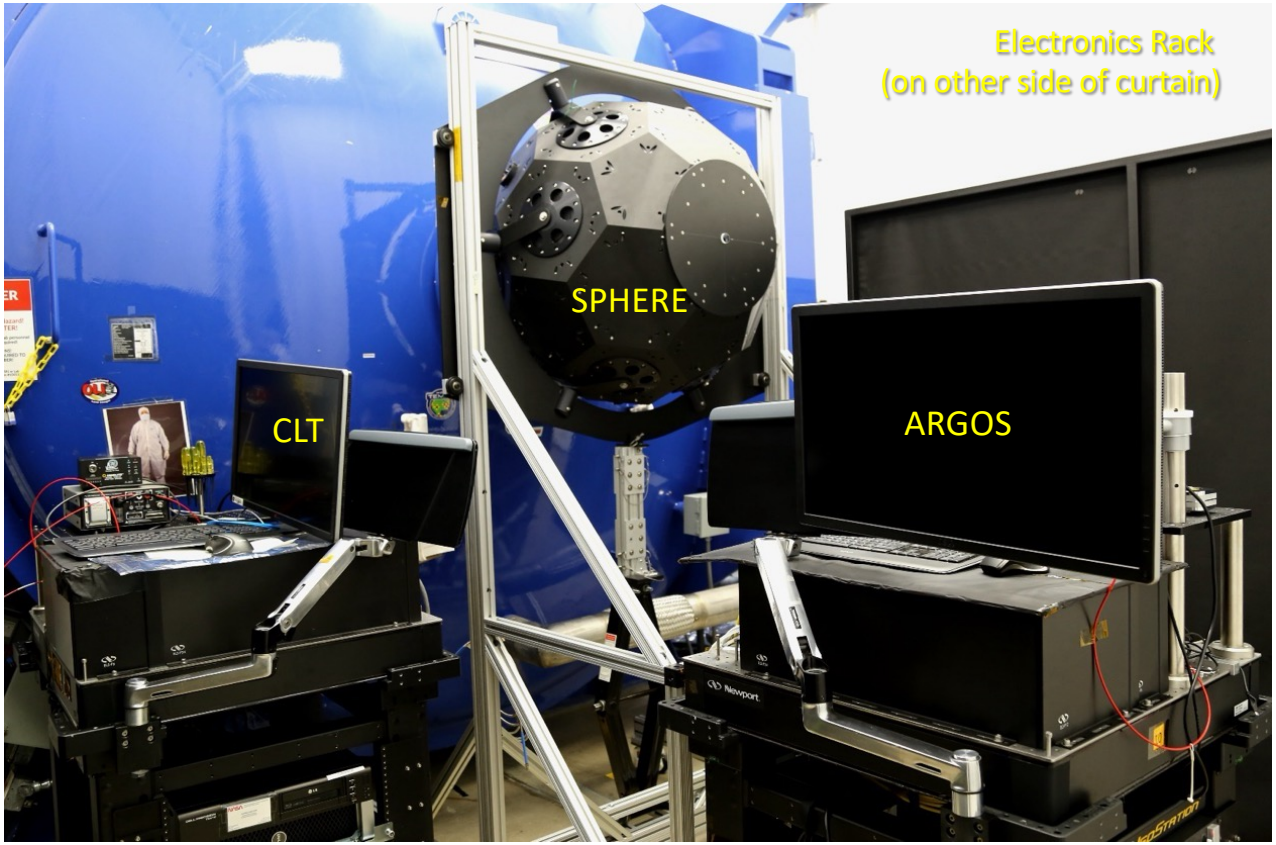
# GLAMR Setup at Ball Aerospace laser-controlled area

- Ball provided a space adjacent to the vacuum chamber to house GLAMR for the duration.
- All GLAMR equipment is on wheels, to be rolled into test space
  - Includes laser tables, integrating sphere, computer tables, e-rack, toolboxes, laser safety curtains



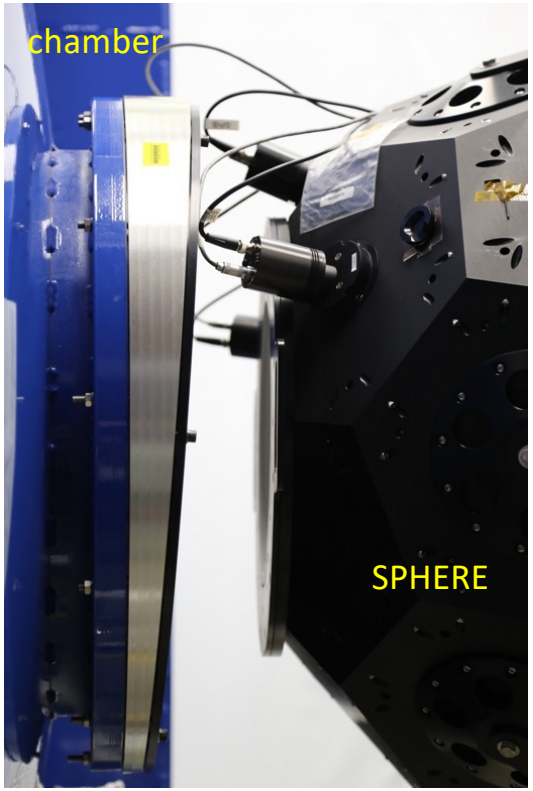
# GLAMR set up at Ball
# eye-safe area in front of chamber

- Sphere is aligned to instrument in chamber
- Electronics rack must be co-located with the sphere
- Sphere Frame allows the sphere port to be centered 72” off ground



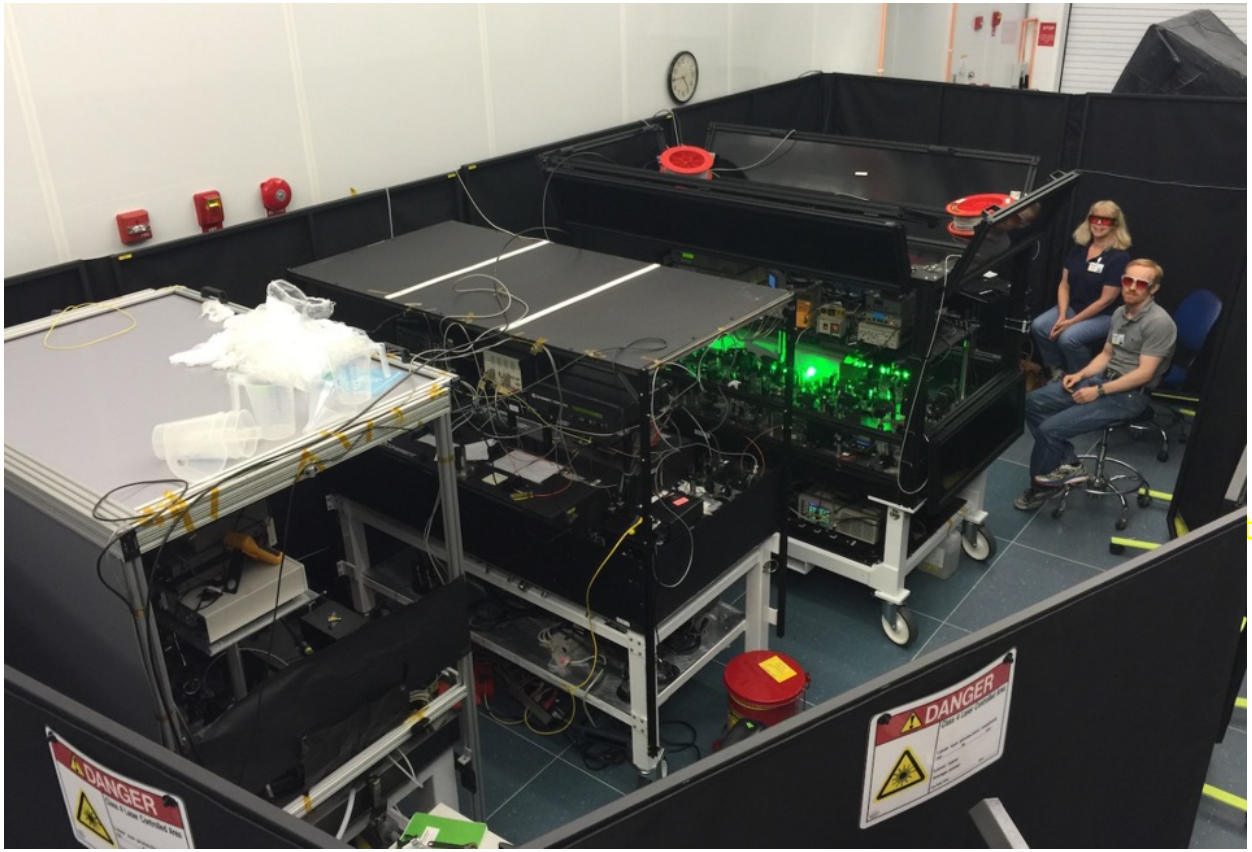
# GLAMR Setup at Ball Aerospace sphere and chamber

- GLAMR transfer radiometers placed inside of chamber, sphere placed just outside window
  - Light-tight shroud couples the sphere to the chamber window




# GLAMR Setup at RTN laser-controlled area (2016)

- Laser-controlled area was built with laser safety curtains in an open area of a large space adjacent to the clean room where VIIRS and the sphere are located



# GLAMR Setup at RTN laser-controlled area (2022)

- Laser-controlled area is the entire end of the control room, adjacent to the clean room where VIIRS and the sphere are located

- During all GLAMR measurement campaigns, access to the GLAMR lasers is limited to GLAMR staff

# GLAMR Setup at RTN
## sphere in clean room with instrument

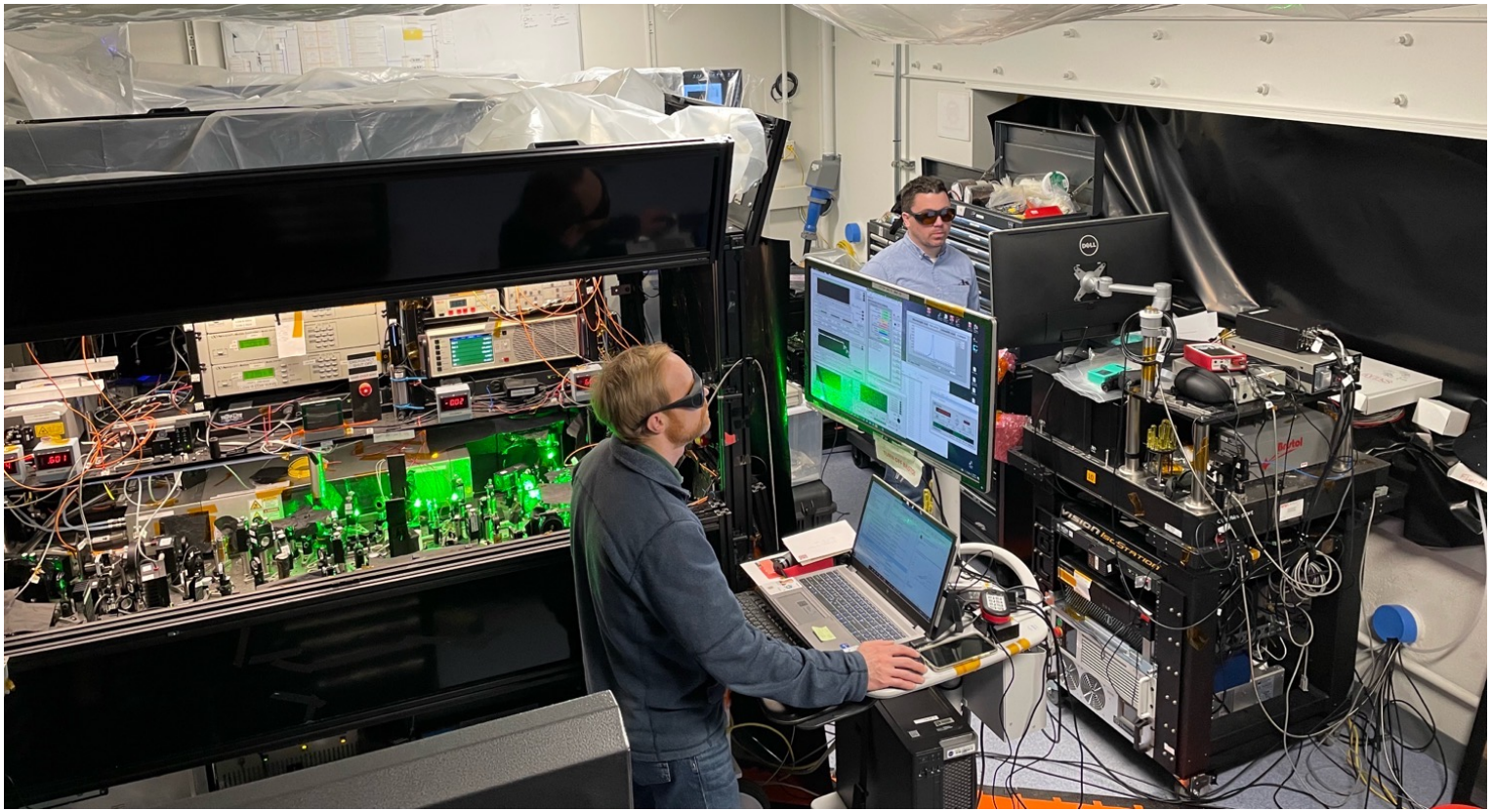
- GLAMR sphere in front of VIIRS in the clean room at RTN
- An electronics rack also sits nearby

- Entire room was darkened for test, so light-tight shroud between instrument and sphere was not necessary

t tent)

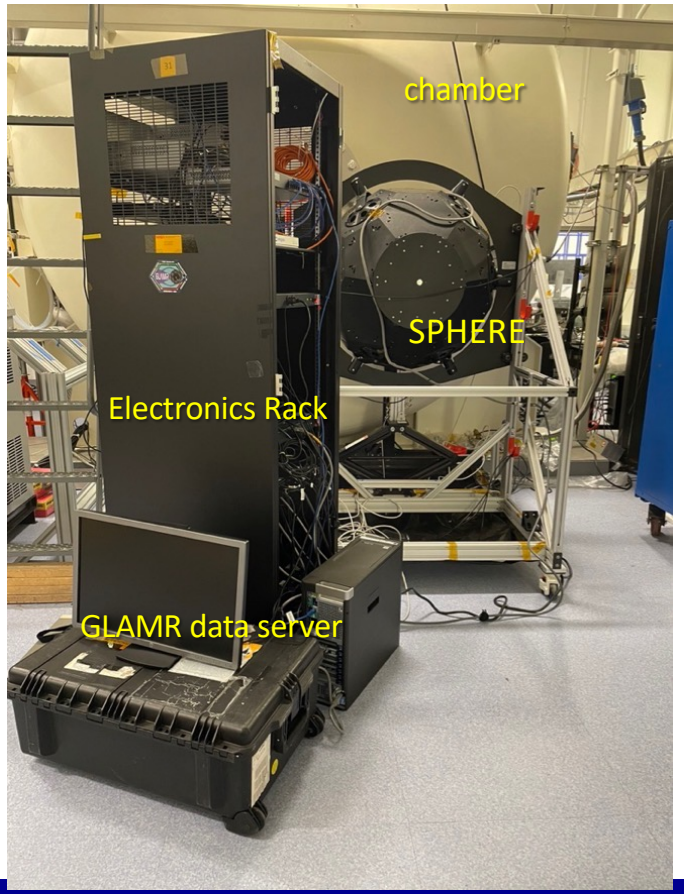
# GLAMR Setup at LASP laser-controlled area

LASP provided a space adjacent to the vacuum chamber to house GLAMR for the duration.



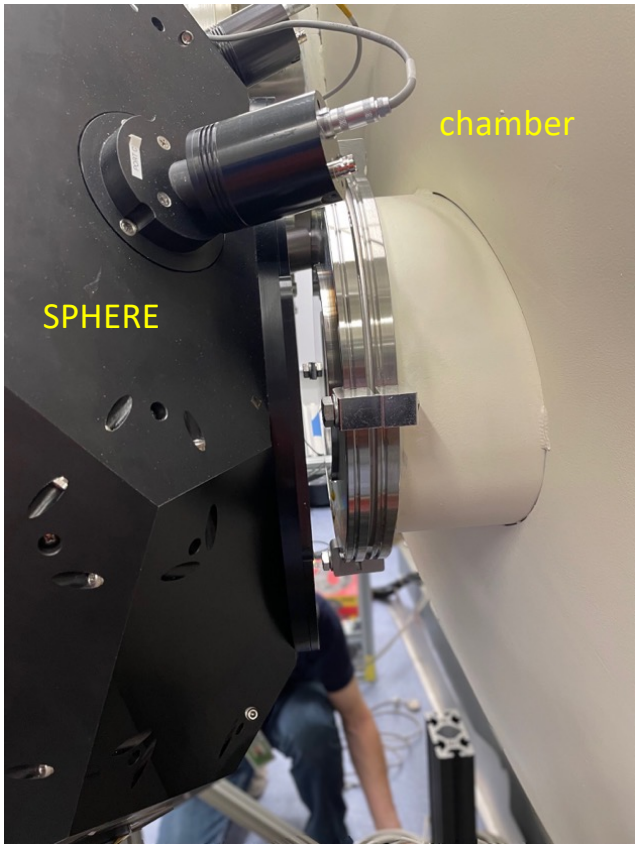
# GLAMR Setup at LASP
## sphere, chamber and electronics rack

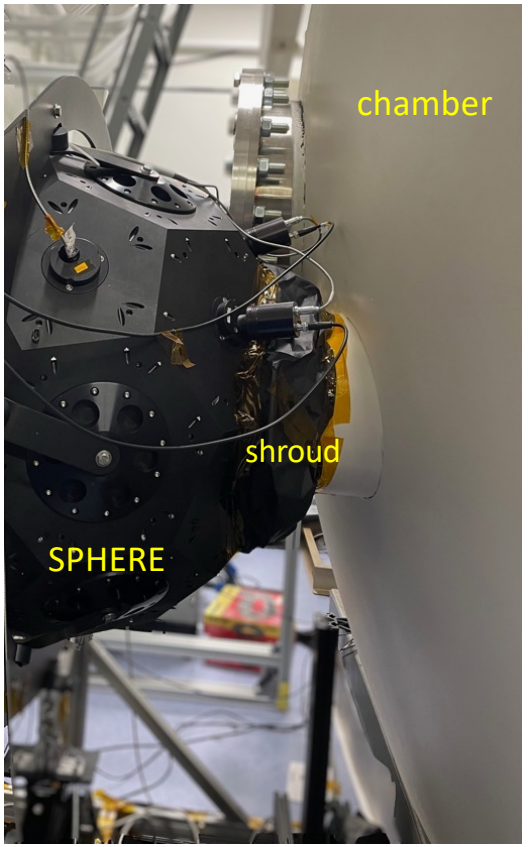
- Sphere is aligned with the instrument via reticle on back of sphere



# GLAMR Setup at LASP sphere and chamber

- Light-tight shroud couples the sphere and the chamber port



# Typical Schedule for Travel Test

- Initial discussions (as far before the test as possible)
  - Establish a rough instrument test date
  - Establish basic test outline (wavelength range and step sizes, radiance levels, light/dark times)
  - Establish requirements on the GLAMR system for the test (stability, uncertainties)
- If GLAMR needs improvements, start on them until ~1 year out from test
- T0 minus 1 year: Schedule discussions begin in earnest
  - Work out test conditions (TVAC/ambient), how long will proposed measurements take, will they fit in the allotted time on the instrument calendar
  - Start bi-weekly meetings for with instrument test team and cal/val or science analysis team to communicate test details
  - Site visit by GLAMR team to review allotted lab space and test environment
- T0 minus 4-6 weeks: the GLAMR facility is set up in the allotted space at test site
  - Pre-ship review confirms that GLAMR is ready for the test
  - Gets GLAMR on-site and functional off the critical path
  - Perform initial calibration of the GLAMR system, required for instrument test
    - If there are additional optical elements in the test (ie a TVAC chamber window), an additional calibration is run when possible)
- T0 minus 2-3 days: GLAMR personnel return on-site to verify system functionality
- T0 minus 1 day: align sphere in front of instrument, run dry run measurements
- T0 to Tn: Instrument test
  - OLI, VIIRS, OCI all required 11-14 days of two shift GLAMR operations
  - GLAMR does not have the personnel to support three shifts
  - At the end of test, a consent to break meeting establishes that all requirements have been met and GLAMR is free to move the sphere
- Tn + 1-7 days: GLAMR runs another calibration to verify stability of the GLAMR system
- GLAMR packs facility and ships home

# Test Facility Requirements for GLAMR deployment

- Enclosed lab space of at least 400 sq feet for the laser systems
  - Most of the space will be a laser-controlled area. An enclosed room is preferable, but an enclosure can be built with curtains.
  - Should be within a 12m fiber run of the location of GLAMR sphere during the instrument test
  - Room temperature stability is required for better laser performance. No more than 2F variation over a day.
- Space for the integrating sphere and electronics rack in front of the instrument during the test (~30 sq feet)
- At least three 20A circuits in the laser-controlled area and one 20A circuit in front of the instrument under test
- Maximum height for the center of the sphere port from the floor is 72". Any test requiring measurements above 72" from the floor will need to provide a platform for the sphere.
- A dry gas line for nitrogen purge
  - ¼ in swagelok tube fittings
- Desk space outside of the laser-controlled area
  - At least 2 seats for analysts

# TESTING AT GLAMR LAB

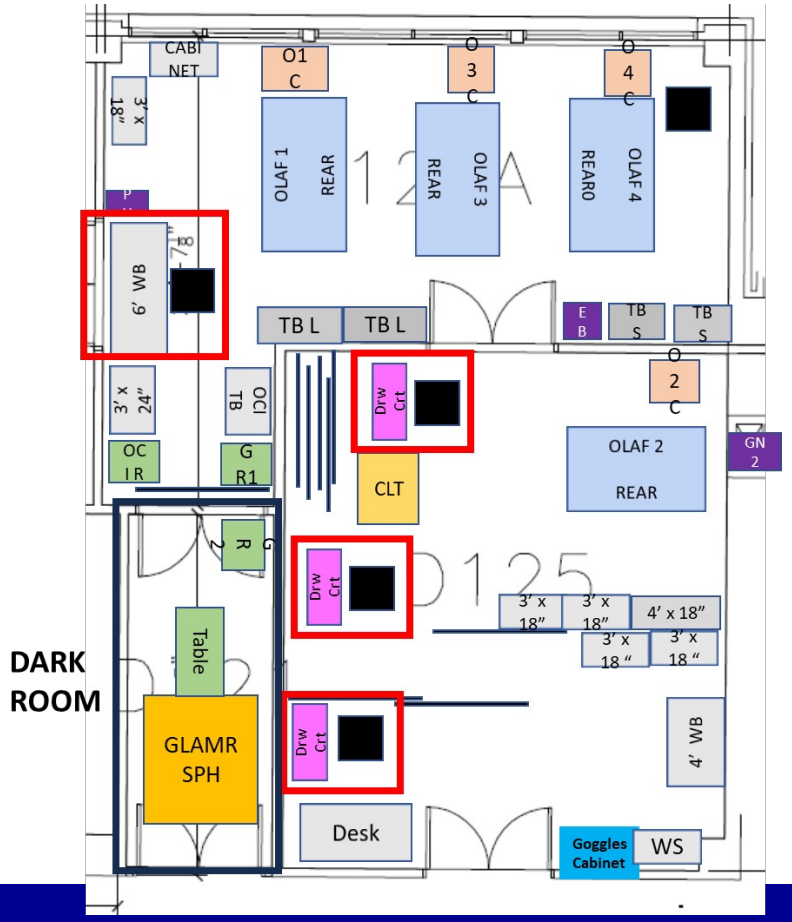
# GLAMR Lab

The drawing shows a representative picture of the GLAMR lab layout. The actual layout may vary based on what lasers are installed in the lab.

The black box identifies the dark room, where the calibration/characterization will take place.

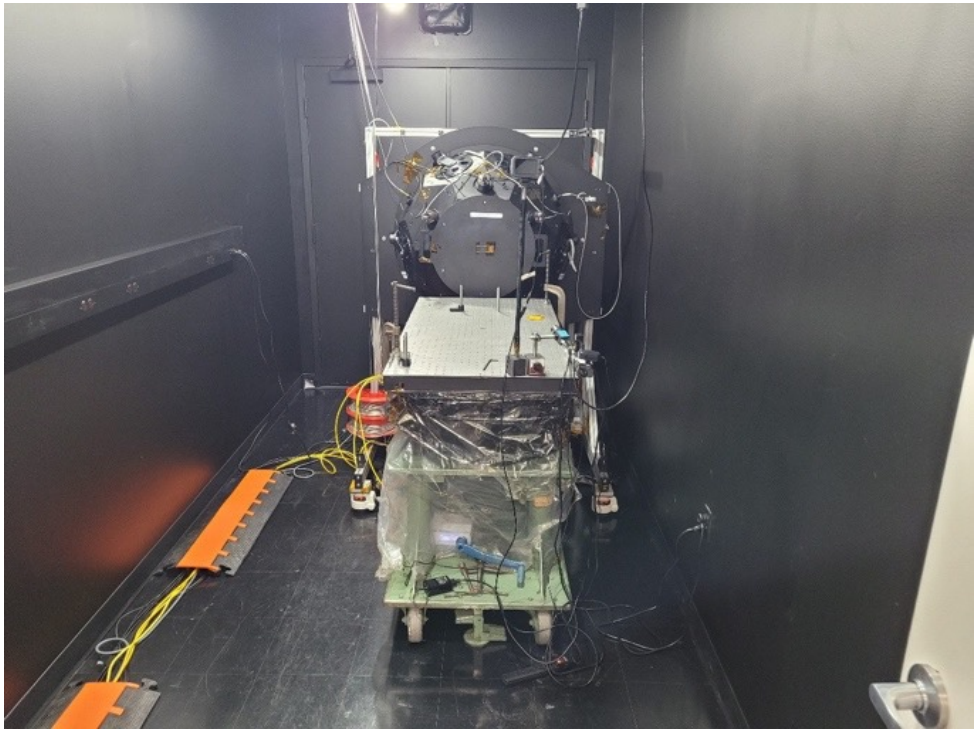
The red boxes indicate potential workstation areas for instrument personnel.

The blue boxes labeled “OLAF#” and the pale yellow box labeled “CLT” are the tunable OPO lasers. Eye protection is required when in the room while they are in use.



# Calibration Environment

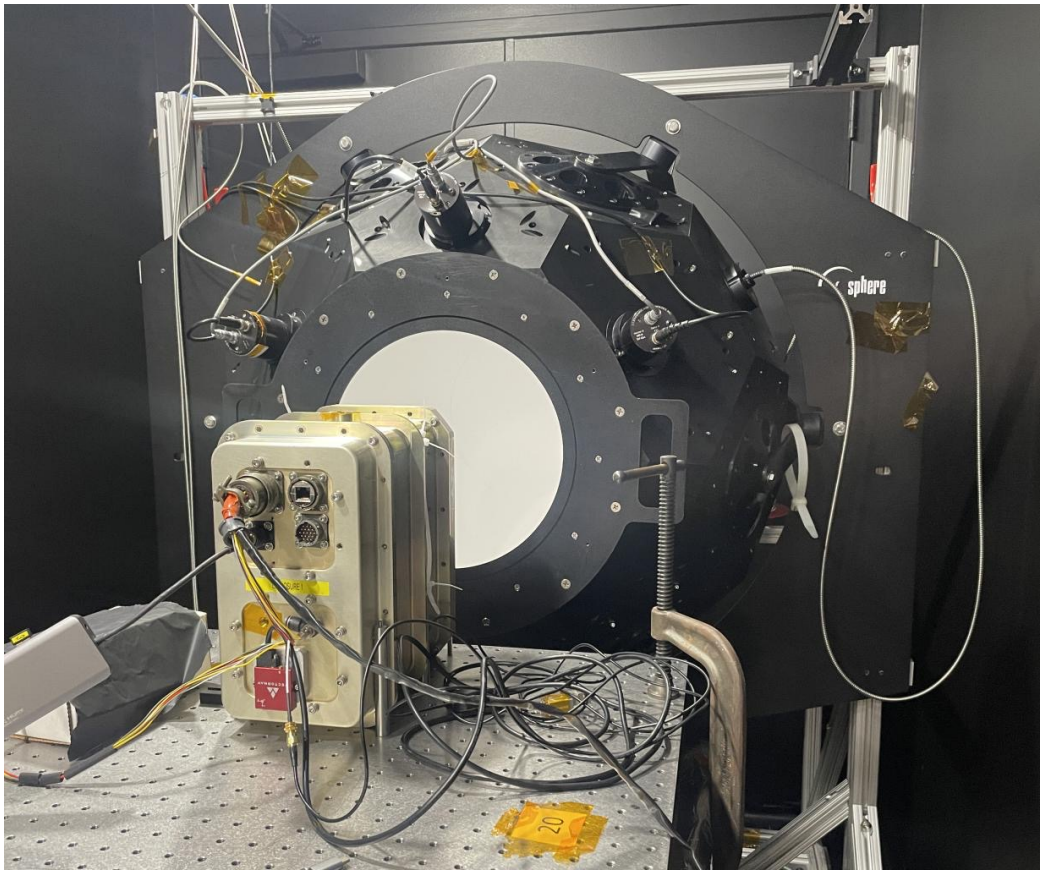
- Integrating sphere with variable port sizes (8”, 10”, 12”)
  - Note that this sphere does not get hot, so proximity to sphere is not a concern for instrumentation.
- Isolated dark room
  - Lasers are fiber coupled to the sphere from adjacent rooms
- Temperature range: 67-75 deg F (19.5-24 deg C) – no lab control
- Humidity range: 15-70% - no lab control
- Height adjustable cart with at 2’ x 4’ breadboard for instrument mounting, pictured at right, in front of sphere
- 110 V, 208 V single phase and 208 V 3-phase power available (power cords are required to be provided by the instrument team)
- Chiller available to provide cooling water
  - 20 psi nominal pressure (adjustable)
  - ~1.3 GPM @ 20 psi
  - 3/8” ID hoses
- Gaseous N2 available for instrument purging (10 psi, 1 scfm flow rate)
  - Dew point <-20 deg C
  - ¼” Swagelok connection
- MasterClock time server available for time synchronization
- Cameras monitor the dark room during calibration efforts
- Clean environment (NOT a clean room)



*Dark room where calibration measurements are run. The integrating sphere is closed in this photo.*

# AirHARP-2 at GLAMR

*AirHARP-2 SWIR instrument in front of the GLAMR sphere*




*AirHARP-2 operator at the instrument control system in the GLAMR Lab*

# Logistics

- **Time synchronization is essential for an efficient GLAMR test.**
  - For time synchronization with our time server, your instrument must connect to GLAMR's network.
- >25 ft cables required to connect instrument in the dark room to the available workspace/monitoring locations
  - Multiple workspaces are available for multiple personnel
  - If you use the GLAMR chiller, similar length tubing must be provided.
  - Results with wireless connections have been poor.
- External internet access is available (requires advance notice and advance setup)
- Tools and facilities available for basic repairs
- Two shift operation is possible depending on the test needs
- Can accommodate standard gas cylinders as long as instrument team provides regulator and their own plumbing
- Real-time telemetry is available via a CCSDS server for use by the instrument team or via a data server for viewing on a monitor.
- Limited capability lab computers are available for use (no internet access)
- Building has a standard loading dock or a garage bay for loading/unloading hardware.

# Test Planning Questions

- What is your desired test plan?
  - Wavelength range, step size, desired dwell times for light and dark periods, wavelength stability, linewidth stability, radiance stability, etc.
- What is your operating plan? How many hours of testing are expected each day? How many instrument operators are available?
- How fast can your data be analyzed to identify any go-backs to replace bad data points?
- Are your instrument operators also performing the data analysis?
- Can you see the instrument response live during testing?
- Are any special purity purge gases required?
- Can your instrument be time synchronized? This is critical for efficient data analysis and calibration activities.
- Are there any damage or safety considerations for your instrument?
- Are triggered acquisitions required or will data be collected asynchronously?
- What requirements are there for mounting and aligning the system?
  - What field of view does the system have?
  - What orientation will it be mounted in?
- If using GLAMR telemetry, can software tests be performed ahead of the tests to ensure GLAMR and the instrument operate properly together?

# For more information


- We are happy to help!
- Please reach out to Julia or Brendan
  - julia.barsi@nasa.gov
  - brendan.mcandrew@nasa.gov