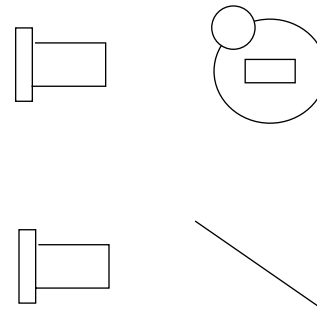


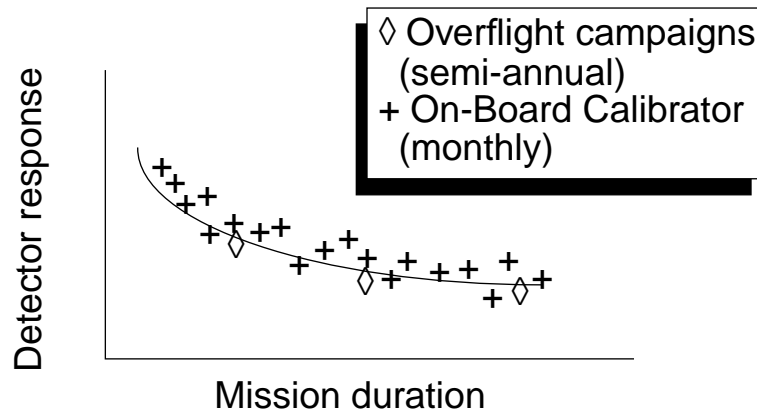
- System design:
 - temporal stability achieved through radiation resistant components, contamination control, and flight UV blockers, lens shades, and cover
 - polarization insensitivity achieved through optical design
 - stray-light control within cameras calibrator subsystems



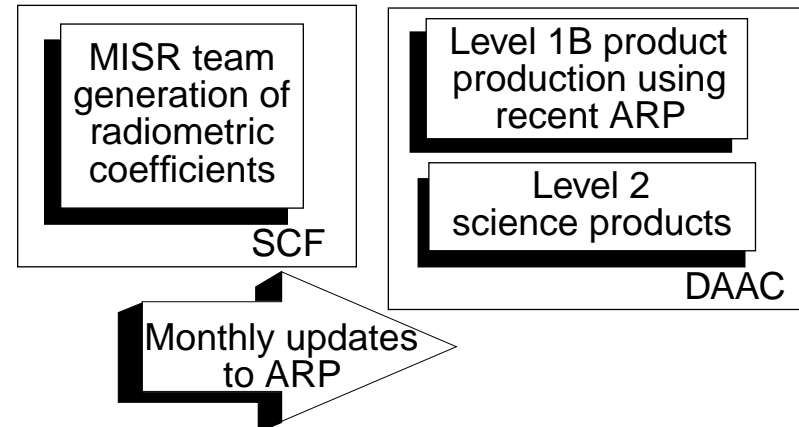
Preflight:
laboratory standards provide measure of integrating sphere output

In-flight:
flight standards provide measure of diffuser-reflected sunlight

- Detector-based standards establish radiometric scale to $\pm 3\%$ (1σ ; $\rho_{eq}=1.0$) uncertainty



- Multiple methodologies reduce systematic errors



- Radiance product reflects best estimate of instrument responsivity



MISR REQUIRES RADIOMETRIC CALIBRATION AND STABILITY



SCIENCE REQUIREMENTS (68% CONFIDENCE)

- **Absolute radiometric uncertainty: $\pm 3\%$ at signal $\rho_{eq}=100\%$**
 - Required for accurate albedo and aerosol retrievals, change detection
- **Relative angle-to-angle radiometric uncertainty: $\pm 1\%$ at signal $\rho_{eq}=100\%$**
 - Required for accurate determination of angular signatures
- **Stability (maximum change): 0.5%/ 1 month; 2%/ 1 year at signal $\rho_{eq}=100\%$**
 - Required to maintain radiometric accuracy during intervals between calibrations

RAMIFICATIONS FOR INSTRUMENT

- High accuracy on-board calibrator
- Detector-based calibration using high quantum efficiency (HQE) and radiation resistant (PIN architecture) diodes
- High stability detectors, filters, and lenses
- Polarization insensitivity
- High signal-to-noise ratio



MISR REQUIRES SPECTRAL UNIFORMITY AND STABILITY

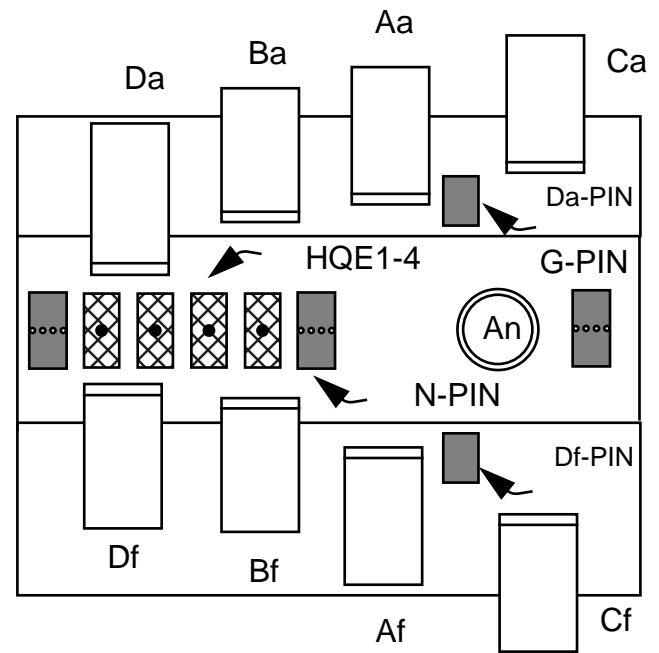
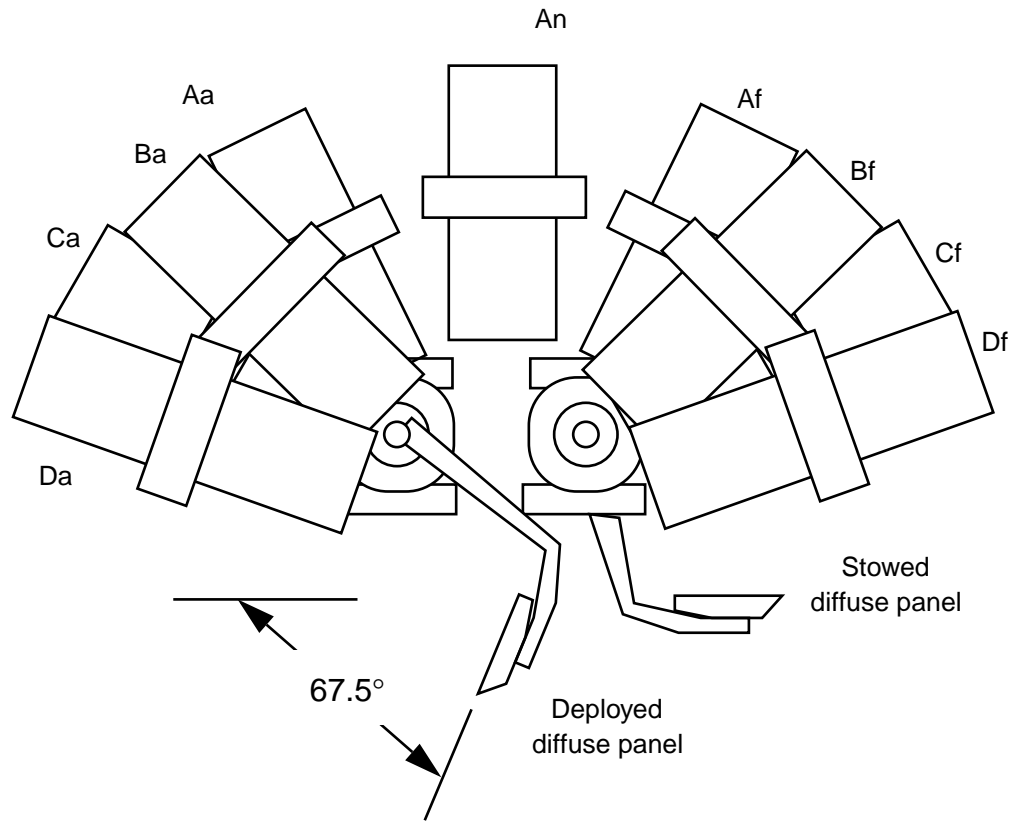


REQUIREMENT	RATIONALE
Accuracy	<ul style="list-style-type: none">- Optimizes science- Avoids solar Fraunhofer lines and atmospheric water absorption- Provides synergism with other instruments
Knowledge	<ul style="list-style-type: none">- Necessary to avoid radiometric error
Uniformity	<ul style="list-style-type: none">- Minimizes complexity of science algorithms- Achieves consistent retrieval across the scene
Stability	<ul style="list-style-type: none">- Eliminates need for on-board calibration within instrument- Achieves consistent retrieval with time

RAMIFICATIONS FOR INSTRUMENT

- **Interference filter and blocker designs to provide high out-of-band rejection**
- **High stability filter coatings (Ion Assisted Deposition technology) to avoid need for on-board spectral calibrator**
- **Gaussian band profiles to provide polarization insensitivity**

- **MISR has stringent calibration requirements**
 - Remote sensing systems flown prior to 1990 had very lax calibration requirements
 - Landsat program did not provide radiance data products
 - SPOT requires absolute calibration to only 10%
 - Conversely, MISR has very stringent (3%) absolute calibration requirements
 - Detector-based calibration elected to meet this challenge
 - Literature reports accuracies of 0.5%, using filtered trap detectors
- **Building flight detectors no easy task**
 - assembly hermetically sealed to allow focal plane stability (protected from humidity, contaminants, filter shifts)
 - light-trap manufactured from using ceramic subcarriers
 - precision apertures manufactured using photolithography techniques (1 μm tolerance)
 - radiation testing required, simulating on-orbit environment
 - radiometric response verified by consistency checks with independent devices (laboratory standards and wedge standards)

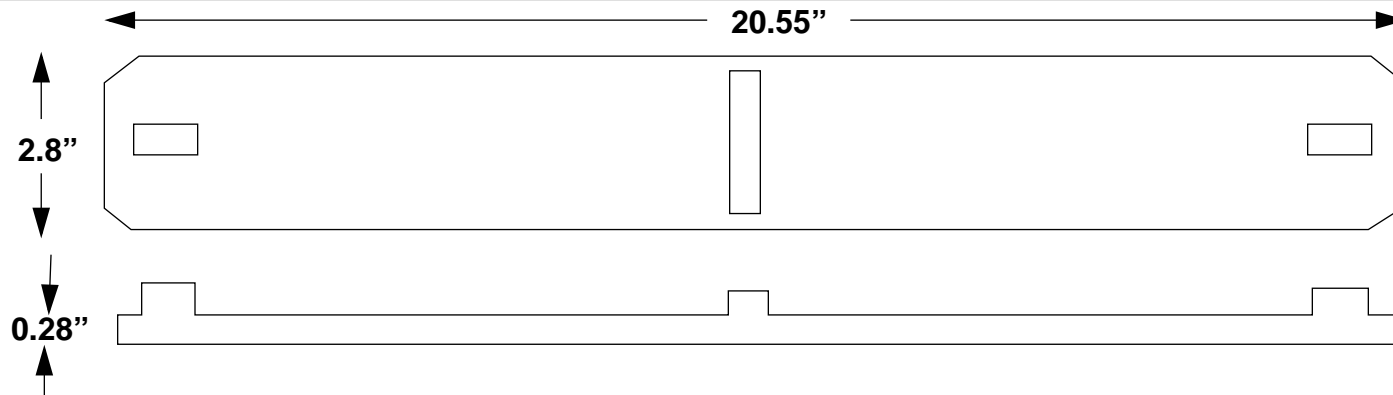


On-Board Calibrator (OBC)

- **High quantum efficiency (HQE) diodes**
 - Detector-based radiometric standard for the instrument
 - Configured in light-trap arrangement to give near 100% QE
- **Radiation resistant PIN diodes**
 - Secondary detector standard (longer lifetime than the HQEs)
- **Deployable Spectralon diffuse panels**
 - Relative BRF needed to transfer diode measurements into camera view angles
 - Absolute reflectance knowledge unnecessary (slow degradation permissible)
- **Mechanized goniometer diode (G-PIN)**
 - Verifies BRF stability of diffuse panels

Radiometric calibration

- Acquire monthly OBC data (6 minute interval at each pole)
- Conduct semi-annual overflight field campaigns
- Calibration coefficients computed from a time trend analysis considering the preflight, OBC, and overflight measurements



Panel design

- Panel difficult to frame, as Spectralon grows 0.29" beyond aluminum tray between survival temperatures -65 to 80°C.
- Panel design has feet protruding into frame to allow thermal growth without distortion and survive launch loads without yielding (yields at 200 psi).
- Spectralon can only be machined to a tolerance of 0.005". Tray will be customized if necessary upon Spectralon delivery.

Handling specifications

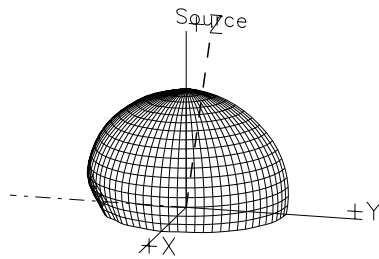
- During manufacture all surfaces to contact resin or Spectralon to be wiped with 200 proof reagent grade Ethyl Alcohol.
- During transport within Labsphere or to JPL material stored in dry nitrogen purged aluminum transportation container with 9 integral witness samples. Spectralon will be housed in EM or PF container for BRDF testing.
- Following machining material baked out at 10⁻⁶ torr, 90°C for 48 hours.



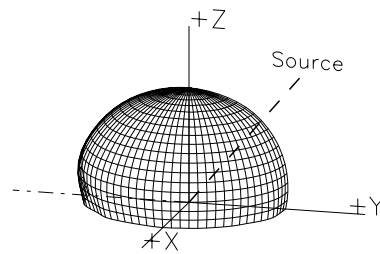
SPECTRALON FLIGHT QUALIFICATION



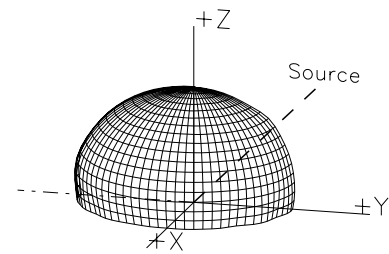
Test	Purpose
Charge arcing evaluation	Frame/ housing configuration versus discharge damage (done)
Process verification tests	Cleaning and handling procedures (done) BRDF study at in-orbit geometries Polarization Solar absorptance/ emittance
Environmental exposure tests BRDF data will be acquired before and after to evaluate stability	UV/ vacuum (repeat) Humidity Thermal vacuum cycling Charged particle, proton (done) Atomic oxygen (analyses planned)
Mechanical and physical property testing	Tension strength Compression strength Modulus Deformation under load Flexural
Vibration testing	Launch vibration loads with particulate contamination evaluation



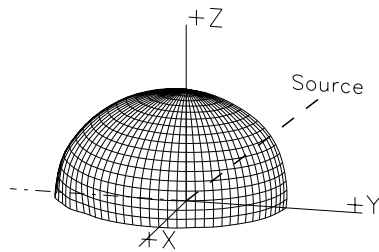
632 nm unpolarized
 Reflectance Factor= 0.9893
 MISR 12669-2, source at 8°



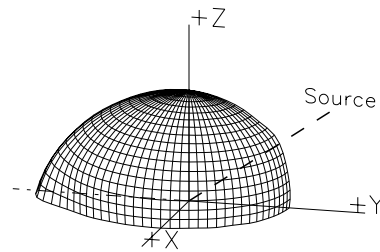
632 nm unpolarized
 Reflectance Factor= 0.9968
 MISR 12669-2, source at 40°



632 nm unpolarized
 Reflectance Factor= 1.0180
 MISR 12669-2, source at 45°



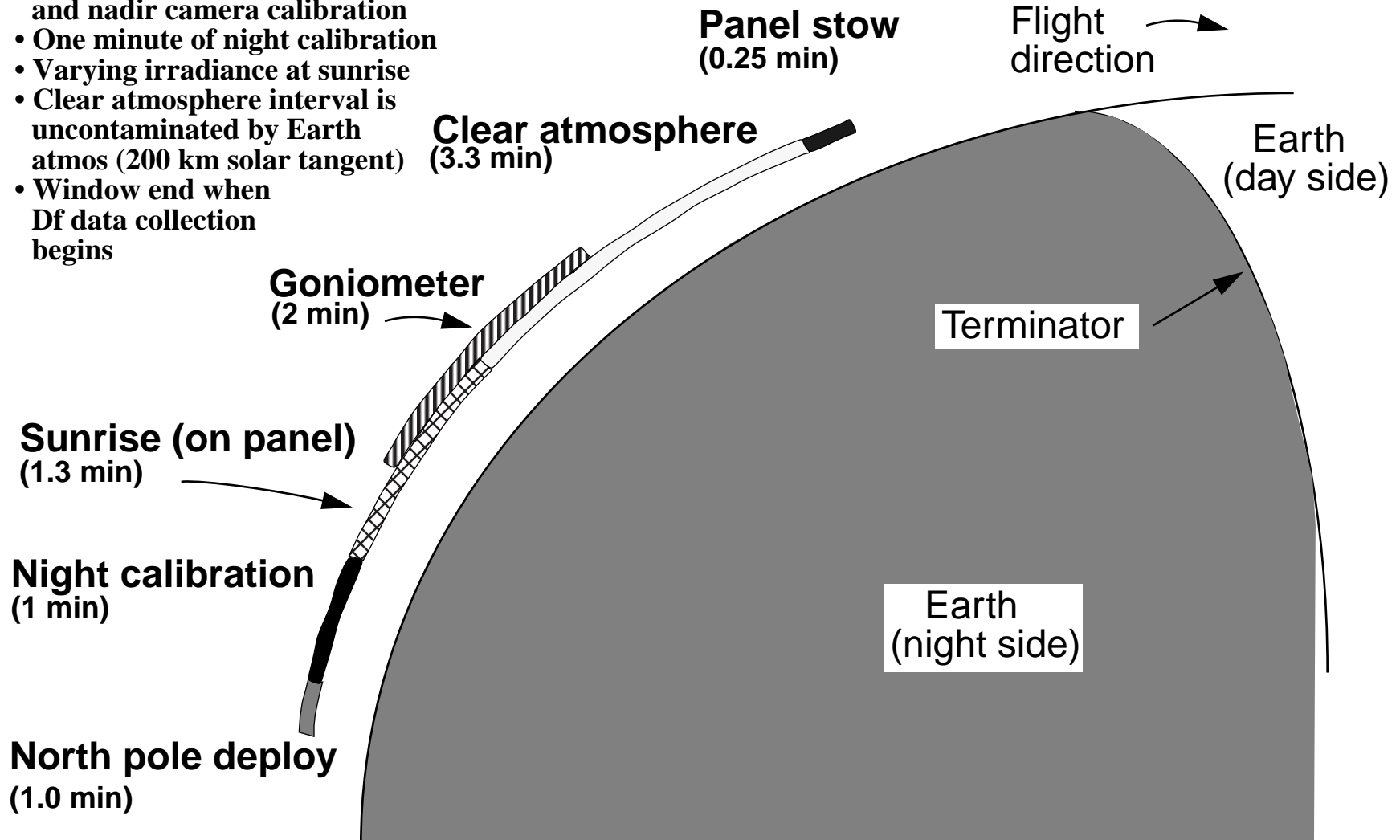
632 nm unpolarized
 Reflectance Factor= 0.9997
 MISR 12669-2, source at 50°



632 nm unpolarized
 Reflectance Factor= 1.0015
 MISR 12669-2, source at 55°

IN-FLIGHT CALIBRATION: MISSION PLAN

- North Pole: panel deployed for aft and nadir camera calibration
- One minute of night calibration
- Varying irradiance at sunrise
- Clear atmosphere interval is uncontaminated by Earth atmos (200 km solar tangent) (3.3 min)
- Window end when Df data collection begins



- **Membership**

- EOS project office lead
- NIST representatives (Carol Johnson, Joe Rice)
- Calibration scientist for each of 5 instrument teams
- Calibration specialists:
 - Vicarious calibration, Phil Slater, Univ. of Arizona
 - Lunar studies, Hugh Kieffer, US Geological Survey

- **Workshops (1 or 2 times a year)**

- **Peer reviews (2 reviews per instrument)**

- **Round-robin experiments**

- Radiometric (integrating sphere output verification)
- Diffuse panel bi-directional reflectance function comparison

-
- EOS contractual agreement reads that MISR calibration must be NIST traceable
 - In-house design does not come with a pedigree traceable to standards held at NIST
 - MISR detector standards are traceable to the Système International (SI) radiance scale via traceable protocols of measuring current, voltage, and distances
 - The internal quantum efficiency of these devices is well understood in the literature
 - Verifications of our scale were provided by comparison to NIST-traceable lamps, and participation in EOS/ NIST sponsored round-robin experiments

- Various transfer radiometers compared MISR integrating sphere output. Results give confidence in ability to achieve 3%(1 σ) absolute requirement.

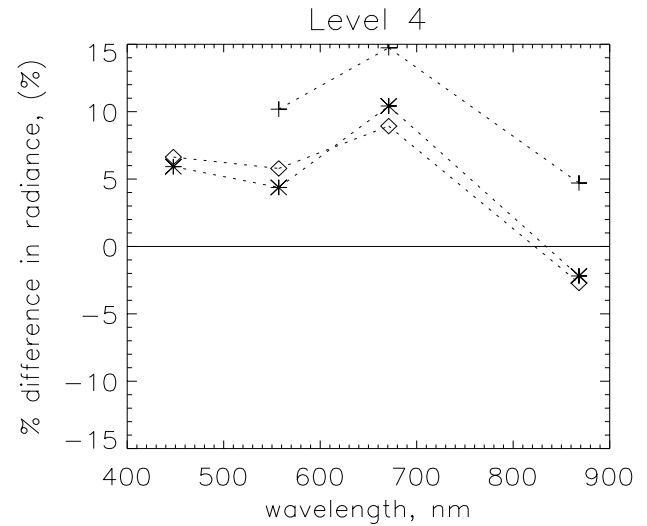
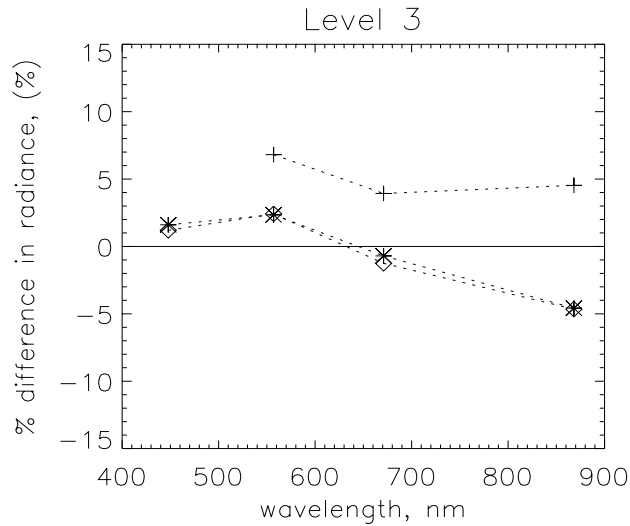
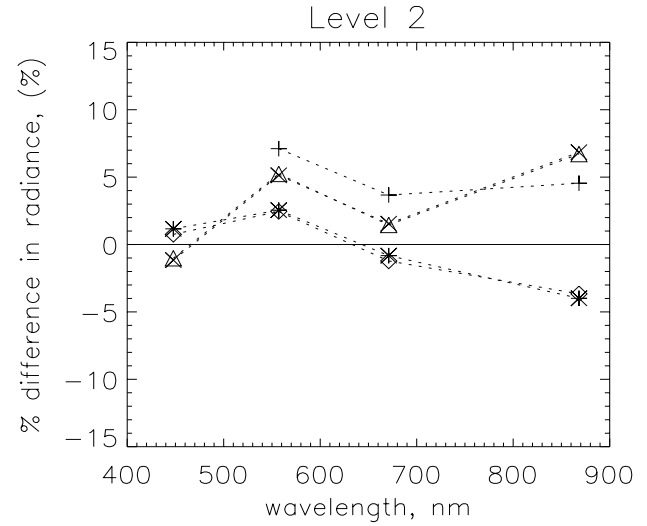
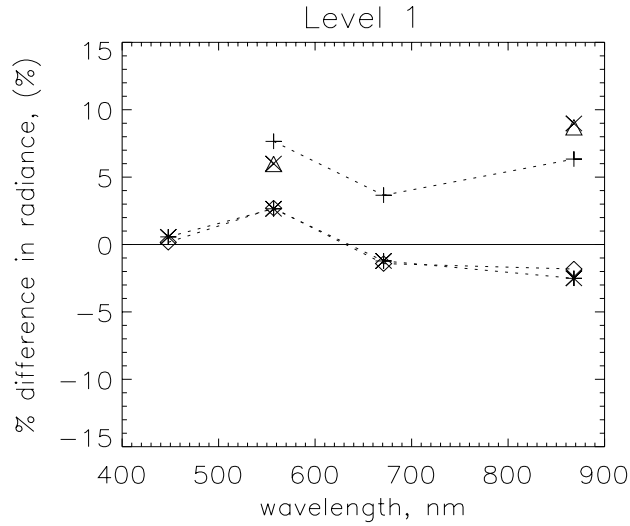
Radiometer	Wavelength (nm)		
	550	650	666
MISR	0.4%		
UofA	-1.1%		-0.8%
NRLM		0.9%	

- Additionally, filter transmittance was measured by several instruments. MISR Cary establishes radiometric scale of Laboratory Standards.

Filter λ_c ,	Wavelength (nm)		
	500	687	748
MISR Cary	baseline	baseline	baseline
JPL Beckman	+1.3%	-0.1%	-1.7%
UofA Optronics		+5.0%	+11.0%
GSFC Perkins and Elmer	+1.2%		

Test date: AUG19

- + NRLM
- ◇ GSFC
- * UofA
- △ NIST (BoD)
- × NIST (EoD)





NIST VS JPL BRDF MEASUREMENTS SPECTRALON SAMPLE, 632.8 NM

