EOS *MISR*

Terra Spacecraft

Multi-angle Imaging SpectroRadiometer (MISR) Calibration and Test Program

Carol J. Bruegge
Jet Propulsion Laboratory
California Institute of Technology

A presentation to the National Science Foundation
November 4, 1998

ACKNOWLEDGMENTS

David Diner	MISR/ AirMISR Principal Investigator
Terry Reilly	Project Manager
Valerie Duval	Calibration Engineer
Carlos Jorquera	Photodiode assembly and test
Nadine Chrien	Radiometric model, polarization, BRF analysis
Barbara Gaitley	Radiometric and spectral data analysis
Ghobie Saghri	Radiometric and spectral facility design
Daniel Preston	Filters/ flight camera testing
Teré Smith	Integration and test
Eric Hochberg	Optical Characterization chamber
Robert Korechoff	MTF, focus, special studies
David Haner	Spectralon BRF testing
Brian Chafin	In-flight data processing software

OUTLINE

The MISR/ AirMISR instruments

Detector-based calibration

- Manufacture of the laboratory and flight standards
- Traceability to Système International Units
- NIST verification (EOS round-robin experiment)

Test program

- "Optical Characterization Chamber": MTF, PSF, focus
- "Radiometric Characterization Chamber": Radiometric, Spectral Polarization
- Instrument level tests: image verification, camera pointing, data fidelity

Special studies

- Out-of-band spectral response, focal-plane scattering, offset video

In-flight calibration

- On-board calibrator, vicarious calibration
- Reconciling multiple calibrations

Data products

- The Ancillary Radiometric Product

PUBLICATIONS LIST (SELECT PAPERS)

Complete publication list is available via the Internet

http://www-misr.jpl.nasa.gov ==> Publications

IEEE'98 EOS Special issue

Bruegge, et. al. See Calibration Overview.

Diner, D.J., J.C. Beckert, T.H. Reilly, C.J. Bruegge, J.E. Conel, R. Kahn, J.V. Martonchik, T.P. Ackerman, R. Davies, S.A.W. Gerstl, H.R. Gordon, J-P. Muller, R. Myneni, R.J. Sellers, B. Pinty, and M.M. Verstraete (1998). Multiangle Imaging SpectroRadiometer (MISR) description and experiment overview. IEEE Trans. Geosci. Rem. Sens., Vol. 36, 1072-1087.

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Diffuse panel studies

T. R. O'Brian, E. A. Early, B. C. Johnson, J. J. Butler, C. J. Bruegge, S. Biggar, P. Spyak, and M. Pavlov, "Initial results of the bidirectional reflectance characterization round-robin in support of EOS AM-1," Conference issue: New Developments and Applications in Optical Radiometry (NEWRAD '97), *Metrologia*, in preparation.

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In-flight calibration

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Chrien, N.L. and C.J. Bruegge (1996). Out-of-band spectral correction algorithm for the Multi-angle Imaging SpectroRadiometer. In *Earth Observing System*. Proc. SPIE **2820**, Denver, Co, 5-9 August.

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IFRCC/ Level 1B1

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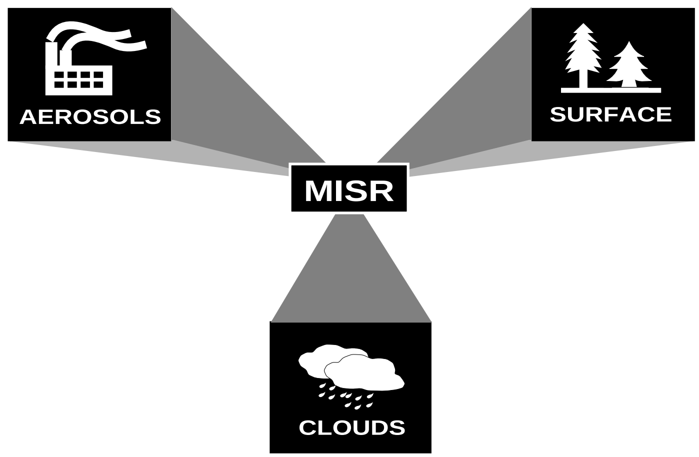
MISR OVERVIEW

Platform: Terra (EOS-AM1)

Launch: No earlier than August 27, 1999

- recent TITAN IV/CENTAUR and DELTA III launch failures may cause a delay

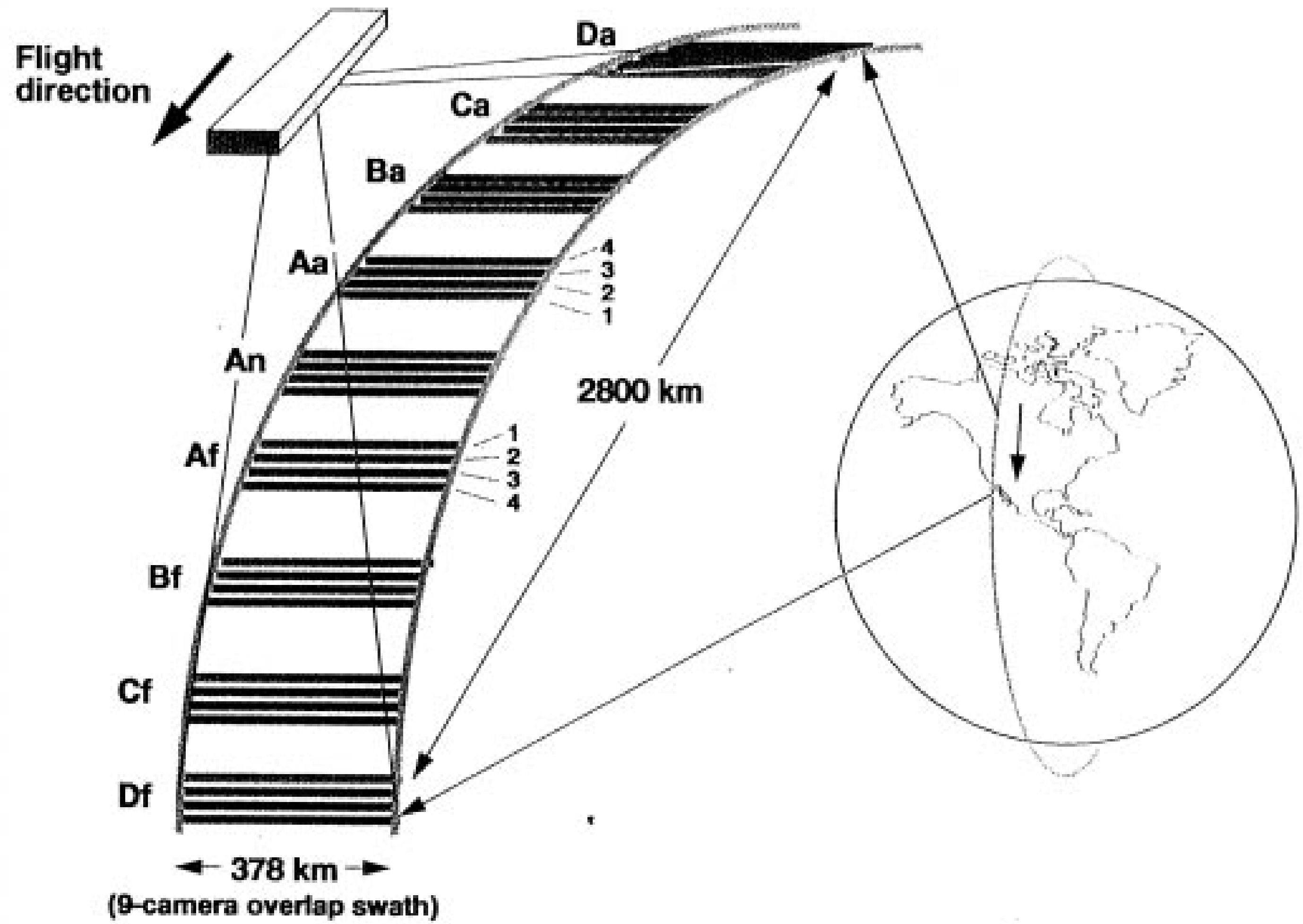
Other EOS-AM1 instruments: MODIS, CERES, ASTER, and MOPITT



MISR capabilities: Multi-angle global view of earth

- 9 cameras pointing nadir to ±70°
- 4 spectral bands 446, 558, 672, and 866 nm
- global coverage every 9 days
- on-board pixel averaging (275 m - 1.1 km)
- average data rate 3.3 Mb/sec

EARTH-VIEW GEOMETRY



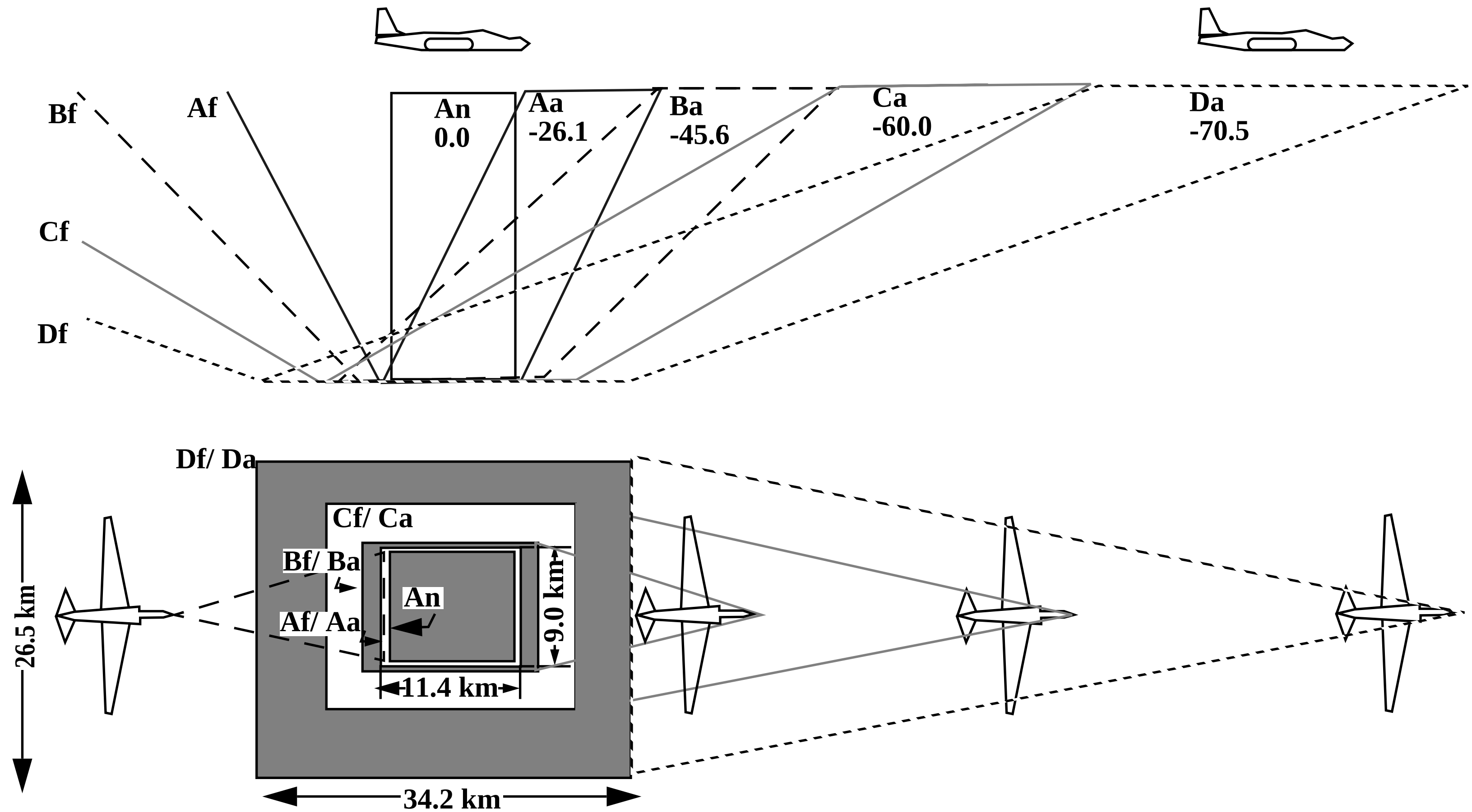
DEVELOPMENT TIMELINE

• **Proposal submitted**	**July 15, 1988**
• **Preliminary design review (PDR)**	**May 25, 1993**
- Calibration peer review	May 23, 1993
- Preflight calibration plans	January 10, 1994
• **Critical design review (CDR)**	**December 6, 1994**
- Calibration peer review II	March 27-28, 1995
• **Calibrate cameras**	
- Engineering model	August 1994-August 1995
- Calibrate flight cameras (10)	August 1995-August 1996
• **Instrument thermal vacuum testing**	**December 1996**
• **MISR arrives at spacecraft integrator**	**May 26, 1997**
• **Develop in-flight calibration processing capability**	**1998**
• **Original launch date**	**June 1998**

AIRMISR INSTRUMENT HERITAGE

- **Original proposal "Low-cost Airborne MISR Simulator" was submitted to the EOS Project Scientist (Dr. Michael King, GSFC) on 10 Nov 1995**
- **Objectives for AirMISR**
  - collect MISR-like data sets in support of the validation of MISR products
  - underfly EOS-AM1 MISR to verify its radiometric calibration
  - enable scientific research utilizing high quality, well-calibrated multi-angle imaging data
  - enable the exploration of measurement enhancements (room reserved in instrument reserved as technology testbed for future cameras)
- **MISR inheritance**
  - implementation features a single pushbroom camera, gimbaled to nine view-angle positions during a 15 minute data acquisition run
  - camera comprised of a MISR brassboard lens ("A" lens design, shortest focal length), and MISR engineering model focal plane
  - spectral bands at 446, 558, 672, and 866 nm (widths of 20 - 40 nm)
  - spectral, radiometric, and point-spread-function (PSF) response measured using MISR-developed laboratories and analysis procedures

DATA ACQUISITION

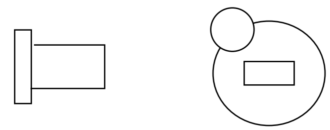


PERFORMANCE COMPARISON

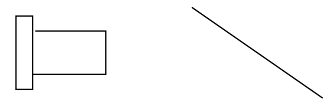
Parameter	MISR	AirMISR
Absolute uncertainty	3% (1σ)	3% (1σ)
Number of detector elements	9 camera x 4 bands x 1504 pixels (~53,000)	4 bands x 1504 pixels (~6000)
Worst detector elements	10% < response loss < 1%	40%< response loss
Number of detector anomalies	~12	~20 in blue ~ 20 in green
SNR	> 900	same, excluding anomalour pixels
Spectral out-of-band	<2%	4% in Band 3

CALIBRATION PLAN

- 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

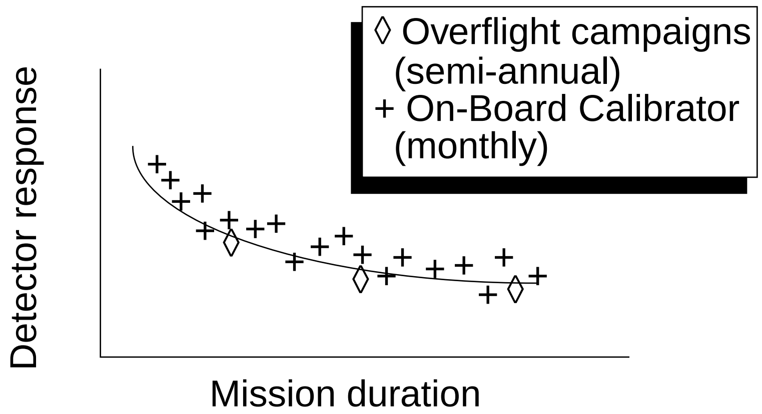


Preflight:
laboratory standards provide measure of integrating sphere output

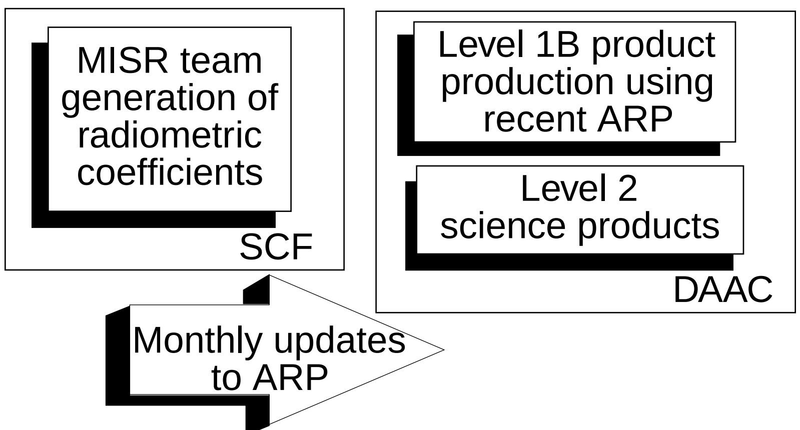


In-flight:
flight standards provide measure of diffuser-reflected sunlight

- Detector-based standards establish radiometric scale to ±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: ±3% at signal ρ_{eq}=100%**
  - Required for accurate albedo and aerosol retrievals, change detection
- **Relative angle-to-angle radiometric uncertainty: ±1% at signal ρ_{eq}=100%**
  - Required for accurate determination of angular signatures
- **Stability (maximum change): 0.5%/ 1 month; 2%/ 1 year at signal ρ_{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	- Optimizes science - Avoids solar Fraunhofer lines and atmospheric water absorption - Provides synergism with other instruments
Knowledge	- Necessary to avoid radiometric error
Uniformity	- Minimizes complexity of science algorithms - Achieves consistent retrieval across the scene
Stability	- Eliminates need for on-board calibration within instrument - Achieves consistent retrieval with time

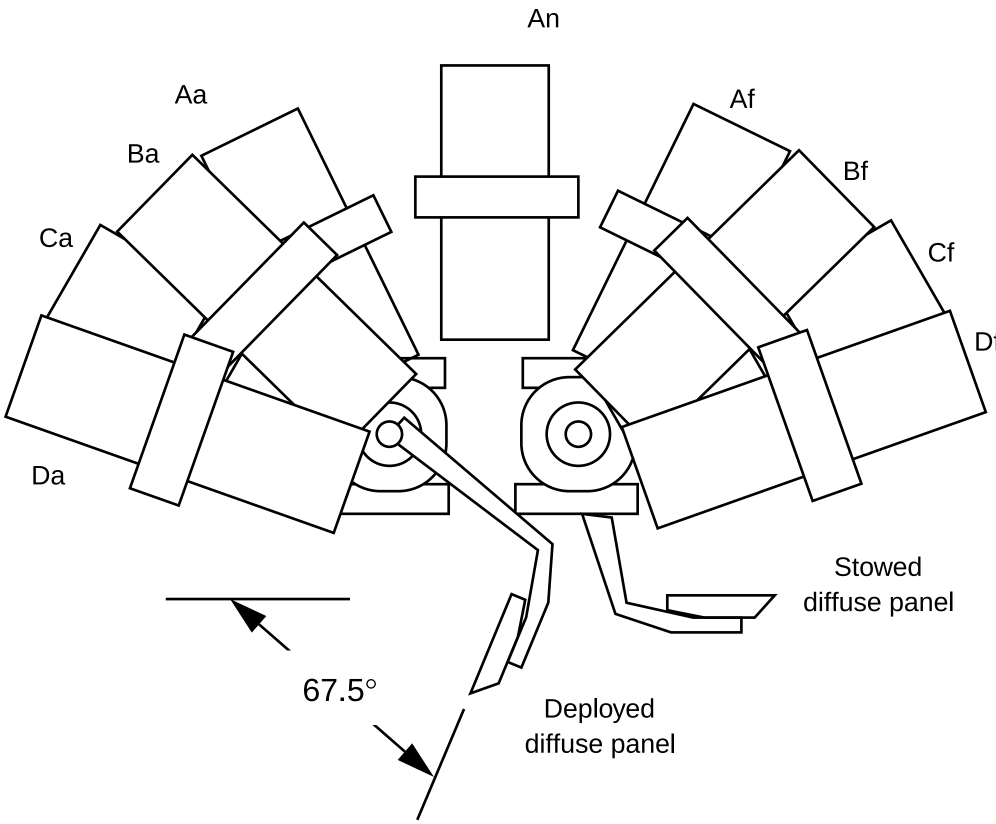
RAMIFICATIONS FOR INSTRUMENT

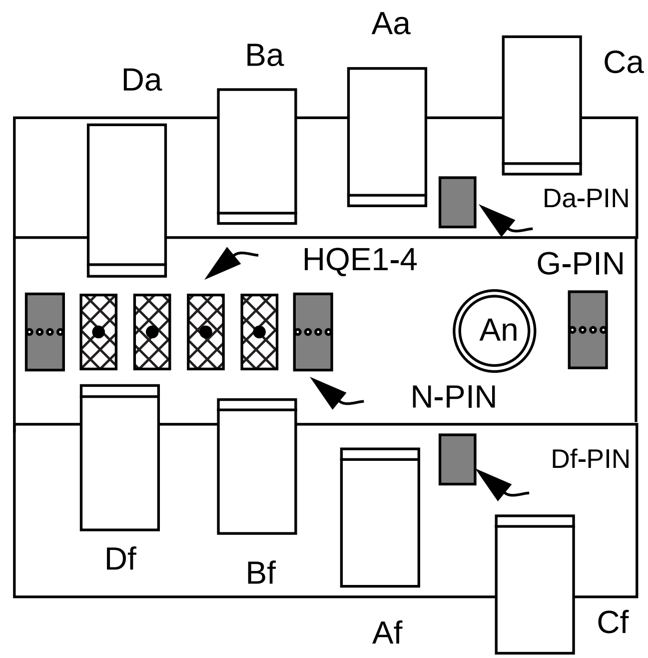
- **Interference filter and blocker designs to provide high out-of-band rejection**
- **High stability filter coatings (Ion Assisted Deposition technology) to avoid need for on-board spectral calibrator**
- **Gaussian band profiles to provide polarization insensitivity**

DETECTOR-BASED CALIBRATION

- **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





IN-FLIGHT RADIOMETRIC CALIBRATION

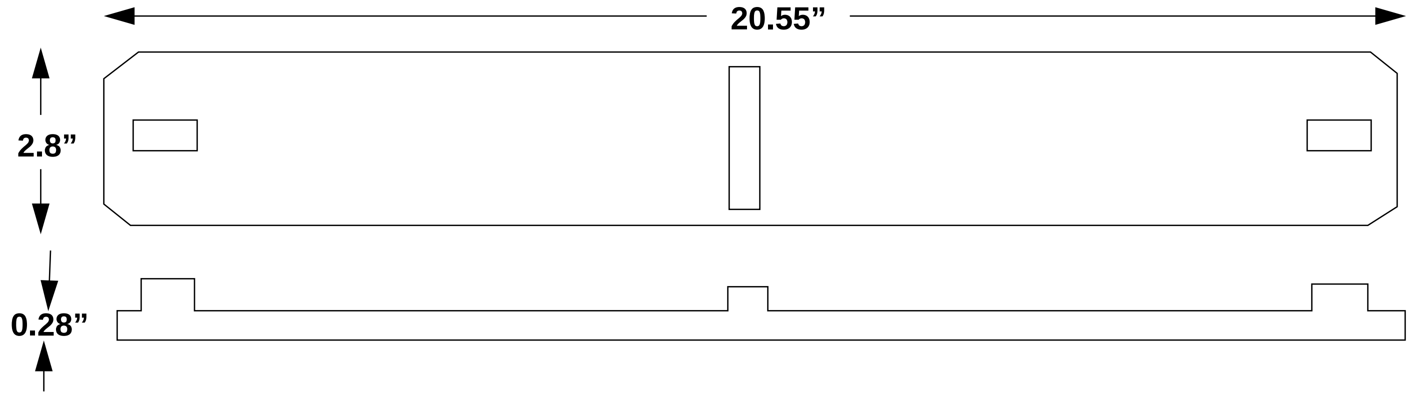
On-Board Calibrator (OBC)

- **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 permissable)
- **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

SPECTRALON DESIGN



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.

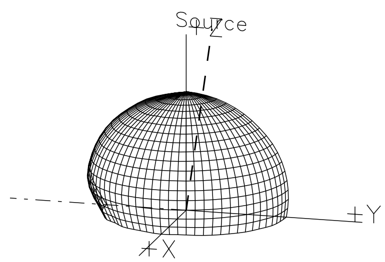
Handling specifications

- 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.

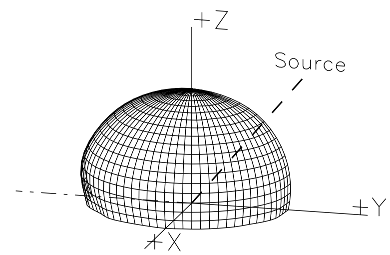
SPECTRALON FLIGHT QUALIFICATION

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

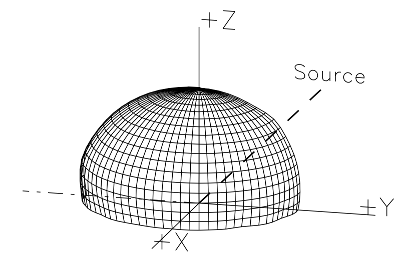
SPECTRALON
HEMISPHERIC BRF



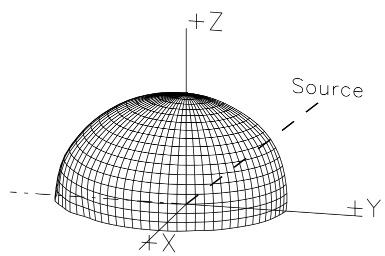
632 nm unpolarized
Reflectance Factor= 0.9893
MISR 12669−2, source at 8°



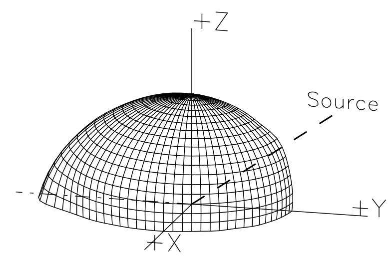
632 nm unpolarized
Reflectance Factor= 0.9968
MISR 12669−2, source at 40°



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



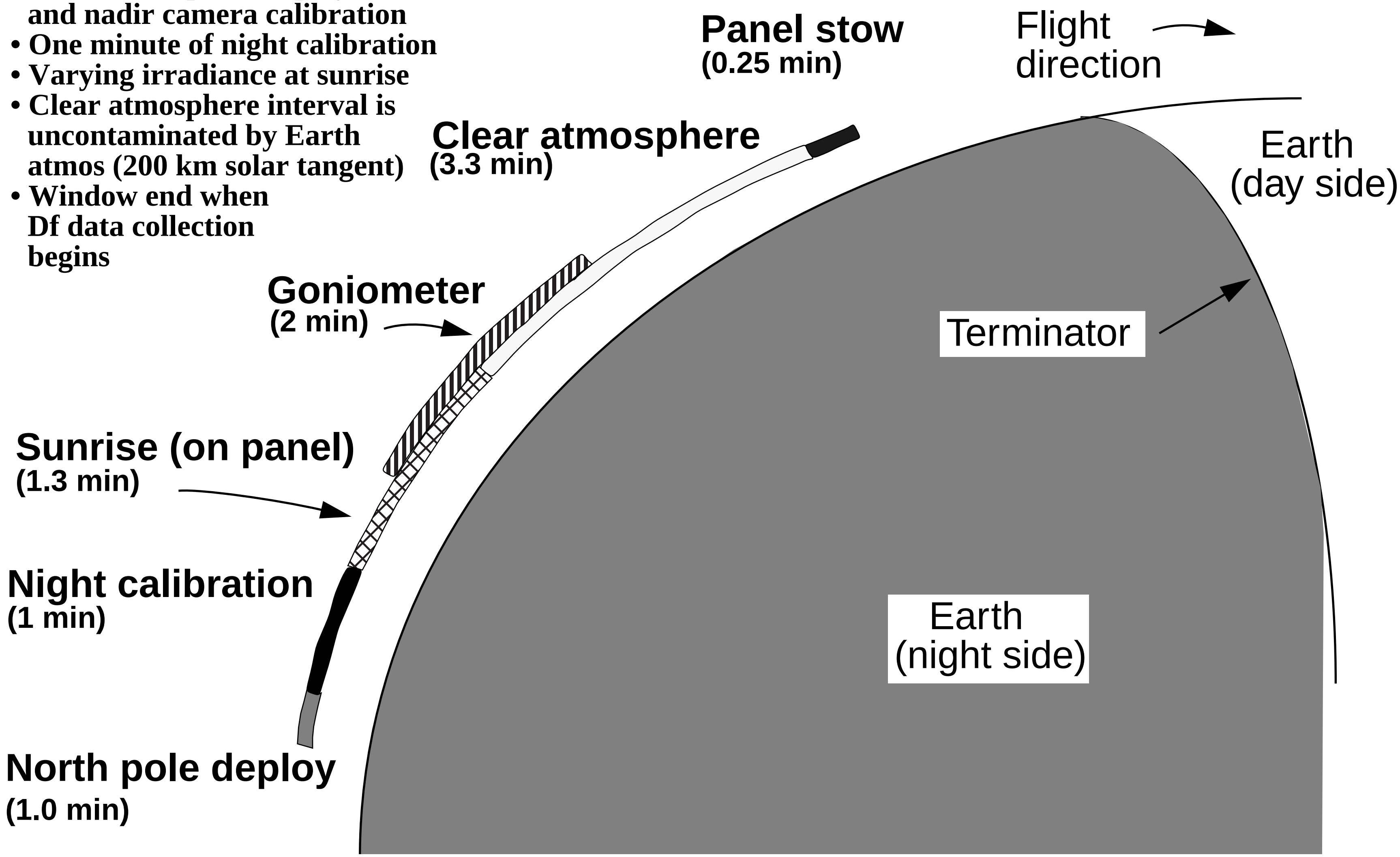
632 nm unpolarized
Reflectance Factor= 0.9997
MISR 12669−2, source at 50°



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)
- Window end when Df data collection begins



EOS CALIBRATION PANEL

- **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

TRACEABILITY

- 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

AUGUST 1994
ROUND ROBIN

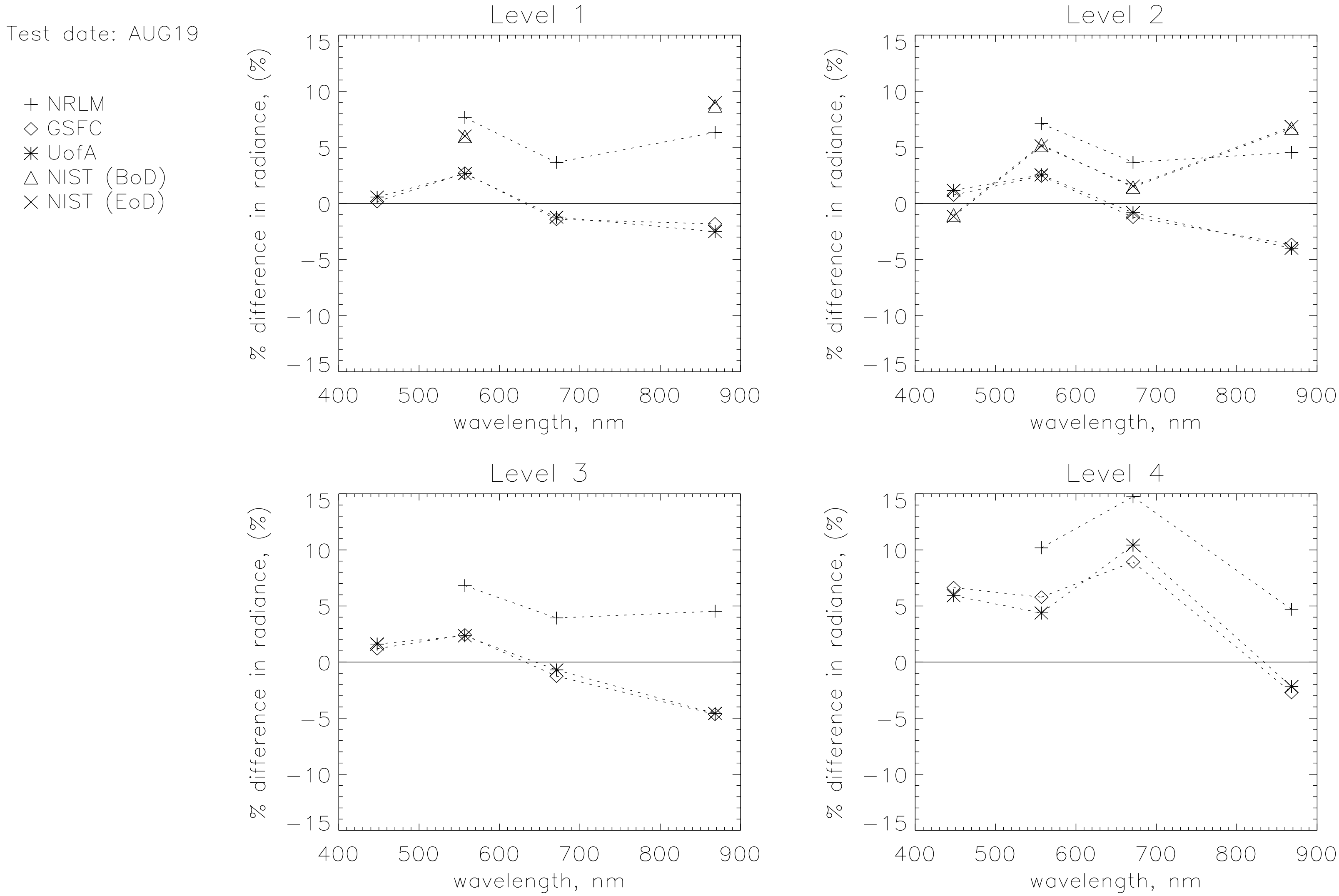
- Various transfer radiometers compared MISR integrating sphere output. Results give confidence in ability to achieve 3%(1σ) absolute requirement.l

	Wavelength (nm)		
Radiometer	**550**	**650**	**666**
MISR	0.4%		
UofA	-1.%		-0.8%
NRLM		0.9%	

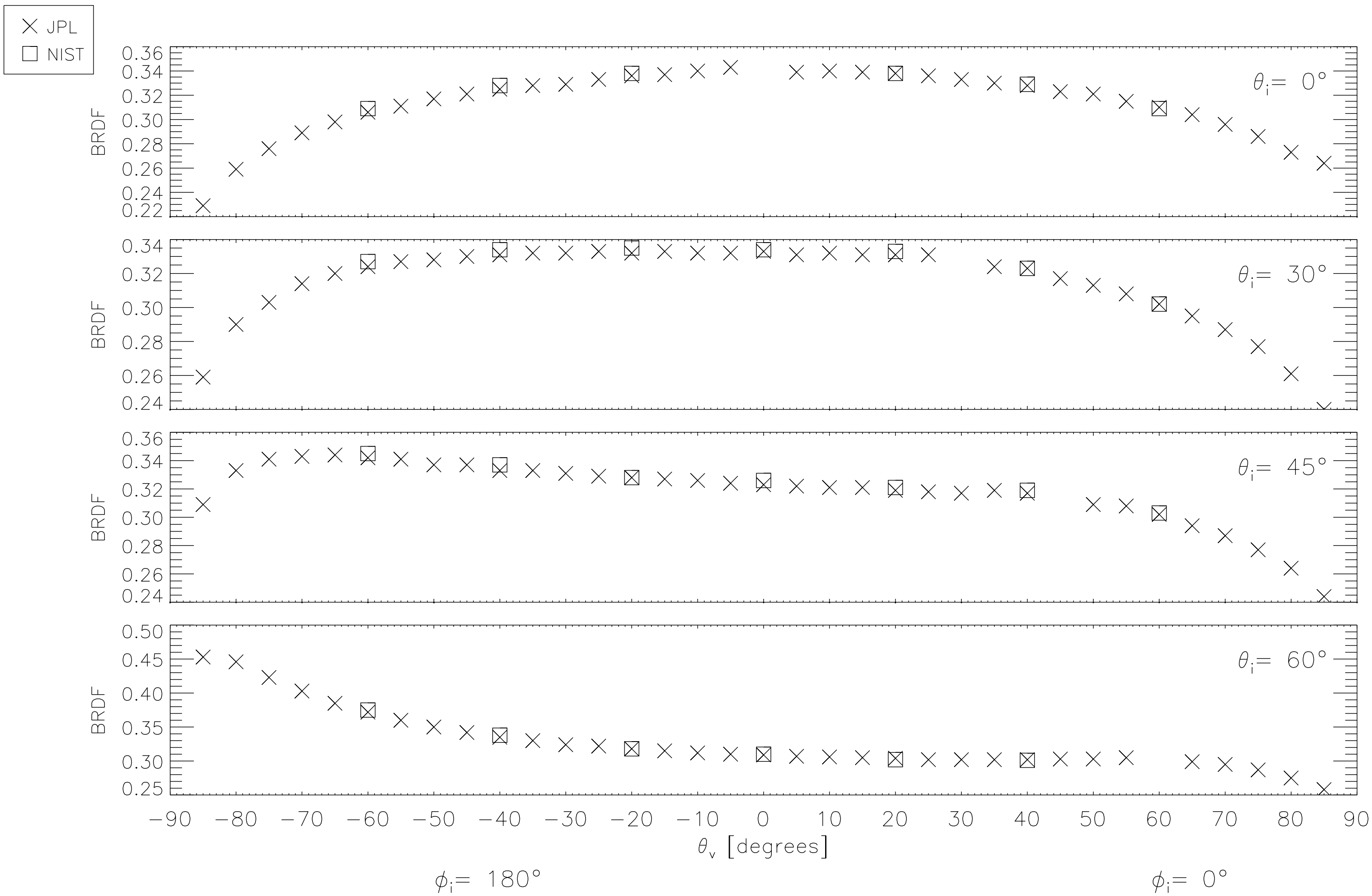
- Additionally, filter transmittance was measured by several instruments.MISR Cary establishes radiometric scale of Laboratory Standards.

	Wavelength (nm)		
Filter λ_c,	**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%		

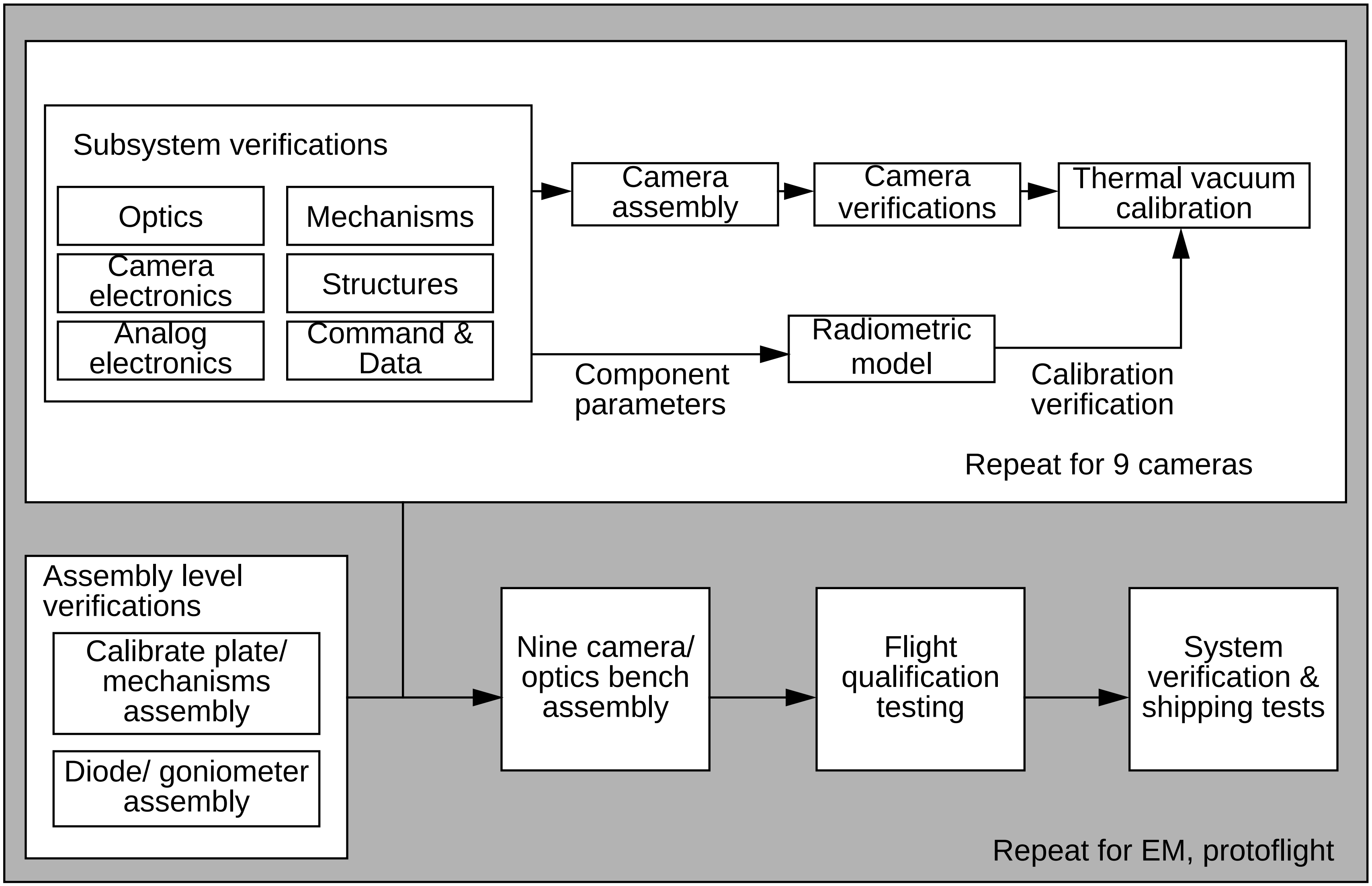
AUGUST 1996
ROUND ROBIN



NIST VS JPL BRDF MEASUREMENTS
SPECTRALON SAMPLE, 632.8 NM



PREFLIGHT CALIBRATION TEST FLOW



HIGH BAY FACILITY

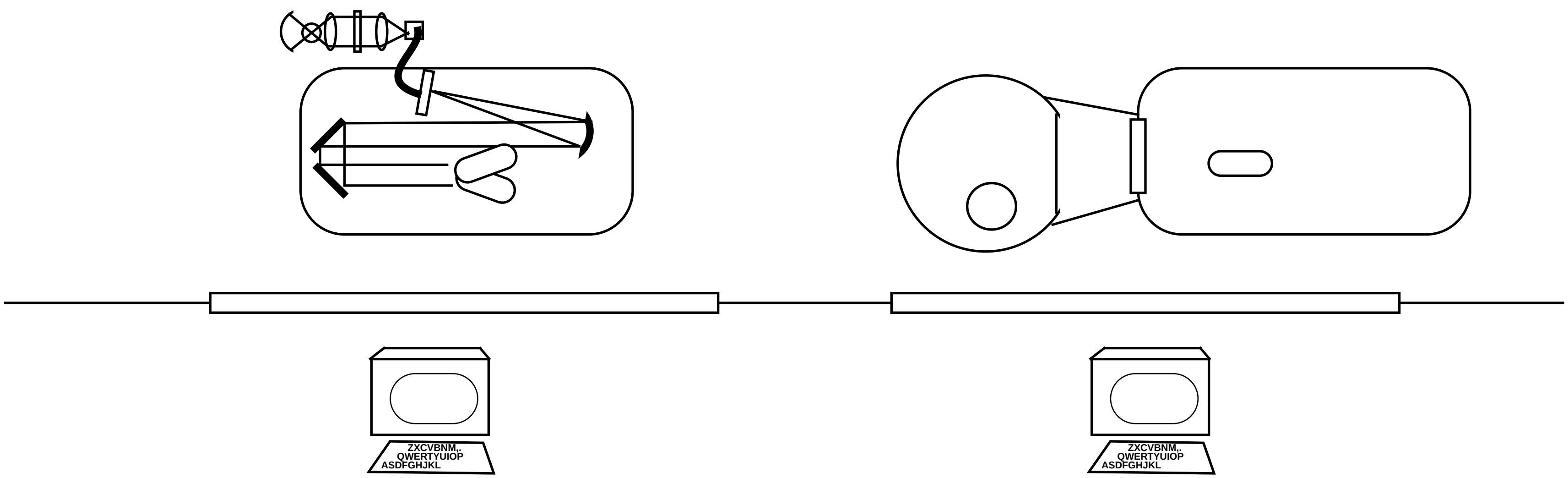
50x100 ft layout
x 30 ft height
Class 10,000 cleanroom

Optical Characterization Chamber

Features: Pinhole target, camera gimbal
Tests: EFT. MTF, PSF, Distortion, saturation

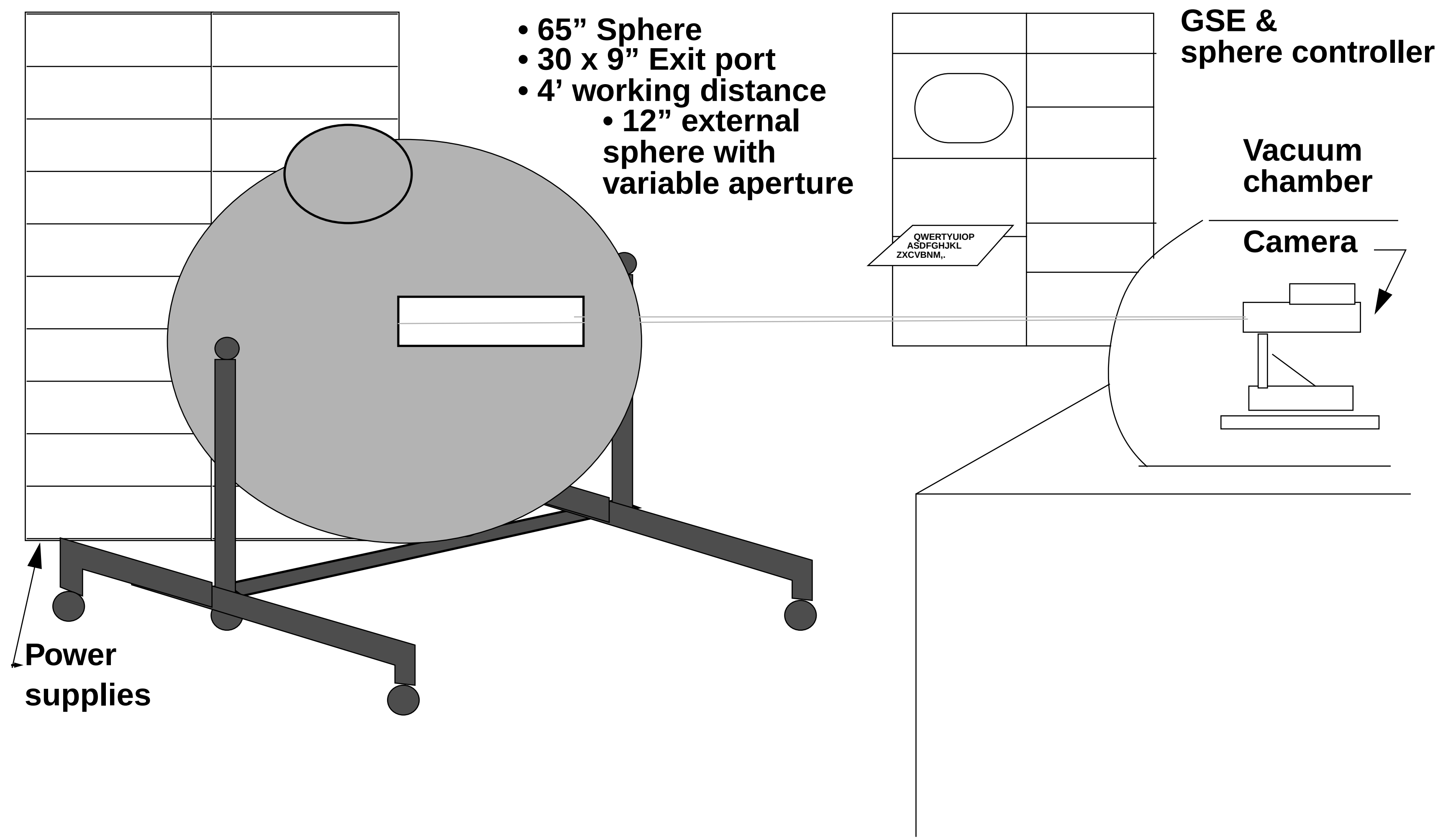
Radiometric Characterization Chamber

Features: 1.65 m sphere, monochromator
Tests: Radiometric and spectral calibration,
polarization verification



Ground Support Equiment room

RADIOMETRIC CALIBRATION FACILITY



MISR CALIBRATION EQUATION

- **MISR will be calibrated in-flight by a regression of incident radiance against output DN.**
  - Preflight data analysis has shown that the cameras are linear, except at extremely low inputs (scene reflectance < 5%).
  - The use of a linear or non-linear equation, e.g. the quadratic

$$DN - DN_o = G_o + G_1 L_\lambda + G_2 L_\lambda^2$$

    has been investigated. This equation is linear at high radiances and quadratic at small radiances. This latter equation will be baselined, upon completion of the current study.
  - L_λ is the sensor band-averaged spectral incident radiance, averaged over both in-and-out-of-band wavelengths and reported in units of [W m^{-2} sr^{-1} μm^{-1}]:

$$L_\lambda = \frac{\int L_{source} \Re \lambda d\lambda}{\int \Re \lambda d\lambda}$$

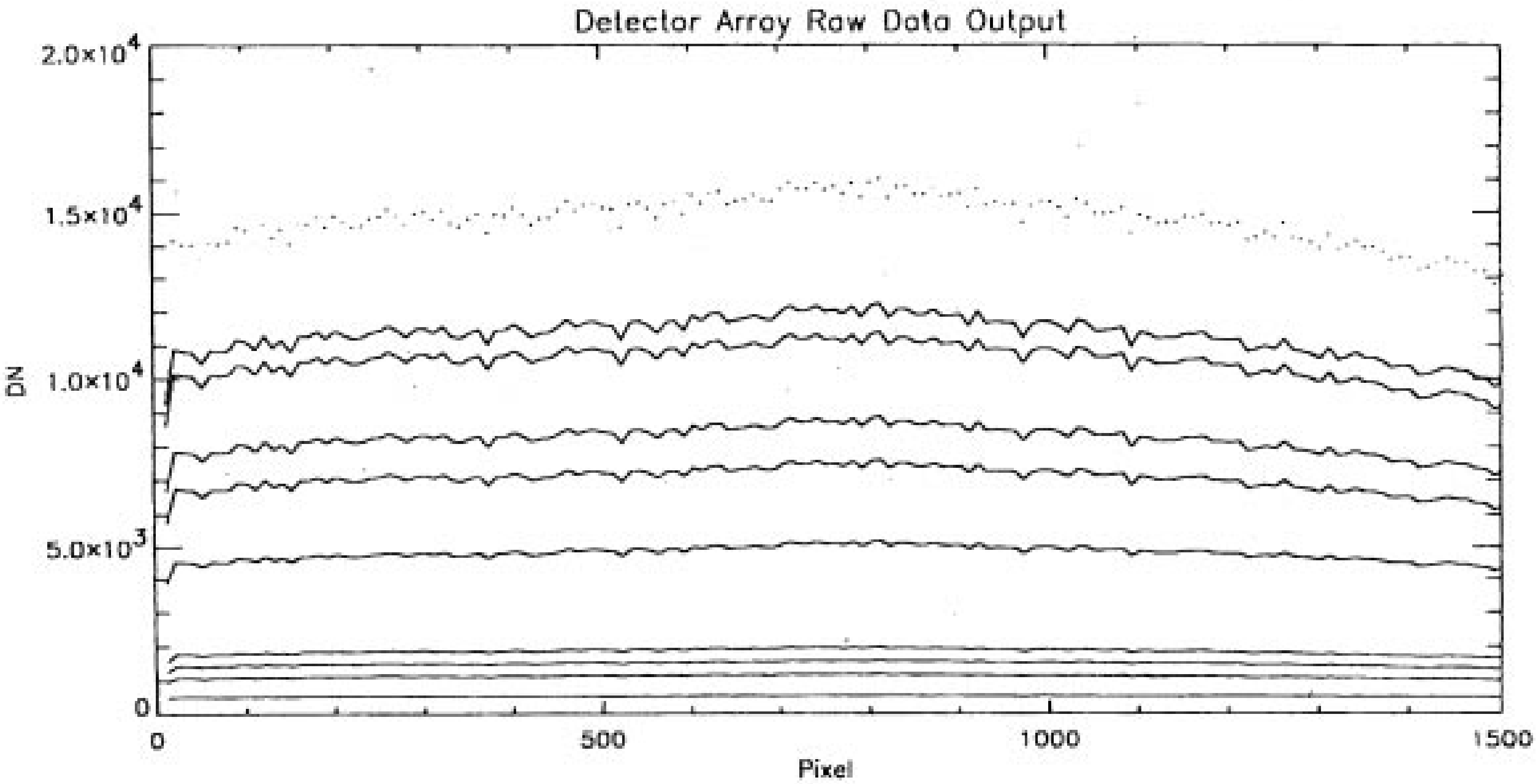
  - R is the relative pixel spectral response; DN is the camera output digital number; G_0, G_1, and G_2 are the pixel response coefficients; DN_o is the DN offset, unique for each line of data, as determined by an average over the first eight "overclock" pixel elements.

RADIOMETRIC CALIBRATION: CAMERA OUTPUT DN

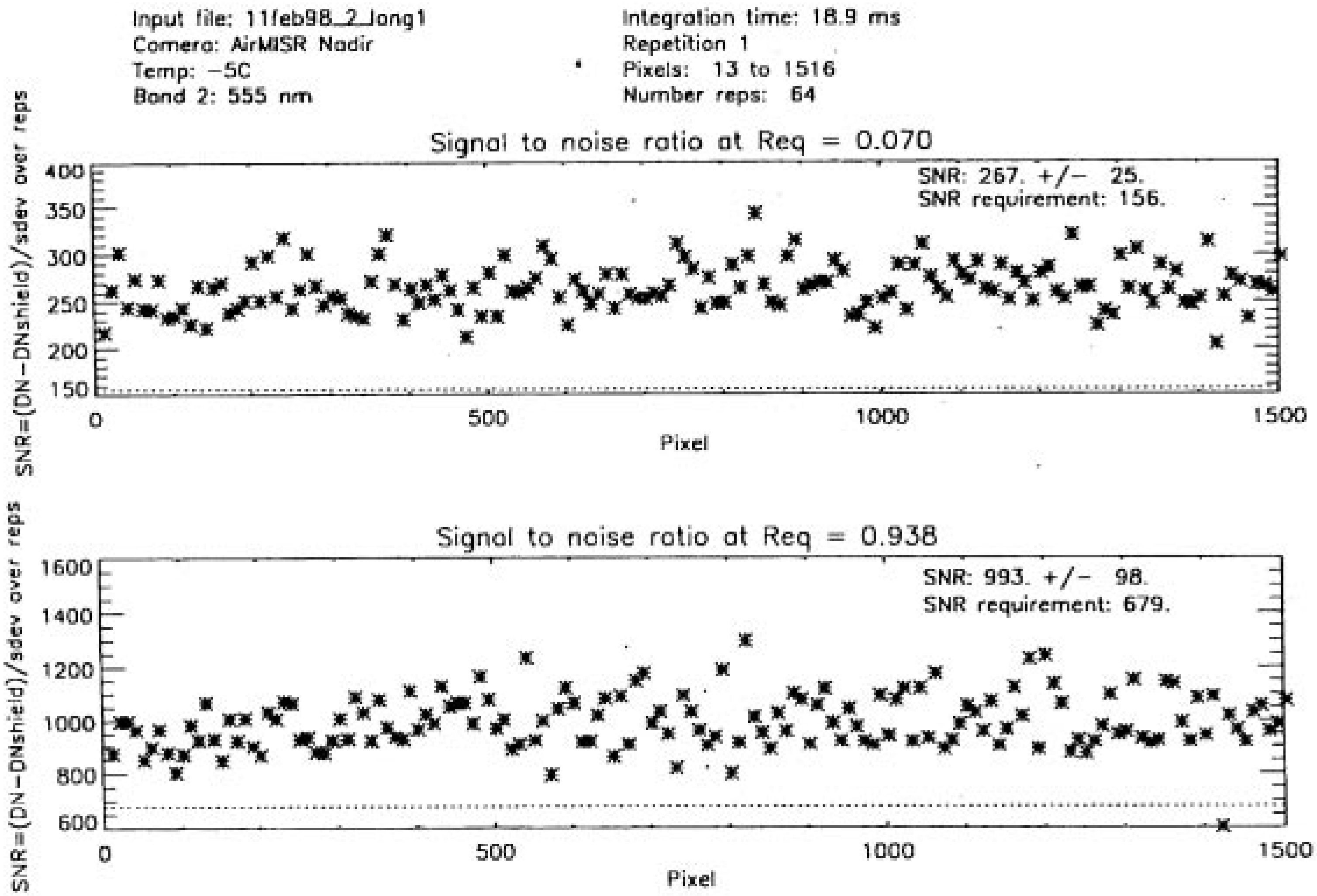
Input file: 12feb98_4_long1
Camera: AirMISR Nadir
FP temp: -5C
Band 4: 865 nm
Integration time: 21.8 ms
Pixels: 13 to 1516
Calibration Repetition 1

Repetition number: Averaged over all reps
For highest light level:
- mean: 14759. +/- 739. DN
- min: 68.26 % of maximum DN
- scatter over reps: 15. +/- 1. DN

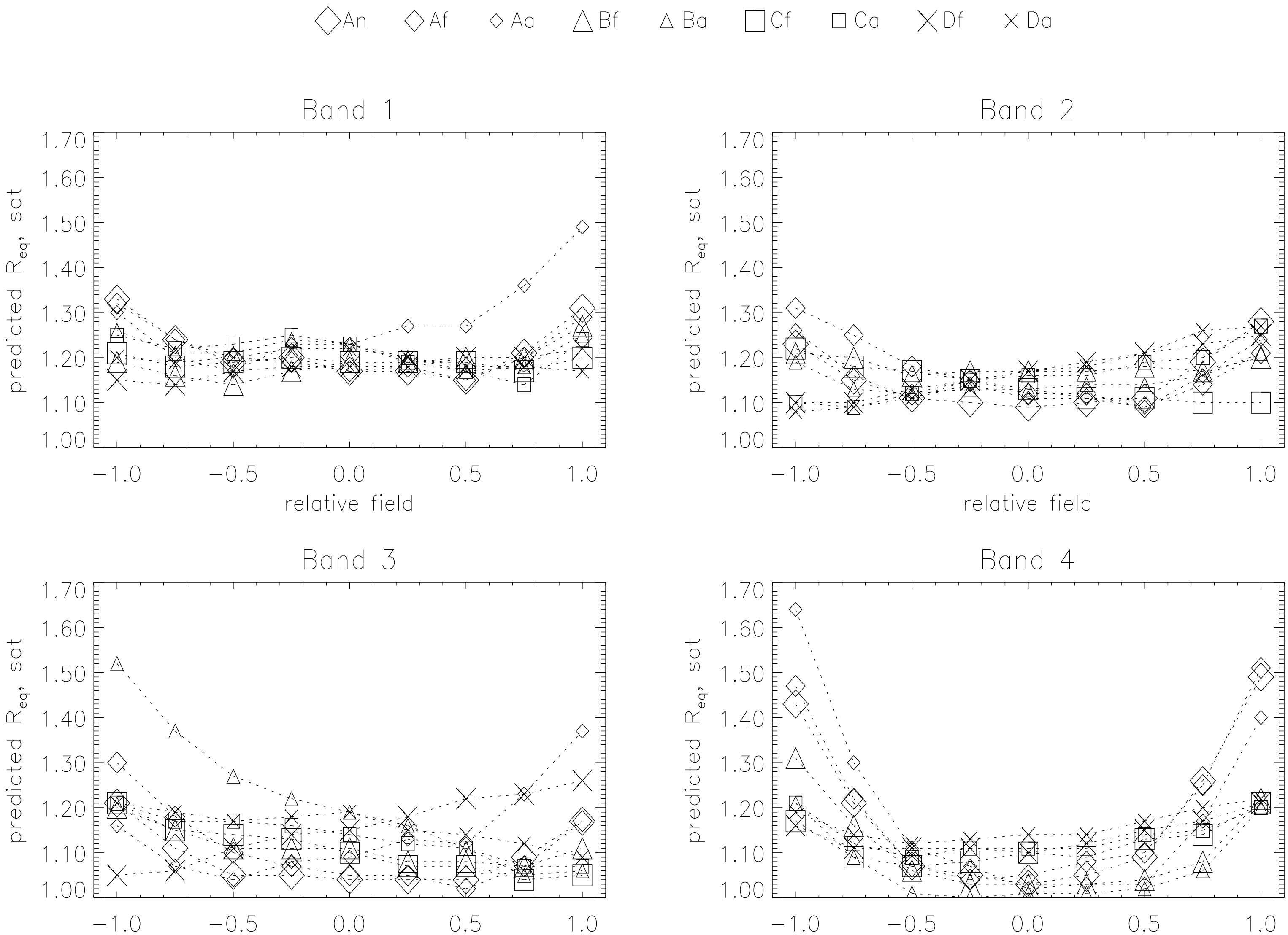
Average DN: 528 1121 1486 1864 4788 7031 8196 10521 11293 14759



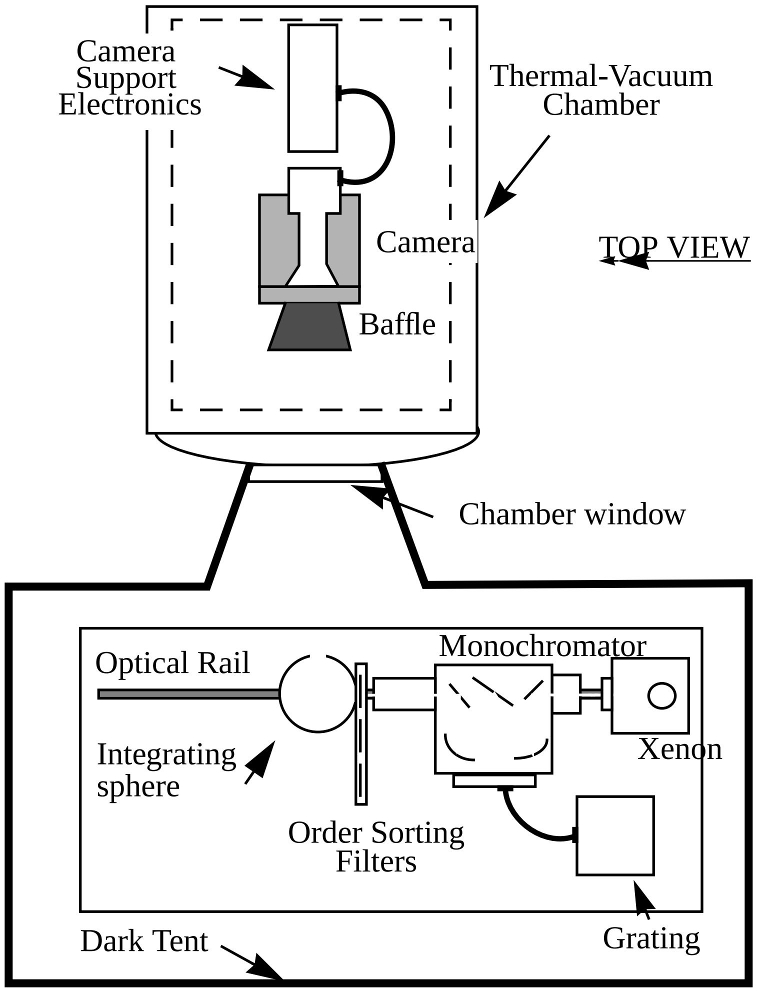
MEASURED CAMERA SNR



MEASURED CAMERA SATURATION LEVELS



SPECTRAL CALIBRATION



COMPOSITE RESPONSE PROFILE:

- **Measured data 400 to 900 nm**
- **In-band at 2.6 nm resolution, 0.5 nm sampling, 7 field position**
- **Out-band at 19.5 nm resolution, 5 nm sampling, 3 field positions**
- **Spectral model insludes focal-plane measurements to 1100 nm, and Code V lens model 365 to 400 nm.**

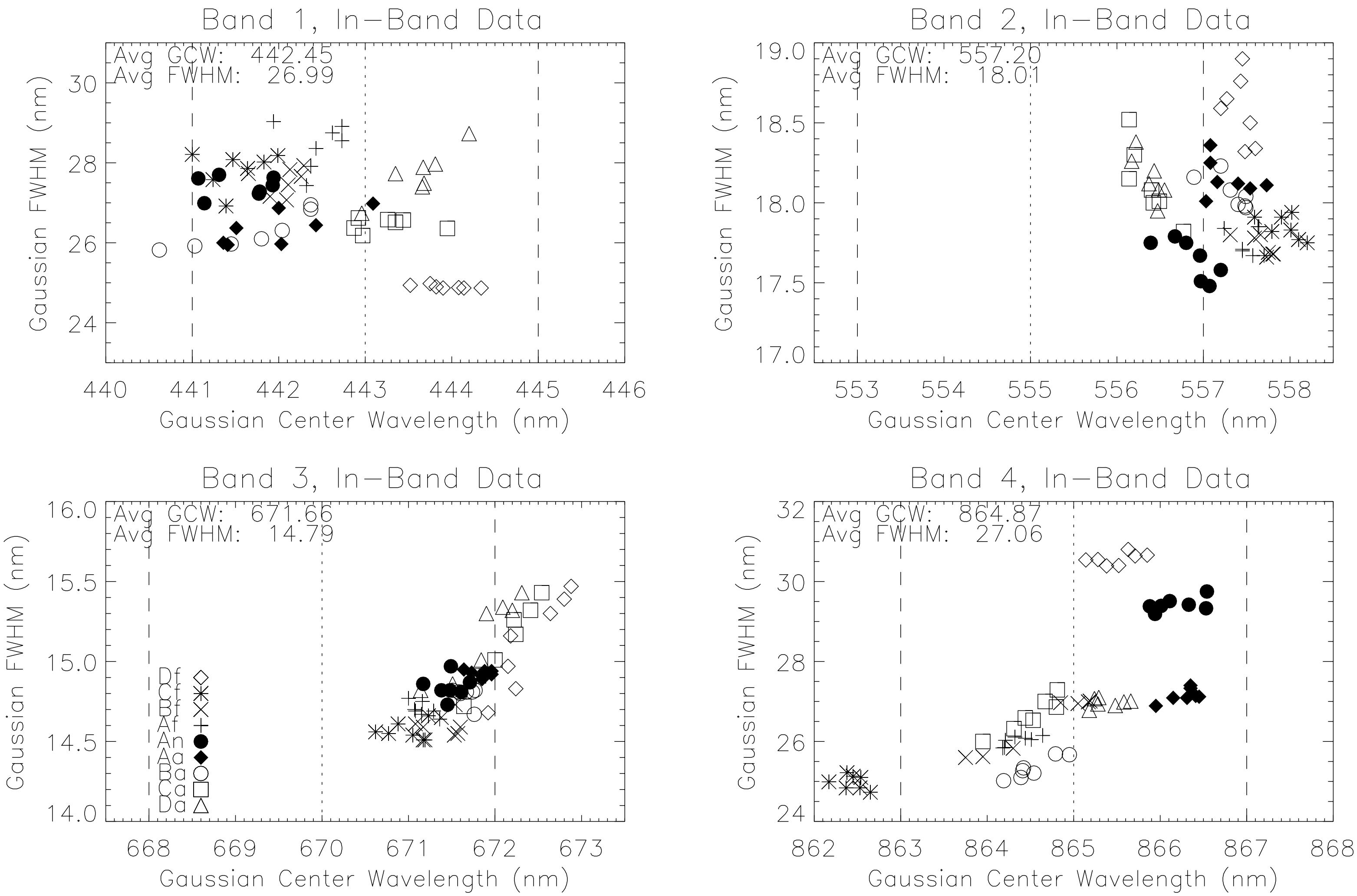
IMPROVED TESTING:

- **Obtained by use of an integrating sphere at monochromator exit slit. Spectral uniformity of illumination improved reduced from several nm to several tenths of nm.**

SPECTRAL RESPONSE FUNCTION DETERMINATION

- **Separate in- and out-band measurements allowed us to cover 10^{-4} sensitivity range**
- **In-band spectral response measurements:**
  - 400 to 900 nm wavelength range
  - 2.6 nm spectral resolution
  - 0.5 nm sampling
- **Out-band spectral response measurements:**
  - 400 to 900 nm wavelength range
  - 19.6 nm spectral resolution
  - 10 nm sampling
- **Radiometric model utliized to extend response region from 365 nm to 1100 nm.**
  - lens model using CODE V at 5 field positions.
  - focal plane measurements of quantum efficiency (350-1100 nm)
  - analog-to-digital gain using camera response to varying integration time (while viewing the integrating sphere)
- **Both measured and band-averaged spectral response measurements published within the ARP**

MEASURED SPECTRAL PARAMETERS



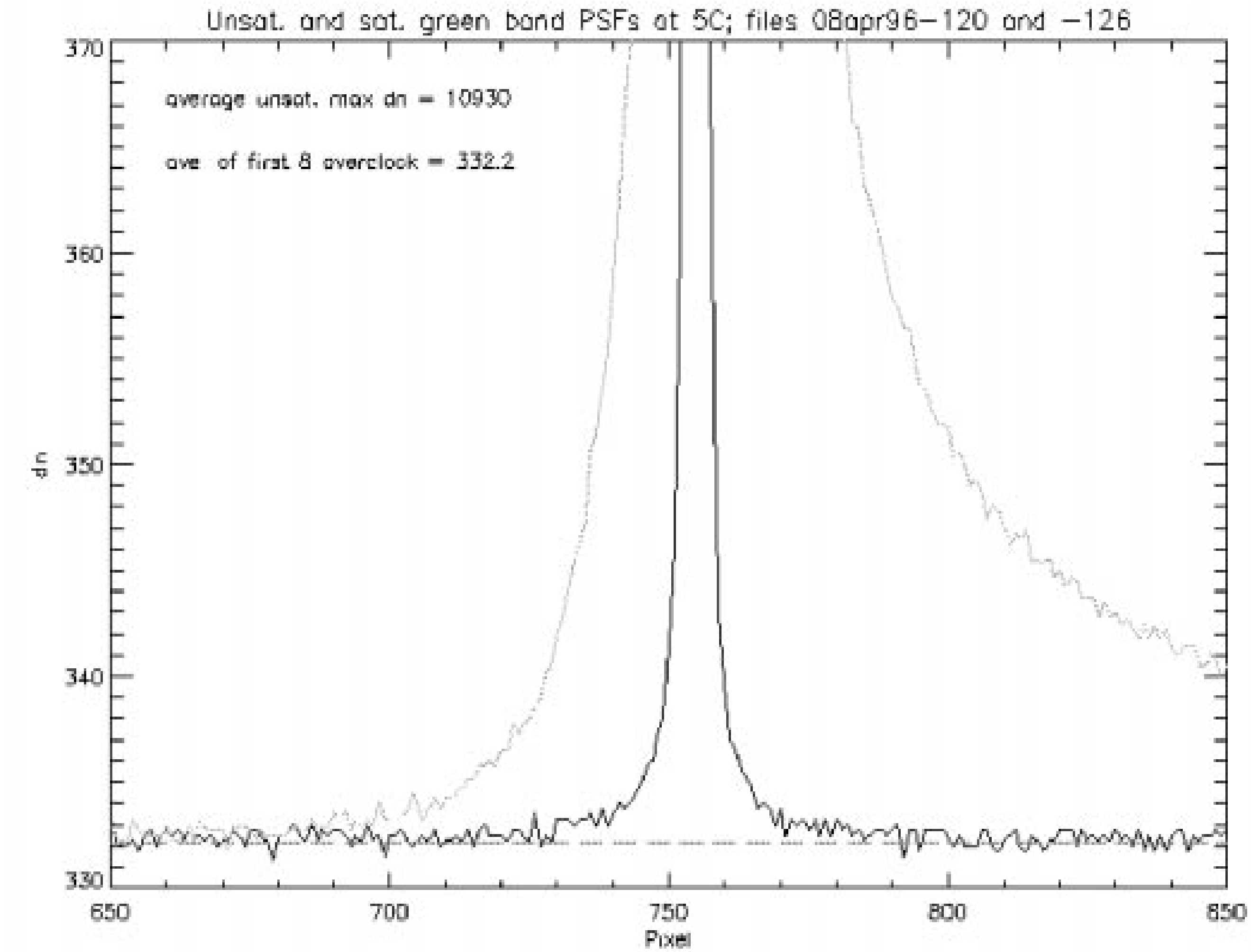
SUMMARY

- MISR testing of 10 cameras (9 flight and 1 spare) has been successfully completed after 1 year development and 1 year testing and analysis
- **6 weeks per camera required to provide OCC (EFL, distortion, PSF), RCC (radiometric, spectral calibration, polarization verification), hot and cold margin, dynamics, and magnetics testing.**
- **Several verification failures appear to have little impact on the mission**
  - swath overlap meets requirements, though camera boresight failures noted
  - response uniformity meets requirement for all but a handful of pixels. Only 8 pixel zones (4 pixel block) out of 13,536 have a local uniformity exceeding 10%
- **Several verification failures result from unprecendented camera specifications, driven by 3 % radiometric requirement. Successful test program allows mission objectives to be met, following ground processing**
  - out-of-band errors can be reduced from 4% to 0.5% when needed. No correction necessary for Band 1, or bright targets
  - PSF deconvolution requires minimal processing: 1D, 51 pixels PSF, 20 iterations (no FFT required)
- **Saturation appears to affect many pixels within the line array.**
  - Saturation unlikely on orbit. Data Quality Indicators will identify affected pixels.

EM CAMERAS INVALUABLE FOR DIAGNOSING / FIXING PROBLEMS

Problem	Cause	Solution	Status
White light leaks in filter	Bondlines between bands	Masks added to filter	Fixed
Interference fringes in flat-field data	Fabry-Perot interference between CCD and filter	Increase spacing between filter and CCD	Fixed
Spurious signal in CCD	Illumination of silicon around CCD bond pads	Addition of light shield to focal plane package	Fixed
Insufficient out-of-band rejection	Spattering in filter coatings	Higher quality flight filter Spatter side down	Improved flight performance
Low-level "halo" around point-source image	Reflection between CCD and filter	See above. Correction in data processing if needed	Improved flight performance
Excess power needed to cool CCD to -10°C	Thermal leaks	Focal plane temperature changed to -5°C	Fixed
Complex assembly procedure to achieve repeatable focus	Lens to camera head interface flanges	Interface redesigned and simplified	New design breadboarded
Low-level inter-band electrical crosstalk (0.07%)	Suspected inadequate grounding	Additional grounding or correction in data processing	Options being investigated

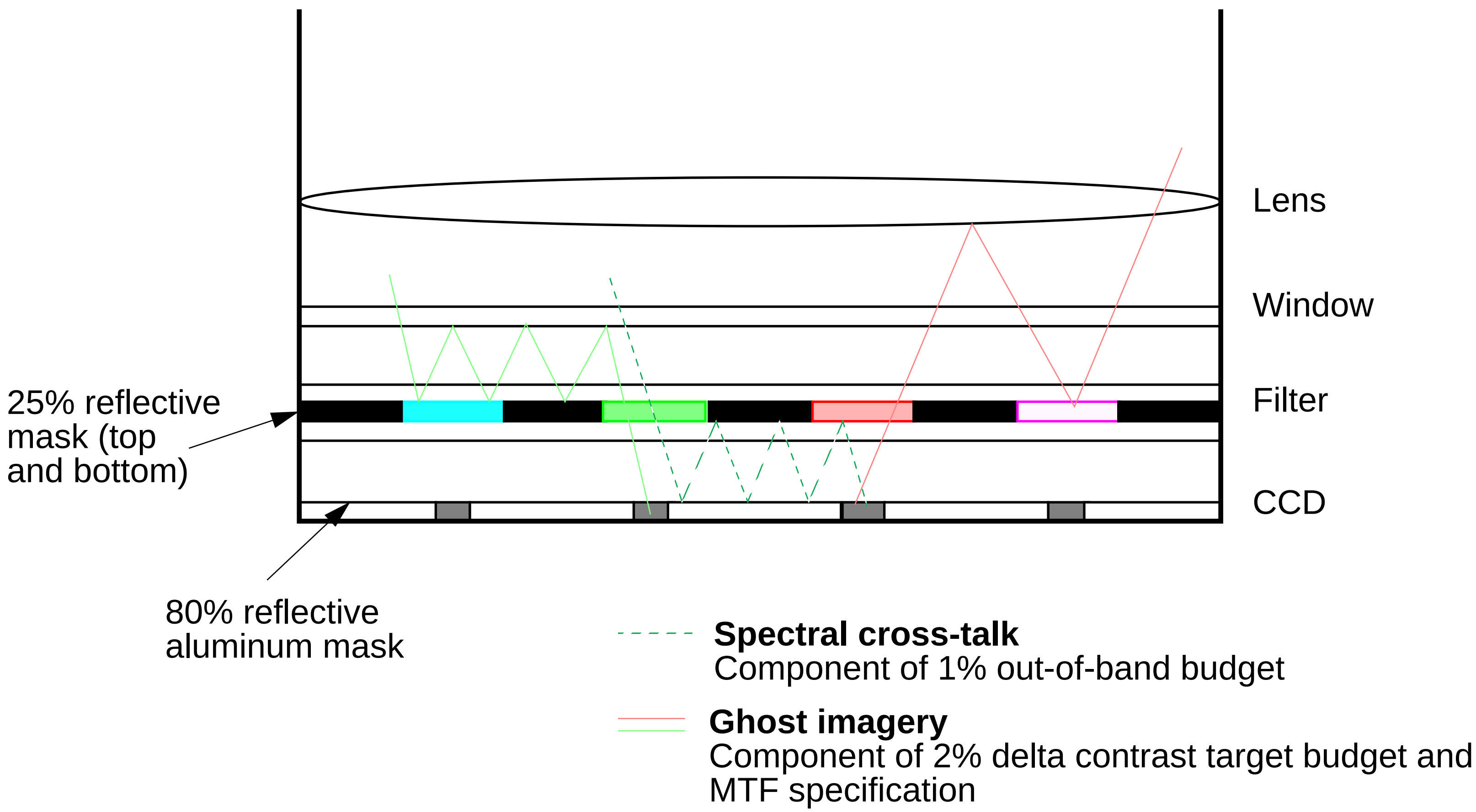
SATURATION BLOOMING



FOCAL PLANE SCATTERING

- **Filter scatter sites and CCD/ filter reflections determined to be cause of finite width PSF and out-of-band performance, see:**
  - Korechoff, R.P, D.J. Diner, D.J. Preston, C.J. Bruegge (1995). In Advanced and Next-Generation Satellites. Spectroradiometer focal-plane design considerations: lessons learned from MISR camera testing. EUROPTO/ SPIE Vol. 2538, pp. 104-116, 25-28 September.

FOCAL PLANE SCATTERING



MULTIPLE IN-FLIGHT CALIBRATION METHODOLOGIES

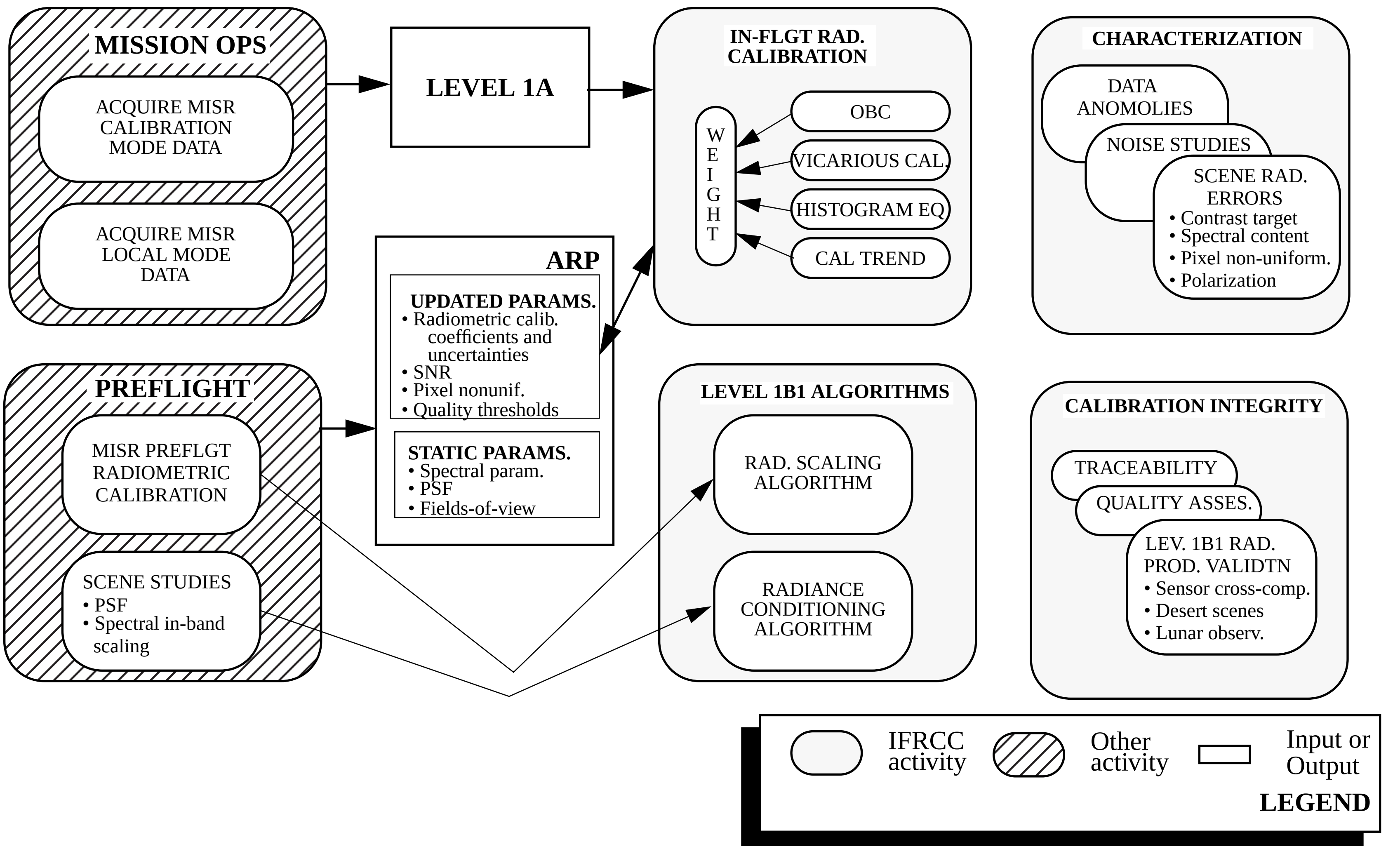
- **MISR will make use of four calibration methodologies, in order to assess calibration uncertainty and reduce systematic errors.**
  - On-Board Calibrator (OBC) hardware are used to establishes an absolute and relative calibration for each pixel. The OBC consists of solar-reflecting diffuse panels (Spectralon), detector standards, and a goniometer to verify there is no degradation in the reflectance shape. Data are acquired monthly.
  - Vicarious calibration (VC) can be one of three types:

    1) High-altitude sensor (e.g. AirMISR) VC

    2) Surface-radiance VC

    3) Surface reflectance VC
  - Histogram equalization statistics are used to provide a relative-calibration of the pixels within an array.
  - Trend analysis are used to fold other calibration data into the coefficient algorithm (e.g. preflight). Retrospective data are weighted less with time.
- **A weighting algorithm will combine the multiple data in order to achieve the most accurate sensor calibration.**

IFRCC PROGRAM ELEMENTS



ARP STRUCTURES

File name	Description
Preflight Characterization Data	• preflight instrument characterization parameters • unlikely to be modified once delivered • measured pixel spectral response functions (7x36), standardized spectral response functions (1 per band), instantaneous fields-of-view
Preflight Calibration Data	• input to DAAC processes • unlikely to be modified once delivered • spectral descriptors relevant to Level 1B1 and Level 2 standard products • band weighted solar irradiances
In-flight Calibration Data	• parameters updated monthly on-orbit • at-launch values are initialized by the preflight calibration data • radiometric calibration coefficients, calibration uncertainties, signal-to-noise ratios, and Detector Data Quality Indicators.
Configuration Parameters	• threshold parameters and process control limits used by DAAC processes

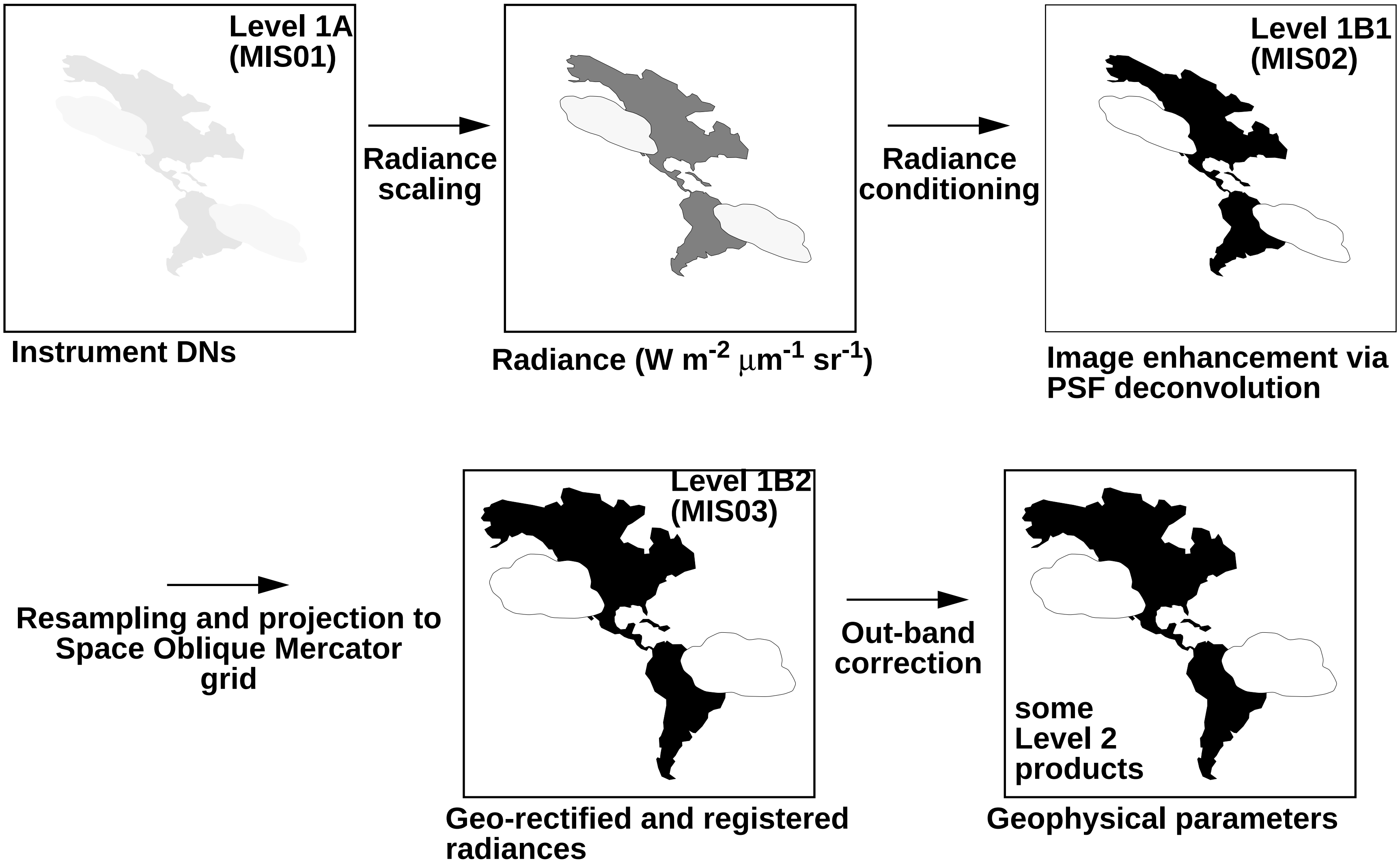
ARPGEN PROCESSING CODE

- **Data conditioning**
  - Resamples photodiode data to CCD data time acquisition
  - Removes corrupt data
- **Regression**
  - Regresses CCD DN data against photodiode measured incident radiances
  - Quadratic fit produces G_0, G_1, and G_2 coefficients for every pixel
  - Data weighted inversely by the DN variances (noisy data weighted less)
  - Process repeated using 3 independent on-board standards (HQE, PIN nadir, PIN at closest view angle to camera being calibrated)
- **Coefficient trending**
  - Uses historical coefficients and present coefficient
  - Performs a quadratic fit to the data
  - Reported coefficient comes from fit. This smooths gain coefficients, in case of noise in the retrieval
- **Coefficient weighting**
  - Final coefficients come from a weighted average of the multiple determinations (vicarious and 3 detector standards)
  - Weighting is inversely proportional to the methodology uncertainty

ARPGEN PROCESSING (CONT.)

- **Performance summary**
  - SNR computed from residuals of CCD DN against photodiode radiances
  - sliding window does local fit of the data, to determine local variances
  - SNR used to update radiometric uncertainty tables
  - CCD element response uniformity updated as part of detector data quality metric

RADIOMETRIC SCALING AND CONDITIONING



LEVEL 1B1 RADIOMETRIC PRODUCT

Parameter name	Units	Horizontal Sampling (Coverage)	Comments
Radiance	$W\ m^{-2}\ \mu m^{-1}\ sr^{-1}$	250 m nadir, 275 m off-nadir, or averages per the camera configuration (Global)	• Radiometrically-scaled data • No geometric resampling • 9 cameras, 4 bands • Uncertainty reported in Ancillary Radiometric Product
Data Qual. Indicator	None	Same as above	• 0 (within spec.); 1 (reduced accuracy), 2 (unusable for science); 3(unusable)

RADIANCE SCALING

- Radiometric calibration coefficients are used to retrieve a band-averaged spectral radiance. Total-band response is included.

RADIANCE CONDITIONING

- PSF deconvolution to sharpen the image, compensating for focal-plane scattering;
- A standardized spectral response function is assumed.

DATA QUALITY INDICATORS (DQI)

- **Data Quality Indicators (DQI) are assigned to each Level 1B pixel. These are assigned the values:**

DQI value	significance	Error component radiance uncertainty contribution	Level 1B2 resample weighting
0	within specification	None	full
1	reduced accuracy	1-3%	half
2	unusable for science	3-50%	none
3	unusable	>50%	none

- **Saturation blooming (Note: in average mode pixel is sat. if sat. in red band)**
  - DQI=0 if no. saturated pixels (nsat)=0
  - else DQI=1 if specific pixel under test has < 0.5% radiometric error
  - else DQI=1 if specific pixel under test has < 3.0% radiometric error; else DQI =2
- **Video offset uncertainty**
  - DQI=0 if line average DN less than threshold (~12,000 DN)
  - else DQI=1 if specific pixel under test has < 0.5% radiometric error
  - else DQI=1 if specific pixel under test has < 0.5% radiometric error; else DQI=2

DATA QUALITY INDICATORS (DQI), CONT.

- **Detector anomaly**
  - Values can be predetermined and stored in ARP
  - SNR used as DQI criteria

SNR	DDQI value
>100	0, else
>90	1, else
> 10	2, else
	3

  - Detector response uniformity used as DQI criteria

Uniformity, 4x4 average mode	DDQI value
<10%	0, else
<15%	1, else
<50%	2, else
	3

Uniformity, 2x2 average mode	DDQI value
<10%	0, else
<15%	1, else
<50%	2, else
	3