National Institute of Standards and Technology
U.S. Department of Commerce

UV to SWIR Reflectance Capabilities in the NIST Sensor Science Division

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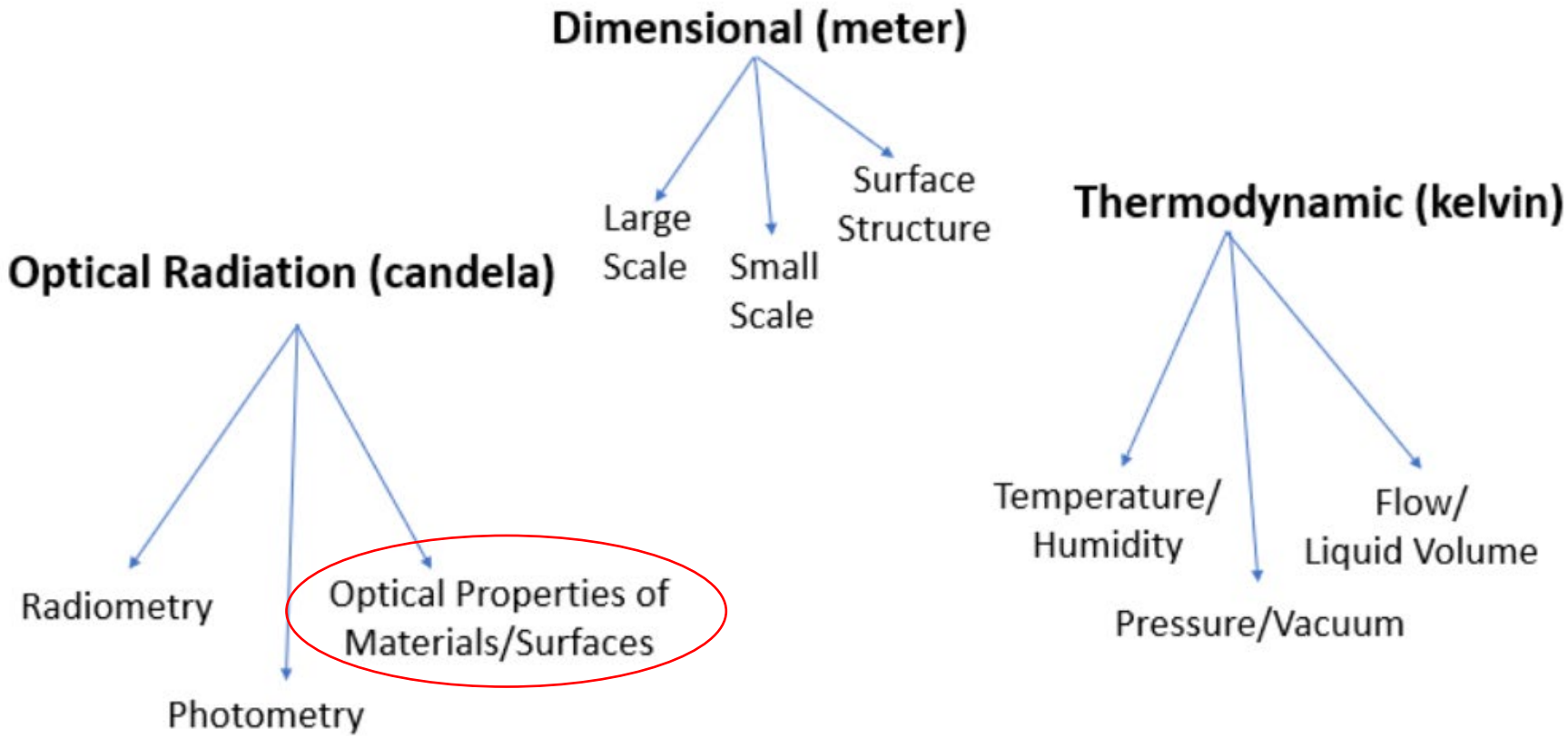
Sensor Science Division

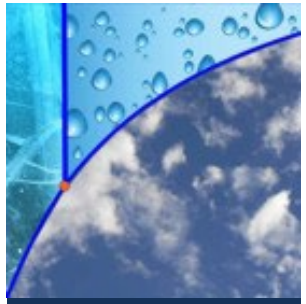
The SSD is responsible for the realization and dissemination of 3 of the 7 base units of the International System of Units (SI): the meter, the kelvin, and the candela.



- Active in over 25 Standards Development Organizations
- SSD work underpins major documentary standards
- International equivalence through key comparisons

- 4,000 artifacts calibrated per year
- Roughly half of all NIST calibrations performed by SSD
- $2.2M in metrology-related services in 2020

Groups

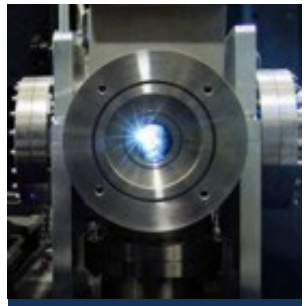


Thermo-dynamic Metrology Group

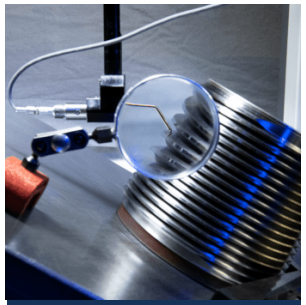
Fluid Metrology Group

Optical Radiation Group

Remote Sensing Group



Ultraviolet Radiation Group



Dimensional Metrology Group

Surface and Interface Metrology Group

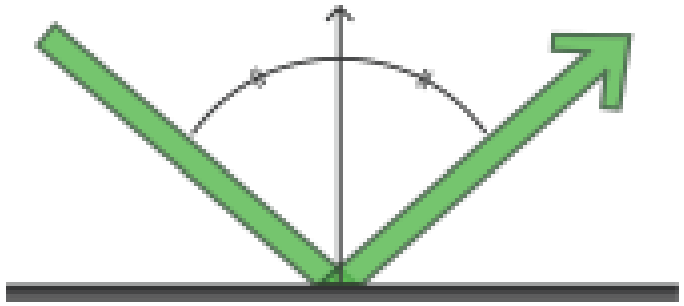
IR Reflectance
1000 nm – 20 micrometers

UV Reflectance
< 250 nm

UV-SWIR Reflectance
250 nm – 2400 nm

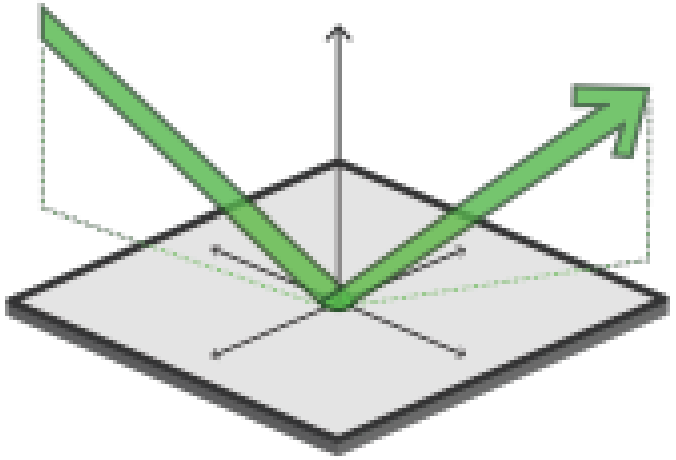
Reflectance Geometries

Specular



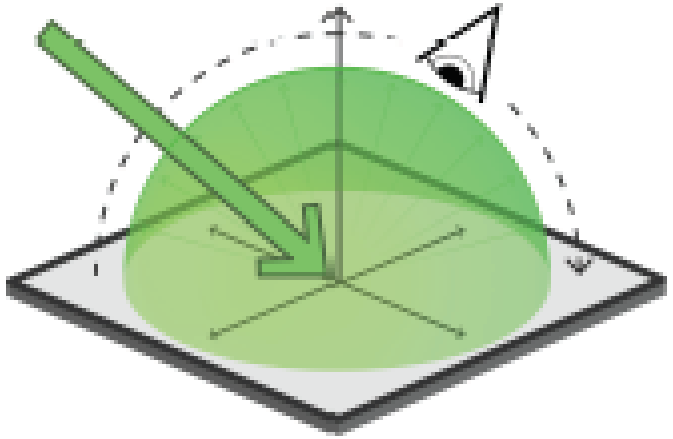
Mirrors, glossy samples

Bidirectional



Diffuse standards, ceramics, opal

Directional-hemispherical



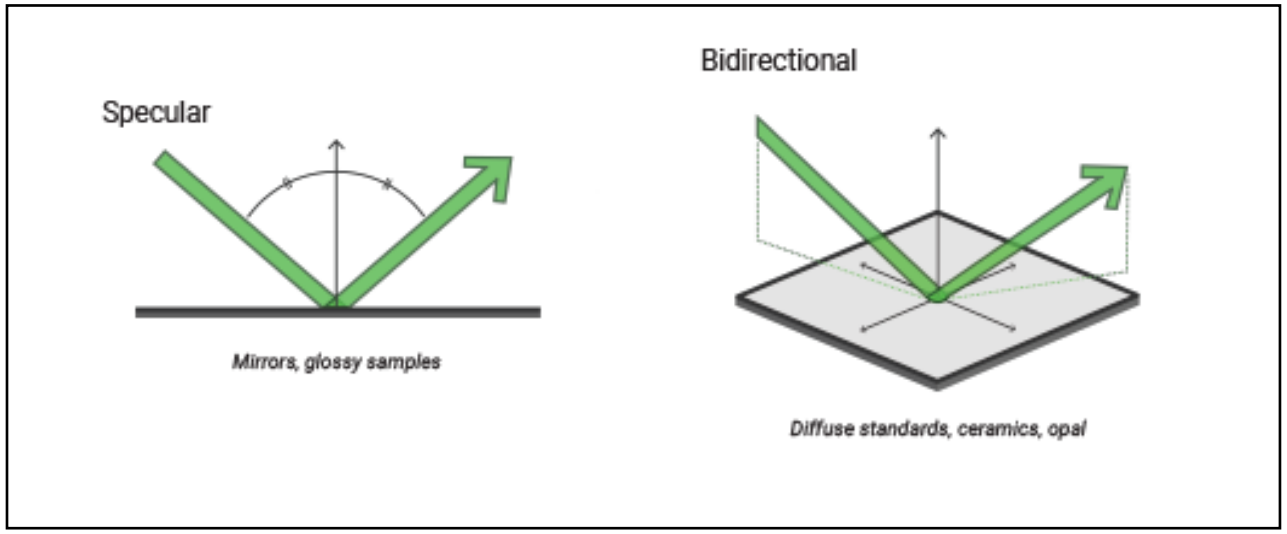
Diffuse standards, ceramics, opal

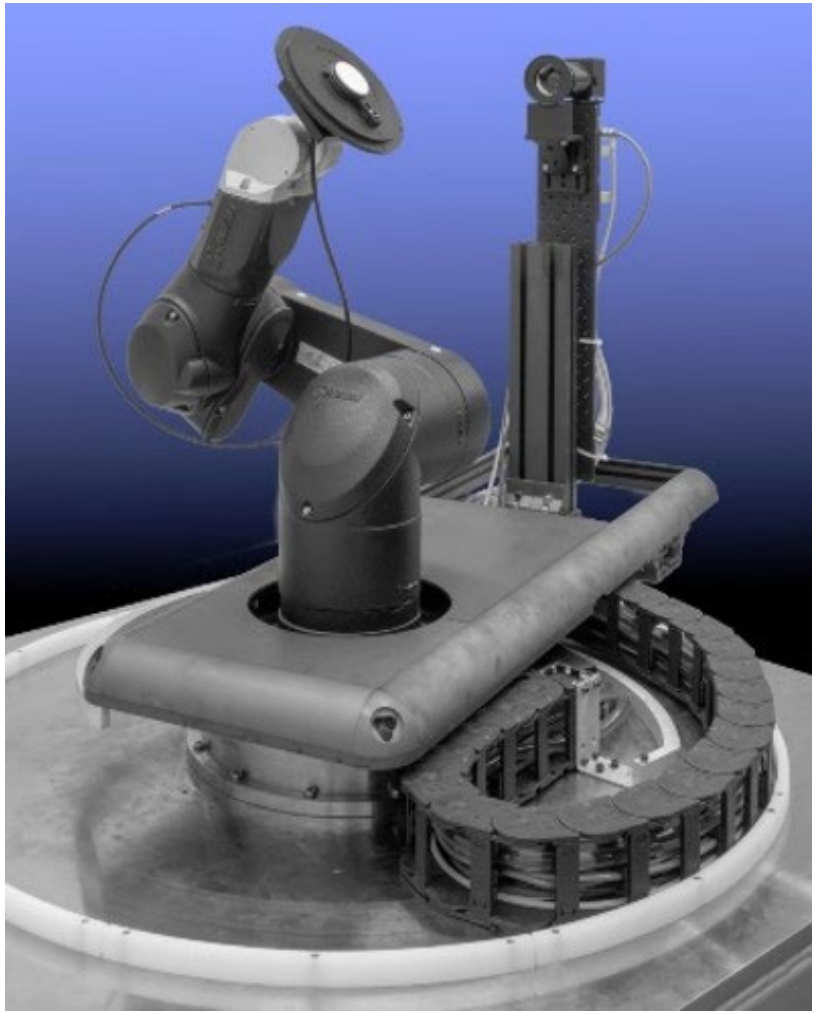
Reflectance Instruments

- ROSI: Robotic Optical Scattering Instrument
- ROSI Sphere: Directional-hemispherical Reflectance Calibrations
- Transfer Instrument: PerkinElmer Lambda 1050 Spectrophotometer
- Reference Surface Colorimeter
- GOSI: Laser-based Bidirectional Reflectance Measurements and Modeling

ROSI – Robotic Optical Scattering Instrument

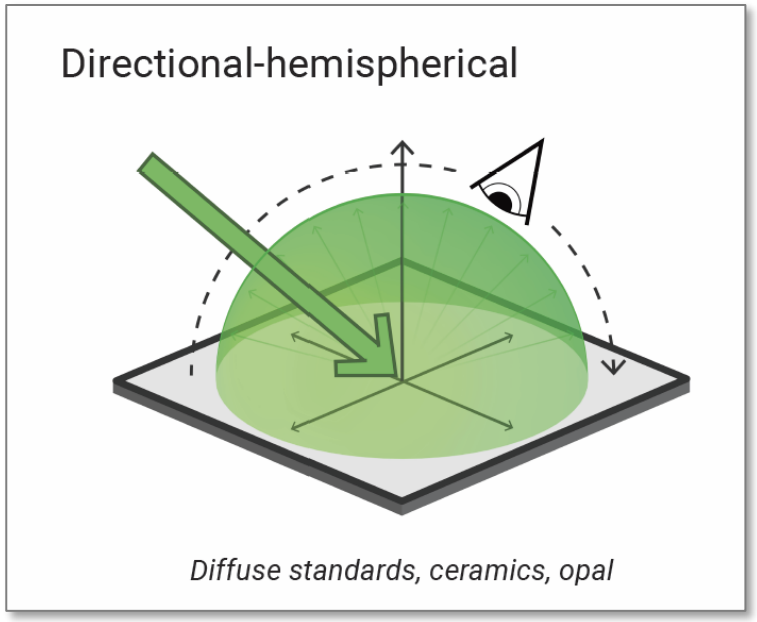
- National Reference Instrument for directional reflectance
  - Specular reflectance (mirrors)
  - Diffuse bidirectional (incidence and view angle specified), BRDF
- Calibrates reflectance standards for industry, military and other National Labs
- 250 nm – 2400 nm tunable operation
- Large samples, out-of-plane, low reflectance capabilities
  - Large reference reflector panels for remote sensing
  - Gonioapparent materials
  - Low reflectance pyroelectric detector coatings, telescope coatings

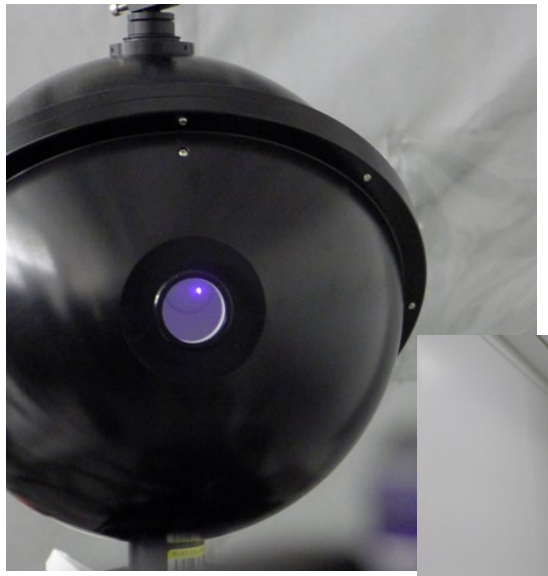


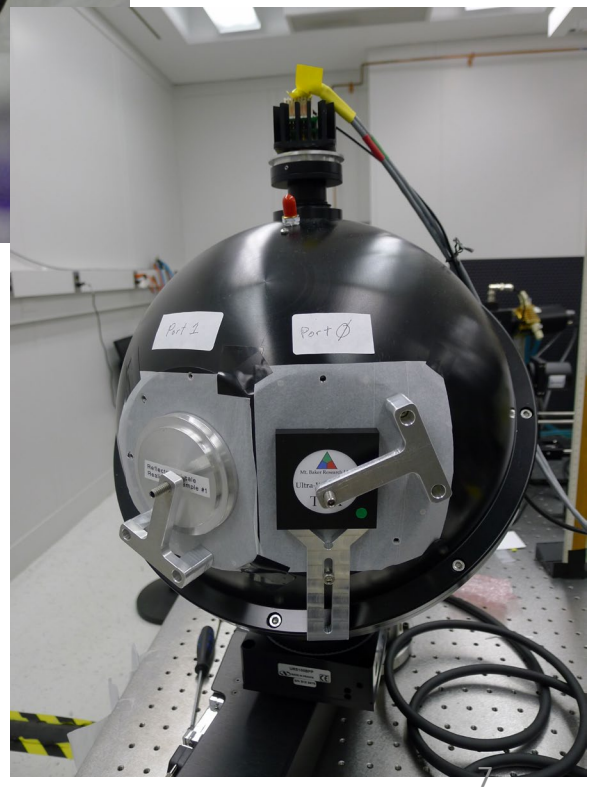


ROSI Sphere – Directional-hemispherical Reflectance

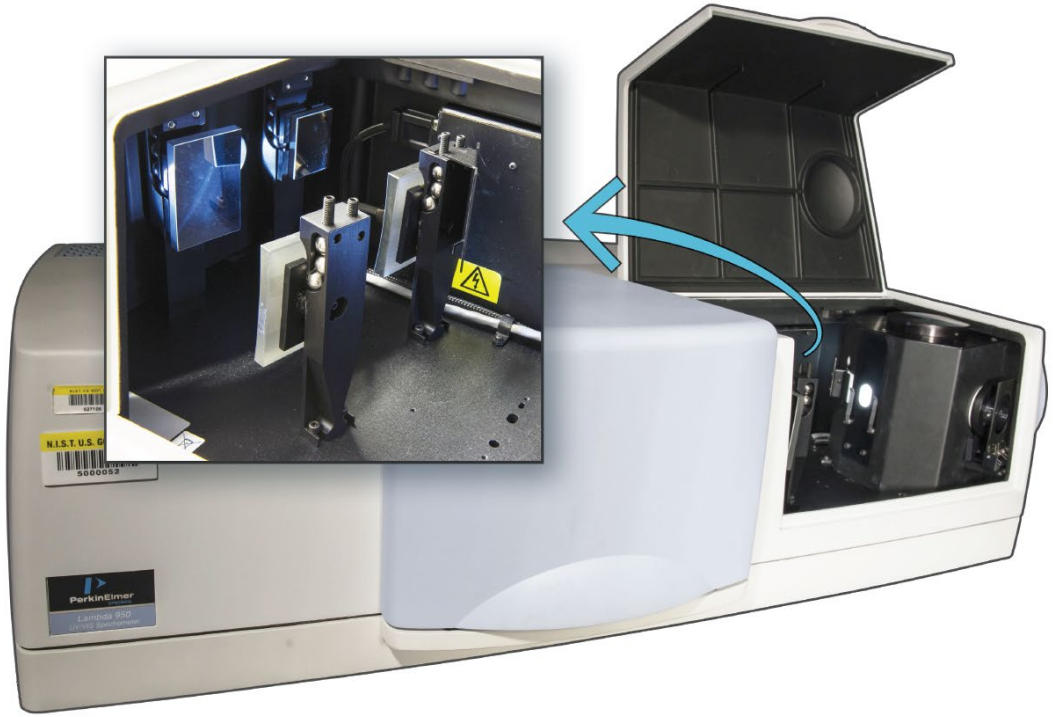
- National reference instrument for directional-hemispherical reflectance
  - Collects reflected flux over the entire hemisphere
  - Specular included geometry
- Calibrates reflectance standards for industry, military and other national labs
- 250 nm to 2400 nm tunable operation



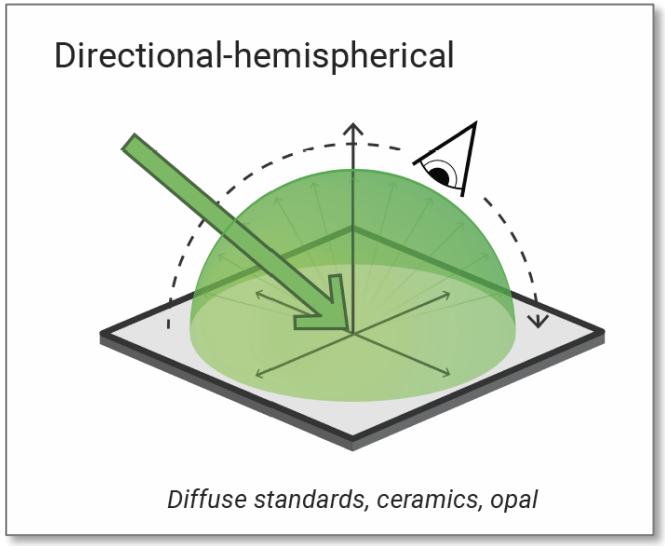




Transfer Spectrophotometer – Lambda 1050

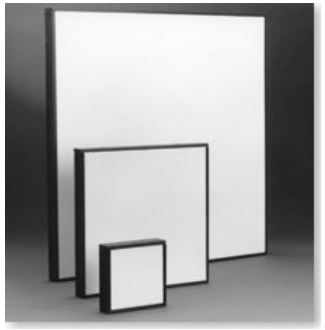


- Commercial instrument
- Measurements based on scales from reference instruments
- Transmittance, directional-hemispherical reflectance
- 175 nm – 2500 nm tunable operation



Reflectance Calibrations Impact

- Maintain national scale for diffuse and specular reflectance
- NIST personnel participate in standards development
- Reflectance scale for industry, military and other National Labs
- Regular calibrations for NASA provide scale for remote sensing satellite calibration and validation
- Color measurement, optical instruments and aerospace industries rely on NIST reflectance calibrations



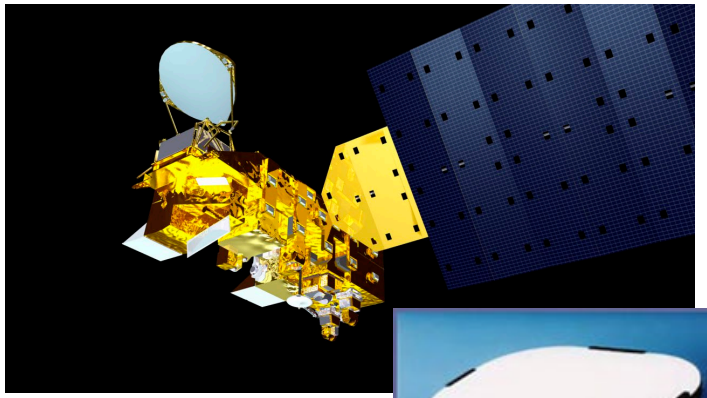
Diffuse reflectance standards

Designation: E2387 – 05 (Reapproved 2011)

Standard Practice for
Goniometric Optical Scatter Measurements[1]

Designation: E259 – 06 (Reapproved 2015)

Standard Practice for
Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries[1]

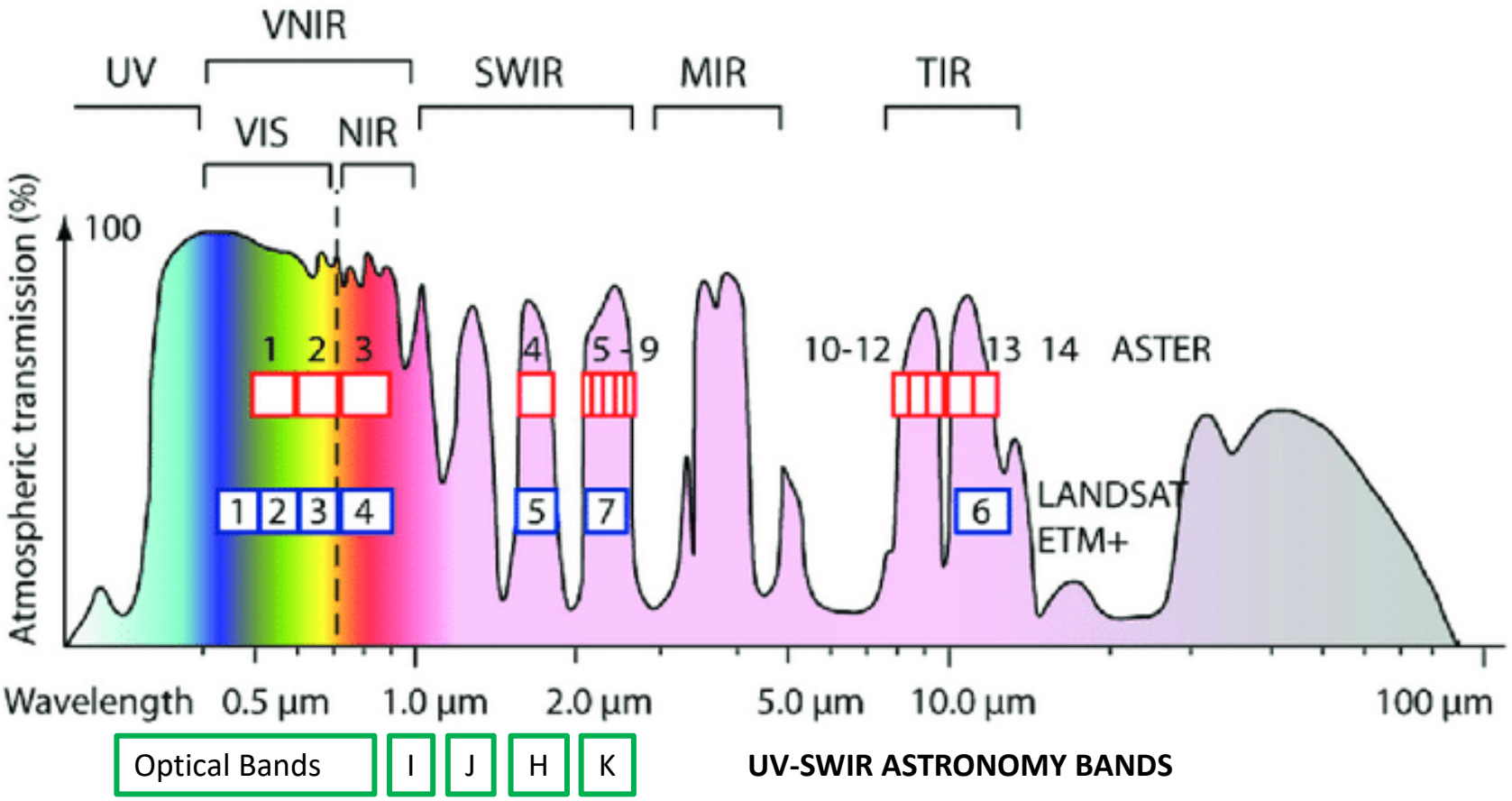


Artist's rendering of NASA's Aqua Satellite

Solar Diffuser, MODIS on Aqua

Considerations for Brightness Mitigation

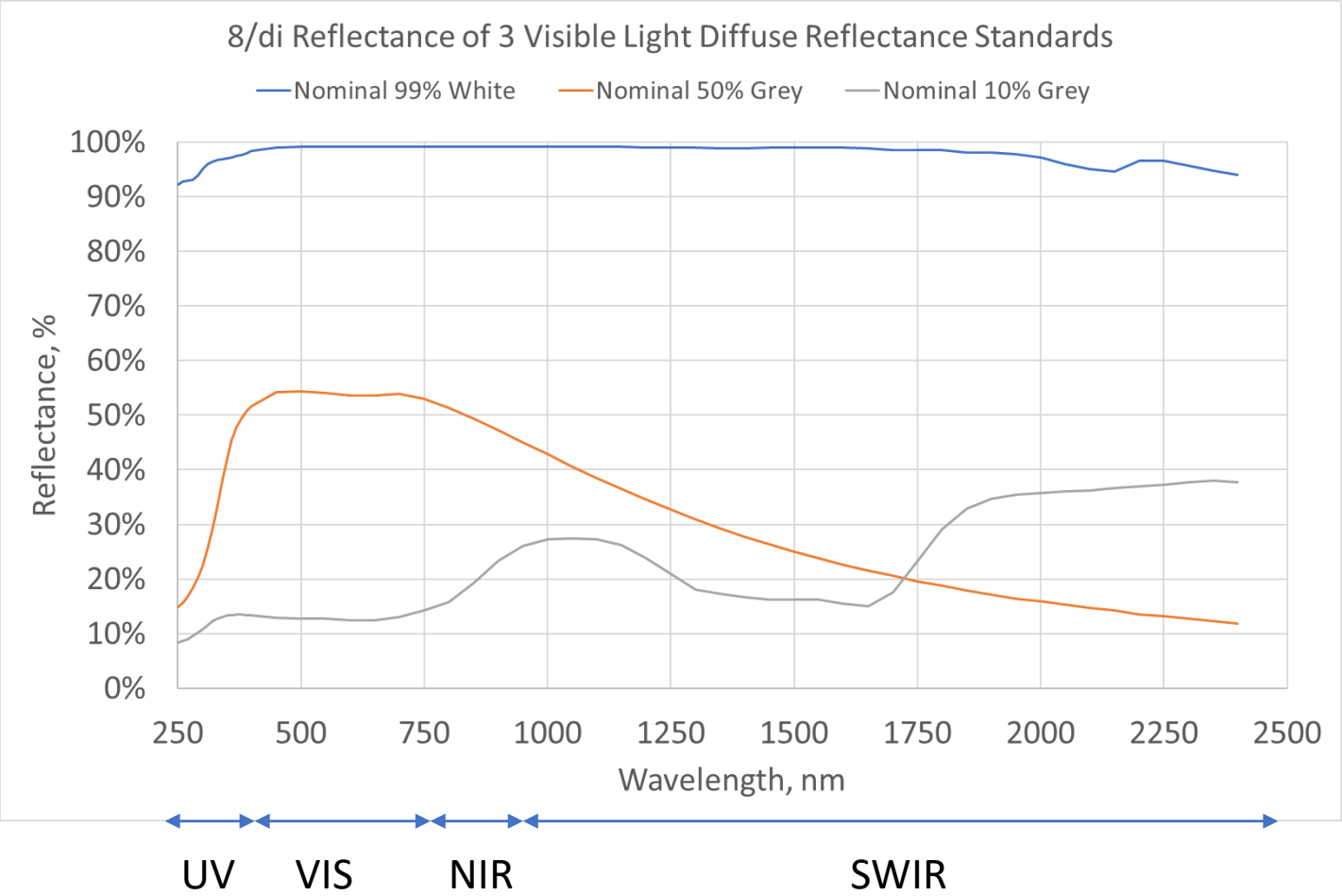
Observation Windows for Terrestrial Imaging



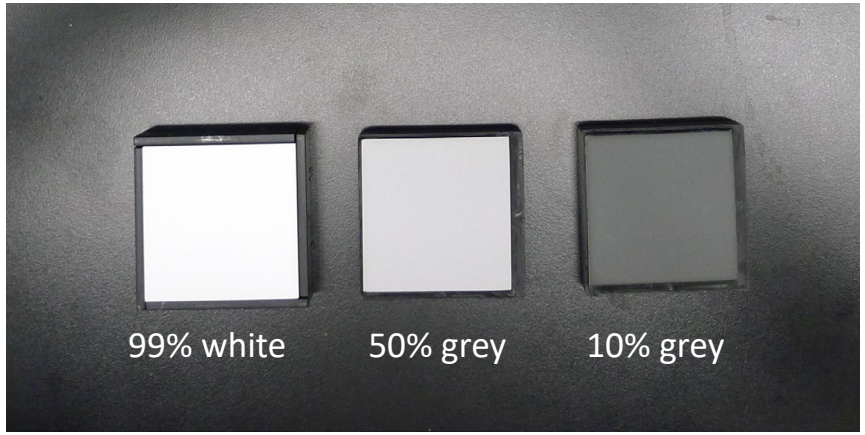
- Terrestrial telescopes operate at optical bands and beyond, into SWIR and IR
- NIST SSD provides reflectance calibrations
  - UV-SWIR 0.25 µm to 2.4 µm using ROSI
  - 1 µm to 20 µm in Remote Sensing Group

Kaab et al., Glacier Mapping and Monitoring Using Multispectral Data, DOI 10.5167/uzh-102068

UV to SWIR Reflectance of VIS Standards



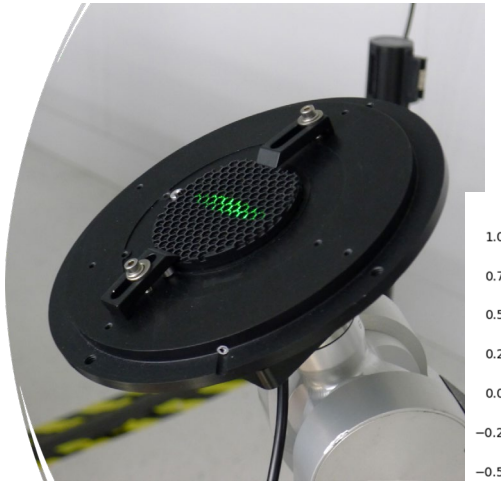
Visual Appearance



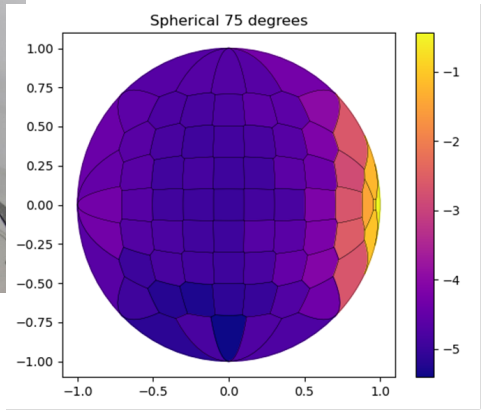
- Commercial standards designed for use in VIS (≅ 400 nm – 800 nm)
- Match nominal value only in VIS region
- Some cases, samples are brighter in SWIR than in VIS

Important to measure reflectance of potential dark components and coatings across the UV-SWIR range and possibly beyond

Examples of Low-R Measurements



$R = 4\% \; to \; 10\%$



3D-Printed Material for UV-C application

Black Coatings for Pyroelectric Detectors

$R = 1.2\% \; to \; 2.7\%$

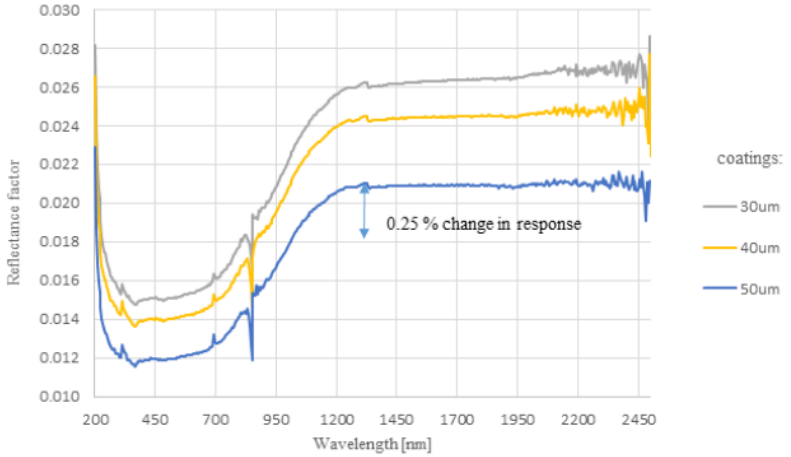
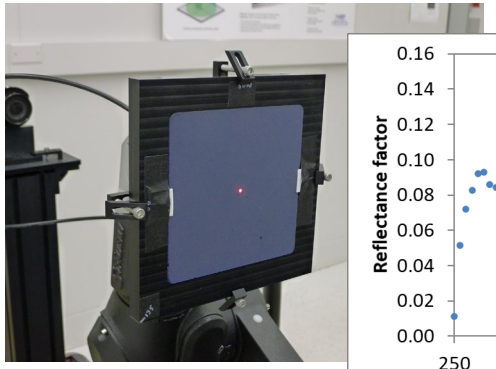
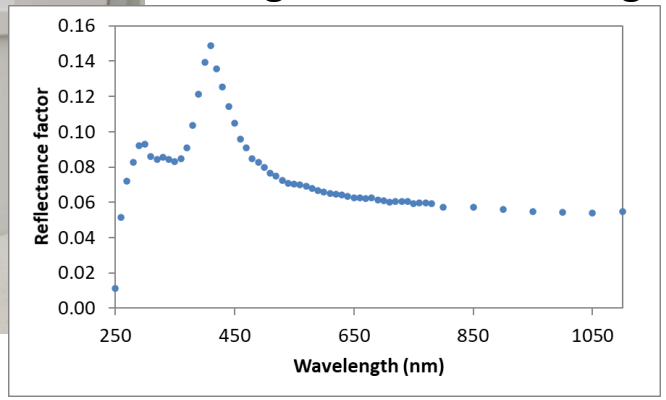


Fig. 2. Reflectance factor versus wavelength of organic-black coatings of different thickness in the wavelength range from 200 nm to 2500 nm.

Blue glass ocean sensing reference tile

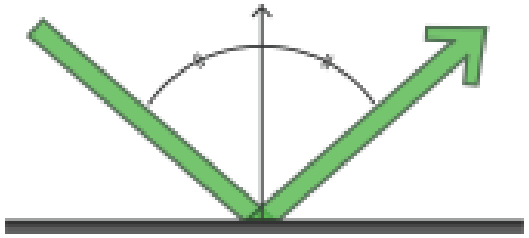




$R = 5\% \; to \; 15\%$

Considerations for Reflectance Geometries

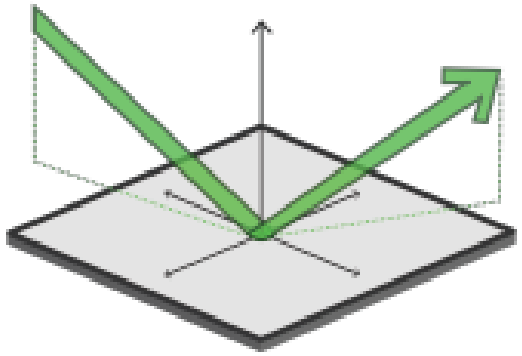
Specular



Mirrors, glossy samples

- Straightforward absolute measurement
- Provides only the mirror reflection, not diffuse, incomplete for all but mirrors
- Incident angle must be known and specified

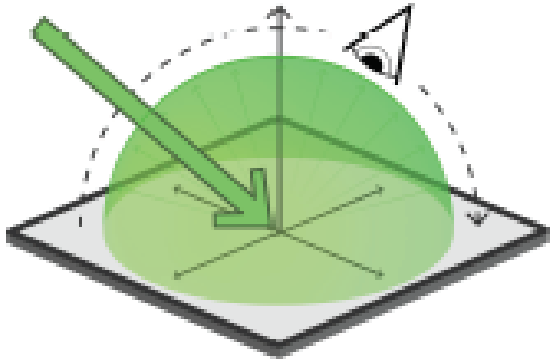
Bidirectional



Diffuse standards, ceramics, opal

- Most general measurement
- Specify incident and view, almost infinite combinations
- Absolute measurement
- Possible to integrate to obtain directional-hemispherical
- Extremely time consuming

Directional-hemispherical



Diffuse standards, ceramics, opal

- Fast measurement giving total reflectance, usually for fixed incident angle, many wavelengths
- Widely available commercial instruments
- Requires a white standard; mismatch between standard and sample reflectance can increase uncertainty

Summary

- NIST Sensor Science Division performs reflectance calibrations and maintains national reflectance scales
  - Specular, bidirectional and directional-hemispherical
  - UV-SWIR 250-2400 nm (0.25-2.4 μm)
  - Additional capabilities in longer IR
- Materials measurement for brightness mitigation will require accurate measurements across the UV-SWIR spectrum
- Measurement geometries should be appropriate for the material and illumination/viewing conditions
- NIST stands ready to assist stakeholders in government, industry and academia in ensuring accurate reflectance measurements for brightness mitigation

Collaborate with Us

- IP-protected arrangements such as Cooperative Research and Development Agreements (CRADAs) and interagency agreements
- Informal arrangements
- Employment and internship opportunities such as NRC Postdoctoral Fellowships, Summer Undergraduate Research Fellowships, Visiting Scientists, and Guest Researchers

For more information about working with the NIST Sensor Science Division

Thank you!