NIST
National Institute of Standards and Technology

Non-regulatory agency (Department of Commerce)

Congressional mandate:
Assist US industry; Improve health, safety, and environment; Conduct fundamental research in science and engineering

1989 Trade Bill added responsibility for extramural programs, especially in the areas of "competitiveness".

Radiometric Physics Division

National standards in radiation thermometry, spectroradiometry, photometry, and spectrophotometry;

Dissemination of these standards by providing measurement services to customers requiring calibrations of the highest accuracy;

Conduct fundamental and applied research to develop the scientific basis for future measurement services.
EXAMPLES

SRM 740 and 741. Defining fixed point for freezing zinc (419.58 °C) and tin (231.9681 °C) for calibrating thermometers and thermocouples.


SRM 1920 (0.74-2.0 μm). Reflectance standard for establishing the accuracy of the wavelength scale of a reflectance spectrophotometer.

SRM 2021 (0.28-2.5 μm). Directional-hemispherical reflectance (black porcelain enamel)
EXAMPLES

Contact Thermometry: Calibration of thermometers, thermocouples, and platinum, germanium, and rhodium-iron resistance thermometers

Radiation Thermometry: Calibration at 650 nm of optical pyrometers or ribbon filament lamps, 800 °C to 4200 °C

Optical Radiation Measurements:
- Spectral transmittance and reflectance, 0.25 to 2.5 µm;
- Spectral radiance ribbon filament lamps, 0.225 to 2.4 µm;
- Spectral irradiance lamps 0.25 to 2.4 µm;
- Photodiode (silicon) spectral response rental package, 0.2 to 1.1 µm;
- Special tests of radiometric detectors, 0.2 to 1.8 µm, 10 µW and greater power levels;
# Selected R/D Programs

## Ambient Environment

<table>
<thead>
<tr>
<th>TASK</th>
<th>( \lambda )</th>
<th>WHO</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient IR Facility for radiance temperature, minimum resolvable temperature, and imaging studies</td>
<td>3-14</td>
<td>Navy</td>
<td>1987</td>
</tr>
<tr>
<td>Calibration of commercial blackbody, 10 °C to 80 °C</td>
<td>8-14</td>
<td>Navy</td>
<td>1989</td>
</tr>
<tr>
<td>Characterization of commercial IR spectroradiometer</td>
<td>8-14</td>
<td>Navy</td>
<td>92-94</td>
</tr>
<tr>
<td>Calibrate 10-cm aperture water-bath blackbody (10 °C to 80 °C)</td>
<td>3-14</td>
<td>Navy</td>
<td>92-94</td>
</tr>
<tr>
<td>Build and characterize tin-point standard blackbody (231.928 °C)</td>
<td></td>
<td>Air Force</td>
<td>92-93</td>
</tr>
<tr>
<td>Calibrate blackbody source for radiance temperature and uniformity</td>
<td></td>
<td>SDIO</td>
<td>1992</td>
</tr>
<tr>
<td>Detector comparator facility for absolute calibration; develop IR detector standards</td>
<td>1.5-25</td>
<td>Air Force</td>
<td>91-94</td>
</tr>
<tr>
<td>Extend photodetector transfer standards to IR; calibrate with the HACR (High Accuracy Cryogenic Radiometer)</td>
<td>to 10.6</td>
<td>Air Force</td>
<td>91-93</td>
</tr>
</tbody>
</table>
## Selected NIST R/D Programs

### Cryogenic Environment

<table>
<thead>
<tr>
<th>TASK</th>
<th>λ</th>
<th>WHO</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryogenic facility for calibration of blackbodies from total power measurements (LBIR)</td>
<td>0.3-30</td>
<td>SDC Army</td>
<td>1989</td>
</tr>
<tr>
<td>Calibration of blackbody sources from 150 K to 1000 K</td>
<td></td>
<td></td>
<td>1989</td>
</tr>
<tr>
<td>Add spectral capability to LBIR</td>
<td>2-30</td>
<td>SDIO SDC</td>
<td>1992</td>
</tr>
<tr>
<td>Spectral calibration of cryogenic sources, detectors, and filters</td>
<td></td>
<td></td>
<td>1993</td>
</tr>
<tr>
<td>Extend noise floor of LBIR detector from 20 nW to 70 pW</td>
<td></td>
<td>SDIO</td>
<td>1992</td>
</tr>
</tbody>
</table>
Selected NIST R/D Programs

Spectrophotometric Measurements

<table>
<thead>
<tr>
<th>TASK</th>
<th>λ</th>
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<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration facility for bidirectional reflectance distribution function</td>
<td>0.33-10.6</td>
<td>Air Force</td>
<td>90-93</td>
</tr>
<tr>
<td>Develop IR diffuse reflectance standards</td>
<td>2-20</td>
<td>Navy</td>
<td>91-93</td>
</tr>
<tr>
<td>Optical heterodyne densitometry (12 decades; cryogenic operation by 1992)</td>
<td>0.633 &amp; 10.6</td>
<td></td>
<td>1990</td>
</tr>
</tbody>
</table>


Relevance to EOS/TIR Calibration
Current Capabilities

AMBIENT (minimum 1 meter path length)

Calibrate customer blackbody sources

Calibrate unknown blackbody for radiance using a well-characterized NIST blackbody source by matching the radiant fluxes with an IR radiometer (Barnes): absolute uncertainty 0.11 °C at 10 °C; 0.25 °C at 45 °C; capable of precision of 1 mK;

Measure uniformity of unknown blackbody source with a minimum resolvable temperature difference of 50 mK at 33 °C (Barnes)
Relevance to EOS/TIR Calibration
Current Capabilities

CRYOGENIC (20 K shield; 4 K ESR detector)

Calibrate customer blackbodies

Total radiant flux measurements; size of BB aperture and temperature are constrained by the detector;

Calibrate thermometers of source with respect to radiance temperature as a function of BB aperture size;

Absolute radiometric uncertainty at the 95% level is about 1%, corresponds to about 1.2% uncertainty in radiance temperature;

No uniformity studies are possible and strict vacuum requirements apply (<1.33x10^{-6} Pa total pressure and <1.33x10^{-8} Pa hydrocarbons before cooling with the 15 K helium gas).

Next LBIR workshop is scheduled for Tuesday morning, September 15, in conjunction with the 3rd annual SDL/USU Symposium on Cryogenic IR Radiometric Sensor Calibration and the EOS/TIR Peer Review Workshop.
### EOS TIR Instruments

**Overall Spectral Coverage (μm)**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIRS</td>
<td>3.4 - 15.4, 0.4 - 1.7</td>
</tr>
<tr>
<td>ASTER</td>
<td>8 - 12, 1.6 - 2.5, 0.5 - 0.9</td>
</tr>
<tr>
<td>CERES</td>
<td>0.3 - 50, 8 - 12, 0.3 - 5</td>
</tr>
<tr>
<td>HIRDLS</td>
<td>6 - 12</td>
</tr>
<tr>
<td>MODIS-N</td>
<td>0.415 - 14.24</td>
</tr>
<tr>
<td>MOPITT</td>
<td>2.3 - 4.7</td>
</tr>
<tr>
<td>SAFIRE</td>
<td>62.5 - 125, 25.6 - 32.3, 6.4 - 15.9</td>
</tr>
<tr>
<td>TES</td>
<td>2.3 - 16.7</td>
</tr>
</tbody>
</table>
EOS/TIR Lab Source Verification
TIR Round Robin

**Definition** TIR Round Robin to VERIFY the calibration of the sources that are used for the absolute radiometric calibration of the individual EOS sensors

**Requirements (preliminary)**

- Spectral response: 2.3 - 15
- 3% total absolute uncertainty in radiance at the 3σ level
- Long term stability
- Proven vacuum compatibility
- Meets EOS schedule
- Calibration at NIST, or NASA-acceptable traceability
Philosophy of Lab Source Verification

* Filter, monochromator, or interferometer
STABLE SOURCE

EOS LAB SOURCE  ROUND ROBIN SOURCE (Blackbody)

PRT resistance vs $T_\lambda$ of the RR source is NIST "traceable"

Problem  Thermal radiation properties of the RR Source could change

Return to NIST often?  
Design way to monitor $\epsilon(\lambda)$?

Option  Circulate a RR detector (not necessarily stable) to compare the sources
STABLE RADIOMETER
(broadband or spectral)
(irradiance or radiance mode)

EOS LAB SOURCE

ROUND ROBIN RADIOMETER

Calibration constants determined or confirmed by NIST
Round robin source could be included for redundancy
DESIRED INFORMATION

INSTRUMENT SPECIFICATIONS

CALIBRATION METHODS (pre-flight and on-board)

ROUND ROBIN
   Overall Philosophy
   Laboratory Sources to be verified
   Environment for measurements
   Revised Requirements