Laboratory Measurement of Bidirectional Reflectance of Radiometric Tarps

**Objective**
- To determine the magnitude of radiometric tarp BRDF
- To determine whether an ASD FieldSpec Pro spectroradiometer can be used to perform the experiment

**Background**
- Radiometric tarps with nominal reflectance values of 52%, 35%, 22%, and 1000-watt FEL lamp source
- Tarp reflectance correction factor for satellite geometry: overpasses
- Precision of tarp signal measurements was estimated to be 0.005 (1%)
- Calibration at different viewing angles to be varied NIST, at incidence angles of 20°, 30°, 40°, and 50°, viewed normal to surface

**Procedure**
1. Measure signal of NIST-calibrated Spectralon panel irradiated by collimated light at incidence angle of calibrated reflectance, viewing normal to panel surface
2. Measure signal of Spectralon panel calibrated at NIST, at incidence angles of 20°, 30°, 40°, and 50°
3. Calculate reflectance of Spectralon panel calibrated at solar zenith angle, viewing normal to panel surface (ground geometry):
   \[ R(\theta_{\text{Lambert}}) = R(\theta) \frac{L(\theta,\text{Lambert})}{L(\theta,\text{NIST})} \]  
   \( R \) = reflectance, \( L \) = signal
4. Measure signal of tarp sample at ground geometry, \( L_{\text{NIST}}(\theta) \)
5. Calculate reflectance of tarp sample at ground geometry (for comparison with reflectance values determined from field measurements made with ASD FieldSpec Pro):
   \[ R_{\text{NIST}}(\theta) = R(\theta) \frac{L(\theta,\text{NIST})}{L_{\text{NIST}}(\theta)} \]
6. Measure signal of tarp sample satellite geometry, \( L_{\text{satellite}}(\theta_{s},\phi_{s}) \), where \( \theta_{s} \) = satellite zenith angle, \( \phi_{s} \) = satellite azimuth
7. Calculate tarp reflectance correction factor for satellite geometry:
   \[ C_{\text{tarp}}(t) = \frac{L_{\text{satellite}}(\theta_{t},\phi_{t})}{L_{\text{NIST}}(\theta_{t})} \]

**Results**
- Minimum and Maximum Values for Tarp Reflectance Correction Factor (\( C_{\text{tarp}} \)) for the 52% Tarp, Averaged over Approximate Spectral Bandwidths for the Satellites

<table>
<thead>
<tr>
<th>Color</th>
<th>450-510 nm</th>
<th>510-690 nm</th>
<th>630-790 nm</th>
<th>750-870 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>1.075</td>
<td>1.098</td>
<td>1.062</td>
<td>1.058</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.914</td>
<td>0.924</td>
<td>0.931</td>
<td>0.936</td>
</tr>
</tbody>
</table>

**Discussion**
- Over spectral range of 450 to 900 nm, ratio of radiance values measured with ASD FieldSpec Pro is close to ratio of reflectance values measured at NIST and calculated from Jackson model (Jackson et al., 1992).
- Signal-to-noise ratio for FieldSpec Pro data was poor, possibly due to internal stray light and low radiance levels in this experiment (ASD FieldSpec Pro is designed for higher radiance found outdoors).
- A decision was made to use the Optronics OL 750 double monochromator/reflectometer instead of the ASD FieldSpec Pro.

**Reference**

For the 52% tarp, the highest values for \( C_{\text{tarp}} \) occurred when satellite viewing direction was closest to the direction of incident solar irradiation. This behavior appears to be caused by tiny shadows cast by the weave of the tarp fabric; these shadows are least visible when the tarp is viewed along the direction of incidence. This behavior is less noticeable for the 35% and 22% tarps and is absent for the 3.5% tarp because the shadows are invisible against the dark tarp surface. For the 3.5% tarp, the tarp reflectance correction factor \( C_{\text{tarp}} \) was observed to increase by up to 5% as the viewing direction approached the direction of specular reflection.

The reflectance was measured for tarp samples that had bidirectional reflectance by Georgi Georgiev and James J. Butler at the NASA/GSFC Diffuser Calibration Facility (DCaF). The DCaF reflectance measurement results are discussed in Georgiev, G., and J. Butler (2003), The effect of weave orientation on the BRDF of tarp samples, Proc. SPIE, 5189:145–152.