NASA IKONOS Radiometric Characterization

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March 25-27, 2002

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<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
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<tbody>
<tr>
<td>Troy Frisbee</td>
<td>NASA, Stennis Space Center</td>
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<tr>
<td>Vicki Zanoni</td>
<td>NASA, Stennis Space Center</td>
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<tr>
<td>Slawek Blonski</td>
<td>LMSO, Stennis Space Center</td>
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<tr>
<td>Erik Daehler</td>
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<tr>
<td>Brennan Grant</td>
<td>LMSO, Stennis Space Center</td>
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<td>Kara Holekamp</td>
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<td>Robert Ryan</td>
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<td>Richard Sellers</td>
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<td>Charles Smith</td>
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<td>Steve Tate</td>
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<tr>
<td>Bill Smith</td>
<td>DATASTAR, Stennis Space Center</td>
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<td>Debbie Fendley</td>
<td>DATASTAR, Stennis Space Center</td>
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<tr>
<td>Braxton Baldridge</td>
<td>NIMA</td>
</tr>
<tr>
<td>Robert Clitone</td>
<td>NIMA</td>
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Objective
- Perform radiometric vicarious calibrations of IKONOS imagery and compare with Space Imaging calibration coefficients

Approach
- Utilize multiple well-characterized sites
  - Widely used by the NASA science community for radiometric characterization of airborne and spaceborne sensors
- Perform independent characterizations with independent teams. Each team has slightly different measurement techniques and data processing methods
  - NASA Stennis Space Center
  - University of Arizona Remote Sensing Group
  - South Dakota State University
  - USDA Department of Agriculture SWRC/USWCL
- Leverage characterization activities with other field measurement programs
Reflectance-based Approach

- Characterize target reflectance at time of satellite overpass
  Measurements taken of target area and a 99% reflectance spectralon panel (Jackson BRDF model)

- Characterize atmosphere at time of satellite overpass
  - Radiosonde data used to determine Rayleigh scattering and water molecule extinction
  - Least squares fit of sun photometer data to determine model atmosphere parameters

- Use MODTRAN radiative transport code to predict at-sensor radiances

- Compare predicted at-sensor radiances to actual radiances acquired by sensor
**Site:** Dry lake bed in central Nevada, predominantly clay surface, no vegetation, surface is hard and nearly impermeable to water. Elevation approx. 1800 m Center point 38.4° N, 116.0° W.

**In-Situ Instrumentation:** ASD FieldSpec FR spectroradiometers, Yankee MFRSR, Airsonde radiosonde, Full sky imager, 99% spectralon panels

**Other Coincident Collects:** Landsat 7, Terra ASTER/MODIS, ATLAS
Lunar Lake Ground Truthing

NASA

Stennis Space Center

2002 JACIE WORKSHOP
Reston, VA
# Data Acquisitions

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<thead>
<tr>
<th>Date</th>
<th>Over Pass Time (UTC)</th>
<th>Satellite Elevation</th>
<th>Satellite Azimuth</th>
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</thead>
<tbody>
<tr>
<td>July 13, 2001</td>
<td>18:39</td>
<td>75.56 deg</td>
<td>207.43 deg</td>
</tr>
<tr>
<td>July 16, 2001</td>
<td>18:48</td>
<td>69.10 deg</td>
<td>275.94 deg</td>
</tr>
</tbody>
</table>

*Standard Original imagery
MTFC applied
Cubic convolution resampling algorithm*
Ground Measurements

- **ASD measurements**
  - An area on the playa ~ 100 m x 100 m, visually uniform, was identified
  - All measurements were taken twice, with two different ASDs to check repeatability
  - Measurements were taken along 8 transect lines evenly dividing the target area
    - All measurements were taken while walking to increase spatial averaging
    - 8000 spectra in total were averaged to obtain the playa reflectance values
    - Spectralon panel measurements were taken between transects
    - Before any measurements were taken, the instrument was optimized and dark current measurements were made
  - All data taken within 20 minutes of satellite overpass

- **Atmospheric measurements**
  - Collect solar radiance data from early morning through post-sensor acquisition
  - Radiosonde launch near time of sensor overpass
    - Data acquired July 13 only
Spectral Albedo for Lunar Lake, NV, 7/16/01

Lunar Lake, NV
July 16, 2001

Reflectance

Wavelength (μm)
MFRSR/MODTRAN predicted Transmission

Lunar Lake, NV
July 16, 2001

MFRSR and Tape7 Transmissions at 130Km Visibility

Normalized Transmission

Wavelength (nanometers)
MFRSR/Reagan: Optical Depth for Lunar Lake 2001

- Optical Depth
- Wavelength of band (nm)

- MFRSR 07-16-01 AM
- REAGAN 07-16-01
IKONOS Relative Spectral Response

IKONOS Relative Spectral Response

Relative Spectral Responsivity

Wavelength (nm)

350 550 750 950

Pan
Blue
Green
Red
NIR
### Lunar Lake IKONOS Radiometric Assessment

Lunar Lake, NV  
July 13, 2001

<table>
<thead>
<tr>
<th>Band (nm)</th>
<th>NASA Estimate (W/m²sr)</th>
<th>IKONOS Measurement (W/m²sr)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 445 - 516</td>
<td>13.574</td>
<td>13.241</td>
<td>2.45%</td>
</tr>
<tr>
<td>2 506 - 595</td>
<td>18.311</td>
<td>18.828</td>
<td>2.82%</td>
</tr>
<tr>
<td>3 632 - 698</td>
<td>14.284</td>
<td>14.561</td>
<td>1.94%</td>
</tr>
<tr>
<td>4 757 - 853</td>
<td>14.892</td>
<td>14.945</td>
<td>0.36%</td>
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</tbody>
</table>

Percent difference is calculated by: \( \text{abs}(1 - \text{IKONOS}/\text{NASA}) \)
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<tr>
<th>Band (nm)</th>
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<th>IKONOS Measurement (W/m²sr)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 445 - 516</td>
<td>13.534</td>
<td>12.783</td>
<td>5.55%</td>
</tr>
<tr>
<td>2 506 - 595</td>
<td>18.380</td>
<td>18.275</td>
<td>0.57%</td>
</tr>
<tr>
<td>3 632 - 698</td>
<td>14.418</td>
<td>14.232</td>
<td>1.29%</td>
</tr>
<tr>
<td>4 757 - 853</td>
<td>15.033</td>
<td>14.683</td>
<td>2.33%</td>
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</table>

Percent difference is calculated by: abs(1 - IKONOS/NASA)
Site: Scattered buildings within a heavily wooded area, man-made reservoirs and canals. Elevation 5.5m - 10m. 30.388 degrees N, 89.61 degrees W.

In-Situ Instrumentation:
ASD FieldSpec FR spectroradiometers, Yankee MFRSRs, Reagan sunphotometer, Airsonde radiosonde, full sky imager, 20m x 20m radiometric tarps, 99% spectralon panels.

Includes material © Space Imaging L.P.
Radiometric Tarps

- 4 20m x 20m tarps with reflectance values of
  - less than 5%
  - between 20% and 25%
  - between 30% and 40%
  - between 50% and 55%
- Spectral measurement range of 400 to 1050 nm
- Standard deviation about average reflectance less than 1% spatially
- Peak to peak variation in reflectance less than 10% within any 100 nm spectral band
- Less than 10% variation in reflectance values when measuring tarps from 10 deg to 60 deg off axis
- Each side is straight to within ±6.0 centimeters over the 20 meter length
- Each tarp panel has 60 square witness samples measuring 30.5 centimeters by 30.5 centimeters.
NASA SSC Ground Truthing

2002 JACIE WORKSHOP
Reston, VA
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<th>Over Pass Time (UTC)</th>
<th>Satellite Elevation</th>
<th>Satellite Azimuth</th>
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</thead>
<tbody>
<tr>
<td>Jan 15, 2002</td>
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<td>77.19 deg</td>
<td>112.97 deg</td>
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<tr>
<td>Feb 17, 2002</td>
<td>16.47</td>
<td>81.88 deg</td>
<td>100.73 deg</td>
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</tbody>
</table>

Standard/Original imagery
MTFC applied
Cubic convolution resampling algorithm
ASD Measurements

- Measurements of several target areas were taken
  - \(\sim 35\text{-m} \times 15\text{-m}\) area of a dried grassy field
  - \(\sim 30\text{-m} \times 20\text{-m}\) area of a concrete parking lot
  - Three \(20\text{-m} \times 20\text{-m}\) radiometric tarps (3.5%, 52% and 22% reflectance)
- Measurements were taken along transect lines (grass and concrete) or tarp perimeter
  - All measurements were taken while walking to increase spatial averaging
  - Between 2500 and 7500 points were taken of each target
  - ASD optimization and dark current measurements were taken prior to target measurements. Periodic spectralon panel measurements were taken
- Stationary ASD measurements taken of a spectralon panel to record sun position effect on radiometry
- ASD measurements taken of a spectralon panel across measurement field to record building presence effect on radiometry
- All data taken within 20 min of satellite overpass
Atmospheric Measurements

- Solar radiance data taken from early morning through post-sensor acquisition
  - (1) MFRSR and (1) Reagan sunphotometer acquired data from the measurement field
  - (1) MFRSR acquired data from a building rooftop approx. 2 miles away
- Radiosonde was launched 30 minutes prior to satellite overpass. Data acquired over a 90-min period up to 23 km
Full Sky Imager

NASA SSC
January 15, 2002
Spectral Albedo for Stennis Space Center, 1/15/03

- 22% Tarp
- 52% Tarp
- 3.5% Tarp
- Concrete
- Grass

Reflectance vs. Wavelength (μm)
Reagan/MFRSR Optical Depth Values

SSC, MS
Jan 15, 2002

![Graph showing optical depth vs. center band wavelength (nm)]

- REAGAN #25 Stennis Field
- MFRSR #451 Stennis Roof
- MFRSR #477 Stennis Field
IKONOS Blue Band Calibration Summary

Blue Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
- SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
- UofA, Railroad Valley, 7/16/01
- UofA, Lunar Lake, 7/16/01
- UofA, Brookings, 7/17/01
- UofA, Brookings, 7/25/01
- UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/72.8
Green Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
- SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
- UofA, Railroad Valley, 7/16/01
- UofA, Lunar Lake, 7/16/01
- UofA, Brookings, 7/17/01
- UofA, Brookings, 7/25/01
- UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/72.7
IKONOS Red Band Calibration Summary

Red Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
- SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
- UofA, Railroad Valley, 7/16/01
- UofA, Lunar Lake, 7/16/01
- UofA, Brookings, 7/17/01
- UofA, Brookings, 7/25/01
- UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/94.9

Predicted Radiance [W/(m² sr)]

Image DN

2002 JACIE W
Reston, VA
IKONOS NIR Band Calibration Summary

NIR Band Calibration Summary

- SSC, Lunar Lake, 7/13/01
- SSC, Lunar Lake, 7/16/01
- SSC, Maricopa, 7/26/01
* SSC, Big Spring, 8/5/01
- UofA, Brookings, 7/3/01
- UofA, Railroad Valley, 7/13/01
- UofA, Lunar Lake, 7/13/01
* UofA, Railroad Valley, 7/16/01
▶ UofA, Lunar Lake, 7/16/01
* UofA, Brookings, 7/17/01
* UofA, Brookings, 7/25/01
△ UofA, Ivanpah Playa, 11/19/01

Space Imaging Calibration Curve, Post 2/22/01

SI Radiance = DN/84.3
### NASA Radiometric Characterization Summary

**Stennis Space Center**

<table>
<thead>
<tr>
<th>Band</th>
<th>NASA Gain</th>
<th>Space Imaging Gain</th>
<th>NASA Gain SI Initial Gain</th>
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<tr>
<td>1</td>
<td>63.3</td>
<td>63.7</td>
<td>0.99</td>
</tr>
<tr>
<td>2</td>
<td>64.9</td>
<td>57.3</td>
<td>1.13</td>
</tr>
<tr>
<td>3</td>
<td>84.0</td>
<td>66.3</td>
<td>1.27</td>
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<tr>
<td>4</td>
<td>74.6</td>
<td>50.3</td>
<td>1.48</td>
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Units of Gain = \([W/(m^2\ sr)] \) /DN
Summary

- The current “Post 2/22/01” calibration coefficients provided by Space Imaging agree well with the NASA team vicarious calibration
  - IKONOS sensor has been radiometrically stable over the past year
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<th>REPORT TYPE</th>
<th>DATES COVERED (From - To)</th>
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<tr>
<td>Conference - High Spatial Resolution Commercial Imagery Workshop IKONOS Reston Virginia</td>
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