



NASA QuickBird Radiometric Characterization

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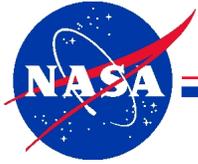
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Characterization Overview

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- Objective
 - Perform radiometric vicarious calibrations of QuickBird imagery and compare with DigitalGlobe calibration coefficients
- Approach
 - Utilize multiple well-characterized sites
 - 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 (provided ground-truth data)



Vicarious Calibration Method

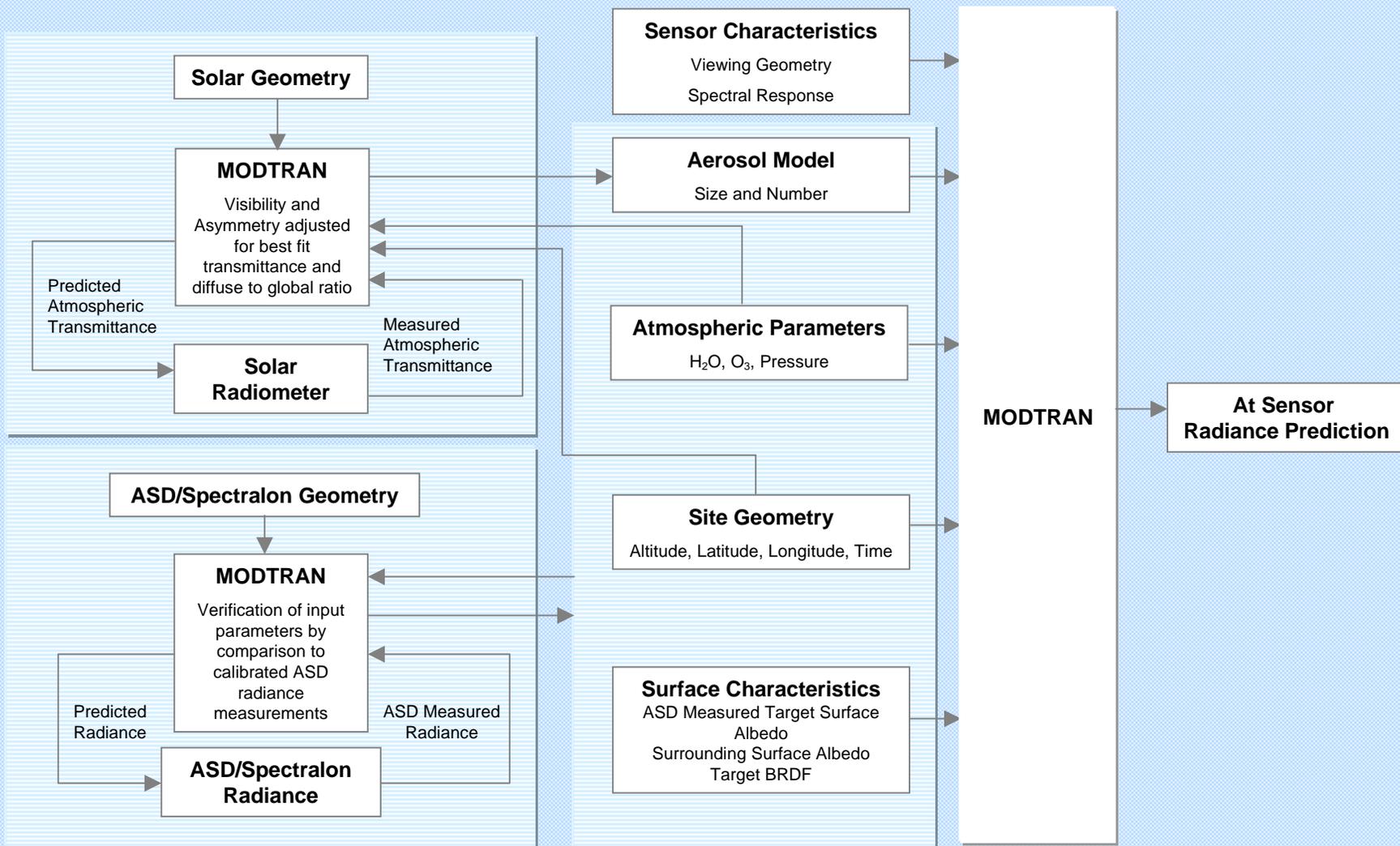
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- Reflectance-based approach
 - Characterize target reflectance at time of satellite overpass
 - Measurements taken of target area and a 99% reflectance spectralon panel (Jackson BRDF model)
 - Characterize atmosphere at time of satellite overpass
 - Radiosonde data used to determine Rayleigh scattering and water vapor extinction
 - Least squares fit of sun photometer data to determine model atmosphere parameters
 - Use MODTRAN radiative transport code to predict at-sensor radiance
 - Compare predicted at-sensor radiance to actual radiance acquired by sensor



At Sensor Radiance Prediction Method

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QuickBird Spectral Response

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- **DigitalGlobe provided the QuickBird system effective spectral quantum efficiencies that were converted to system spectral response**

$$R(\lambda) = \frac{Q(\lambda) \cdot \lambda}{h \cdot c}$$

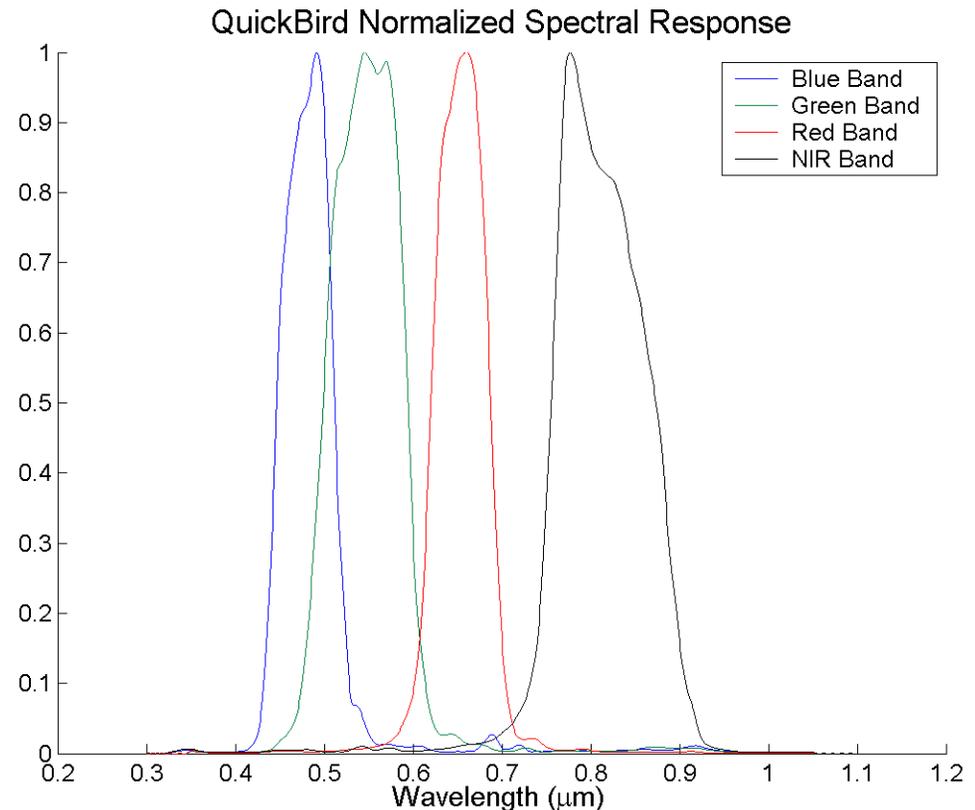
$R(\lambda)$ = spectral response

$Q(\lambda)$ = quantum efficiency

λ = wavelength

h = Planck's constant

c = speed of light





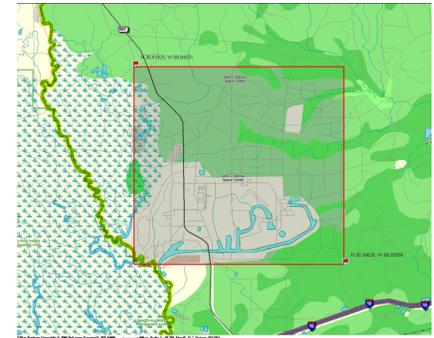
NASA Stennis Space Center, MS

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- **Site:** Scattered buildings within a heavily wooded area; manmade reservoirs and canals
- **Elevation:** 5.5 m–10 m
- **Centerpoint:** 30.356° N, 89.62° W



General Scene



QuickBird Image Area
8.5 km x 8 km

- ***In-situ* Instrumentation:** ASD FieldSpec FR spectroradiometers, Yankee multifilter rotating shadowband radiometers (MFRSRs), automated solar radiometers, Sippican radiosonde, full sky imager, 20-m x 20-m radiometric tarps, 99% reflectance Spectralon panels

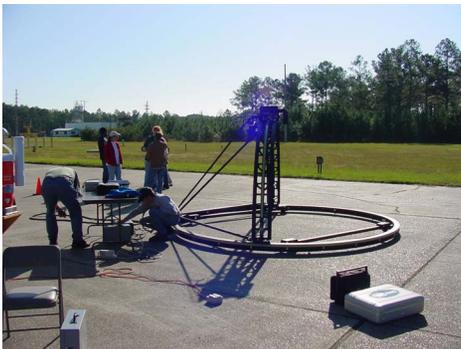


QuickBird True-Color Imagery
November 14, 2002



NASA SSC Ground Truthing

Stennis Space Center



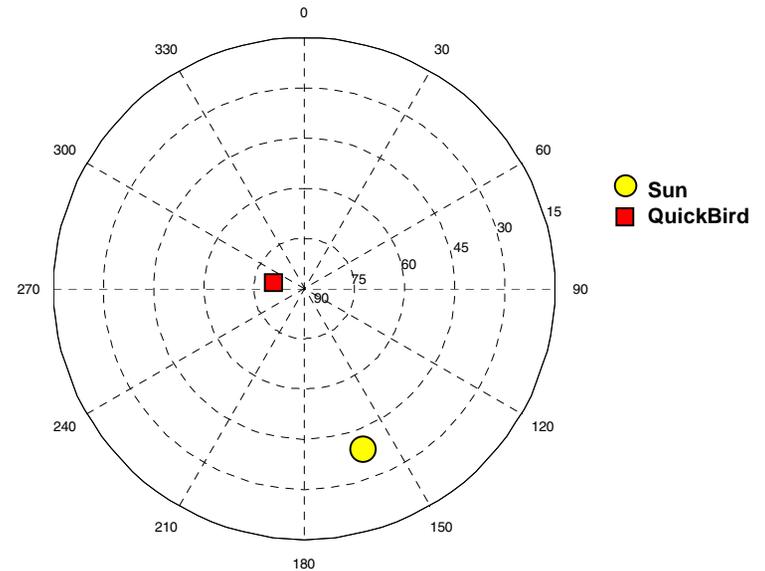
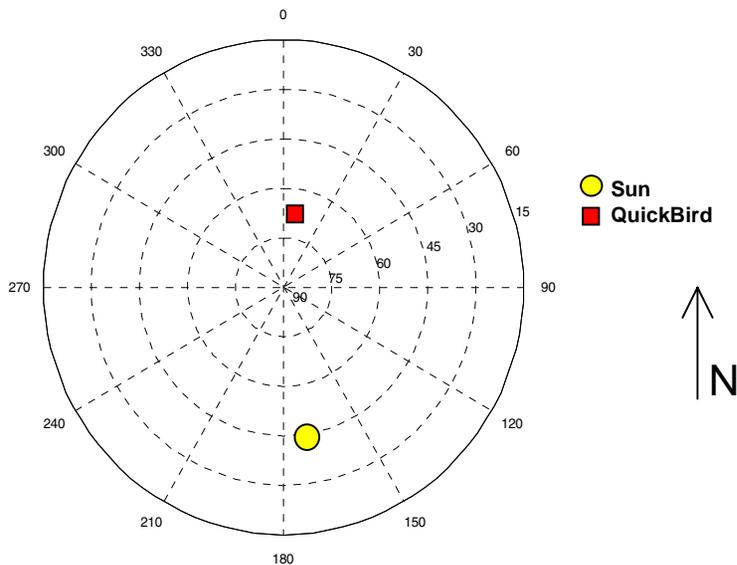


Data Acquisitions

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Date	Overpass Time (UTC)	Satellite Elevation	Satellite Azimuth	Sun Elevation	Sun Azimuth
Feb 17, 2002	16:45	67.12 deg	10.77 deg	47.26 deg	170.45 deg
Nov 14, 2002	16:44	79.38 deg	274.80 deg	39.38 deg	161.81 deg

Standard imagery
Nearest neighbor resampling algorithm



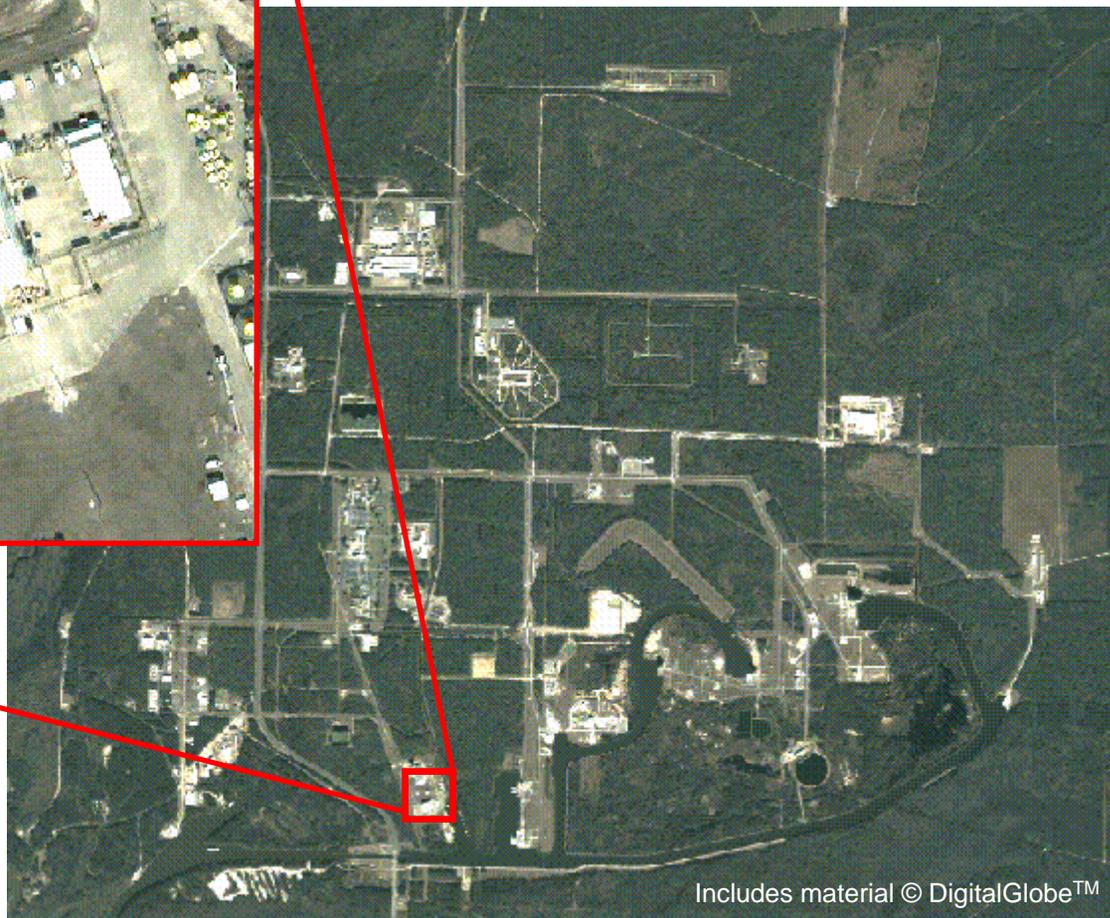


QuickBird Image of NASA SSC

Stennis Space Center



February 17, 2002
True-Color Image
Pan Sharpened





Radiometric Tarps

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- Four 20-m x 20-m tarps with reflectance values of approximately 3.5%, 22%, 33%, and 52%
- Spectral measurement range of 400 to 1050 nm
- 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° to 60° off axis
- Each side is straight to within ± 6.0 cm over the 20-m length
- Each tarp panel has 60 square witness samples measuring 30.5 cm x 30.5 m





ASD Measurements

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- Measurements of several target areas were taken
 - ~35 m x 15 m area of a dried grassy field
 - ~30 m x 20 m area of a concrete parking lot
 - Three 20 m x 20 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
 - Periodic spectralon panel measurements were taken
 - ASD optimization and dark current measurements were taken prior to and during target measurements.
- All data taken within 20 minutes of satellite overpass



Atmospheric Measurements

Stennis Space Center

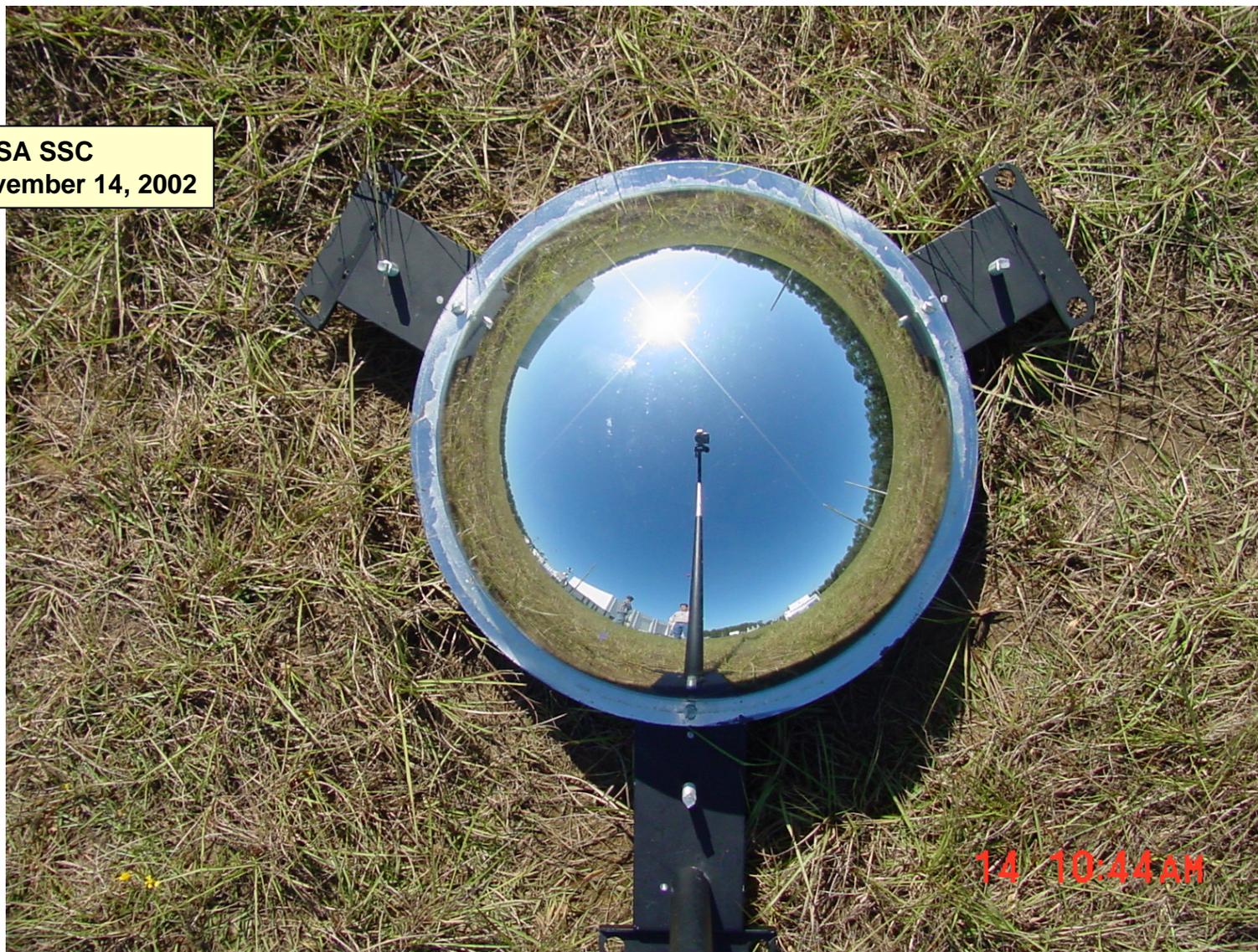
- Solar irradiance data taken from early morning through post-sensor acquisition
 - 1 MFRSR and 2 ASRs acquired data from the measurement field
 - 1 MFRSR acquired data from a building rooftop approximately 2 miles away
- Radiosonde was launched 15 minutes prior to satellite overpass. Data acquired up to 20 km on 2/17/02 and up to 10 km on 11/14/02.



Full Sky Imager

Stennis Space Center

NASA SSC
November 14, 2002

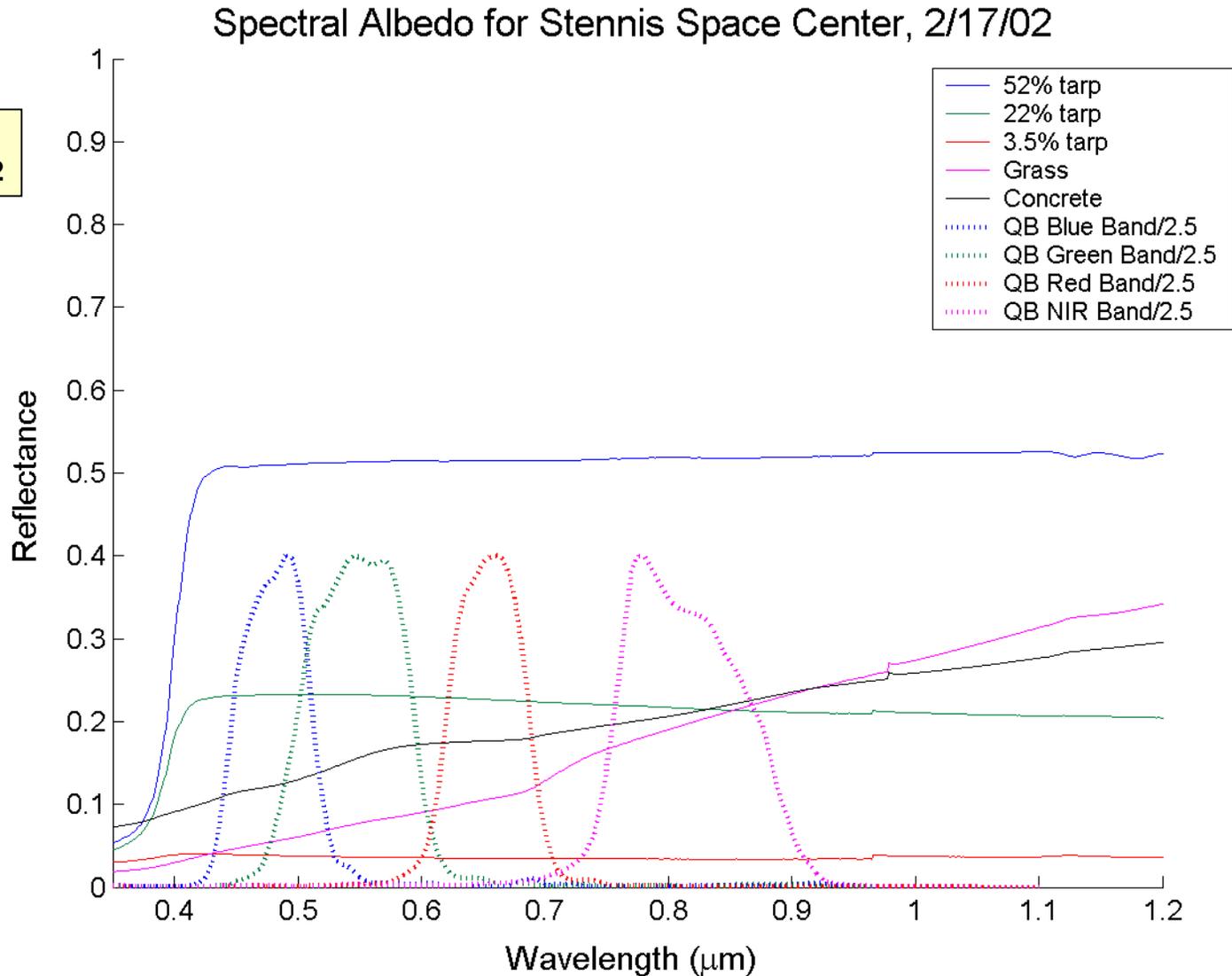




Spectroradiometer Data

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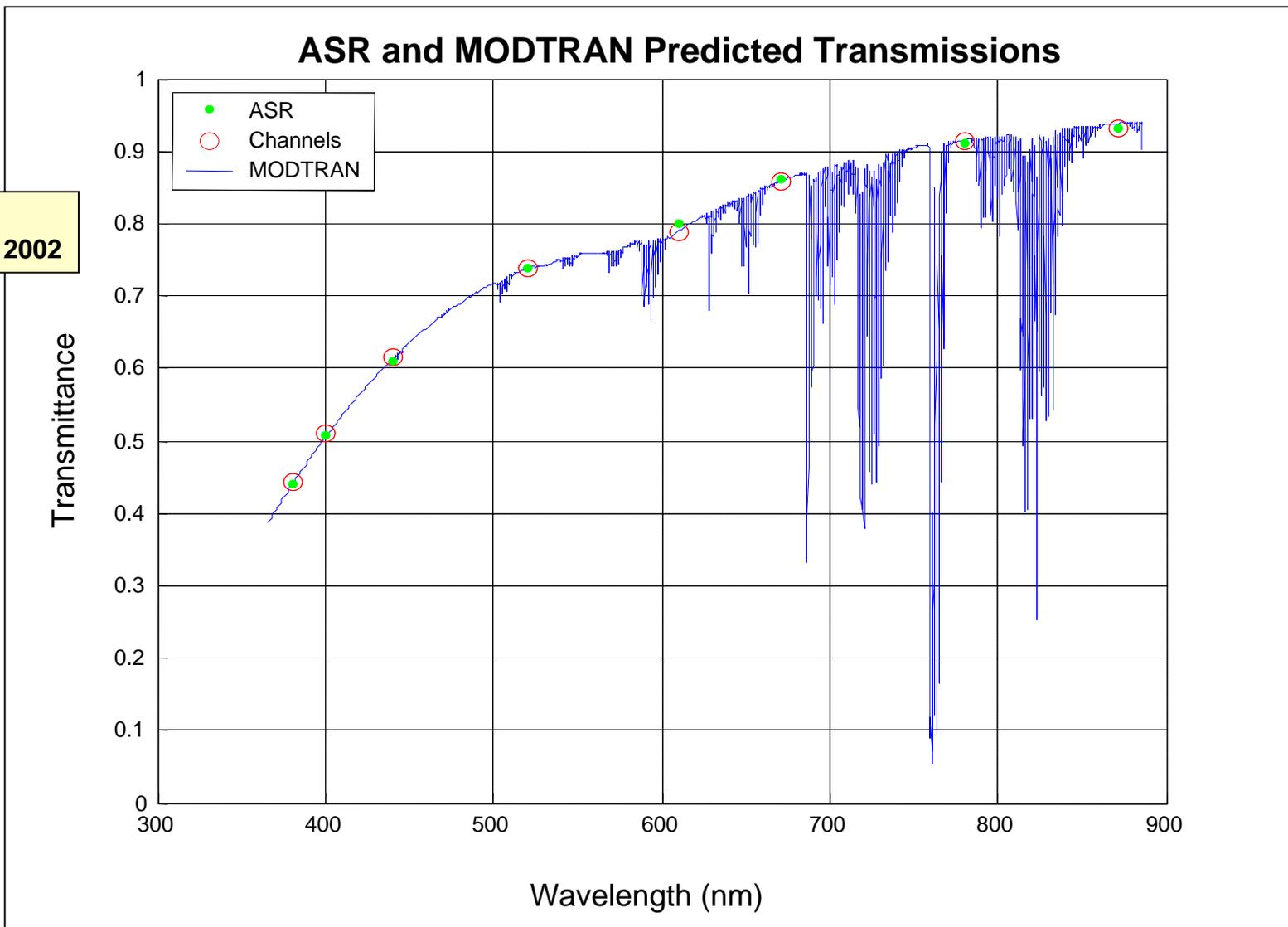
NASA SSC
February 17, 2002





ASR/MODTRAN Predicted Transmission

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NASA SSC
November 14, 2002

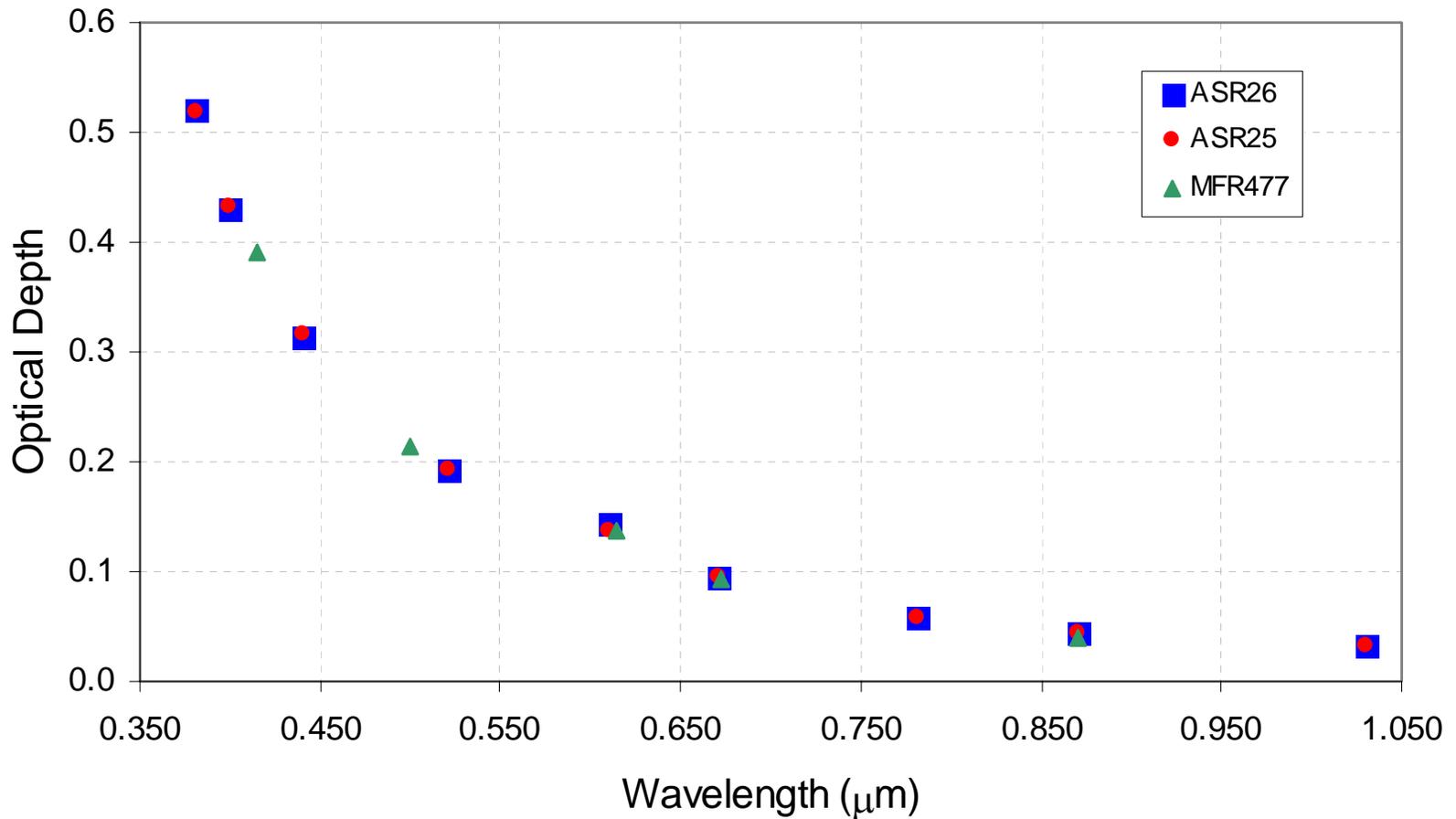


ASR/MFRSR Optical Depth Values

Stennis Space Center

NASA SSC
November 14, 2002

Optical Depth for SSC, November 14, 2002





Brookings, South Dakota

Stennis Space Center

- **Site:** Grass field beside 3M plant on the outskirts of the city of Brookings; church parking lot with grass area
- **Elevation:** approx. 500 m
- **Centerpoint:** 44.3° N, 96.8° W

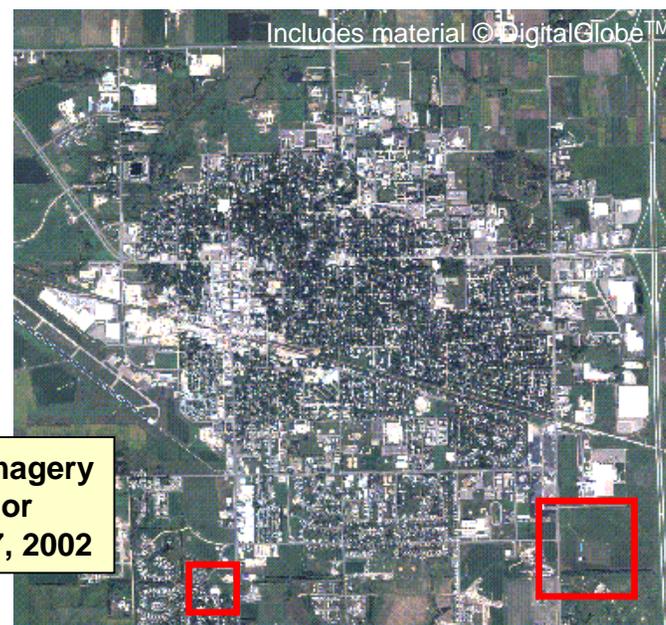


General Scene



Brookings Image Area
6.5 km x 10.5 km

- **In-Situ Instrumentation:** ASD FieldSpec FR spectroradiometers, Yankee MFRSRs, automated solar radiometer, Sippican radiosonde, 20 m x 20 m radiometric tarps, 99% reflectance Spectralon panels



QuickBird Imagery
True Color
September 7, 2002



Brookings Ground Truthing

Stennis Space Center



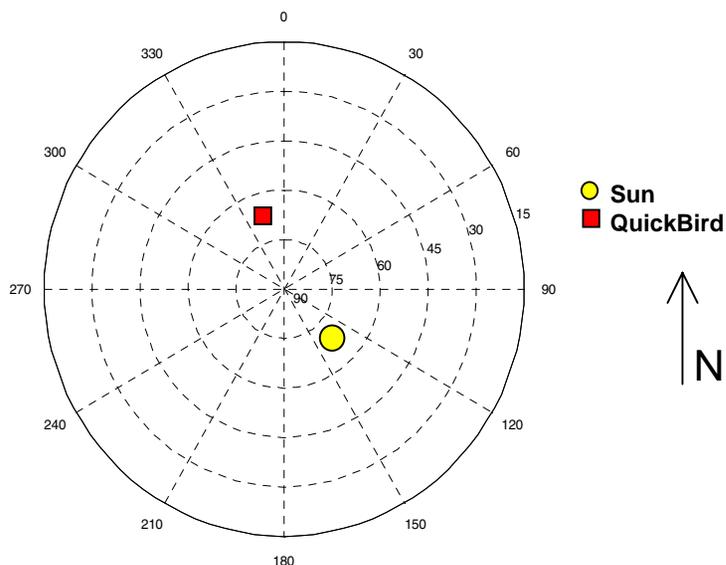


Data Acquisitions

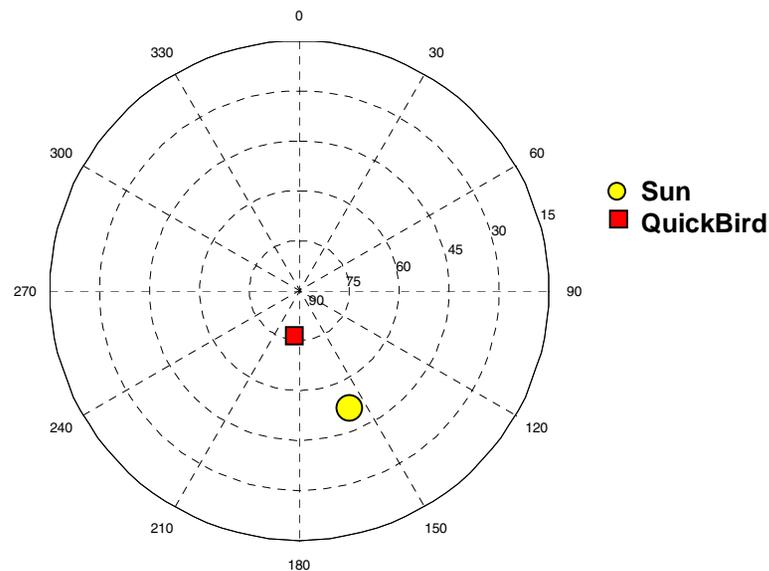
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Date	Overpass Time (UTC)	Satellite Elevation	Satellite Azimuth	Sun Elevation	Sun Azimuth
July 20, 2002	17:26	64.12 deg	349.85 deg	62.64 deg	144.43 deg
Sept. 7, 2002	17:22	74.85 deg	191.17 deg	49.37 deg	155.48 deg

Standard imagery
Cubic convolution resampling algorithm



Brookings, SD, 7/20/02



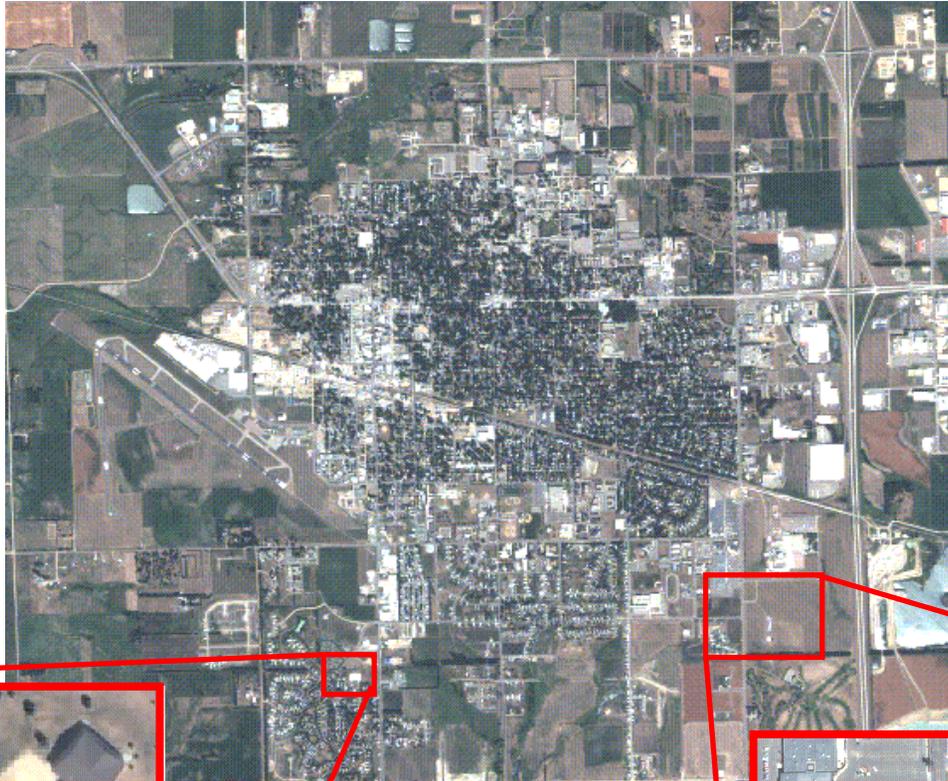
Brookings, SD, 9/7/02



QuickBird Image of Brookings

Stennis Space Center

July 20, 2002
True-Color Image
Pan Sharpened



Includes material © DigitalGlobe™



ASD Measurements

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- ASD measurements of several targets were taken
 - Two 20 m x 20 m radiometric tarps (3.5% and 52% reflectance)
 - ~150 m x 150 m area of a grassy field
 - ~35 m x 50 m area of parking lot
 - ~ 5 m x 35 m area of parking lot and grass area next to parking lot
- Measurements were taken along transect lines (grass and concrete) or tarp perimeter
 - All measurements were taken while walking to increase spatial averaging
 - Periodic Spectralon panel measurements were taken
 - Prior to and during target measurements, the instrument was optimized and dark current measurements were made

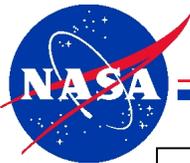


Atmospheric Measurements

Stennis Space Center

- Collect solar irradiance data from early morning through post-sensor acquisition
- Radiosonde launch near time of sensor overpass
 - Data acquired July 20 only

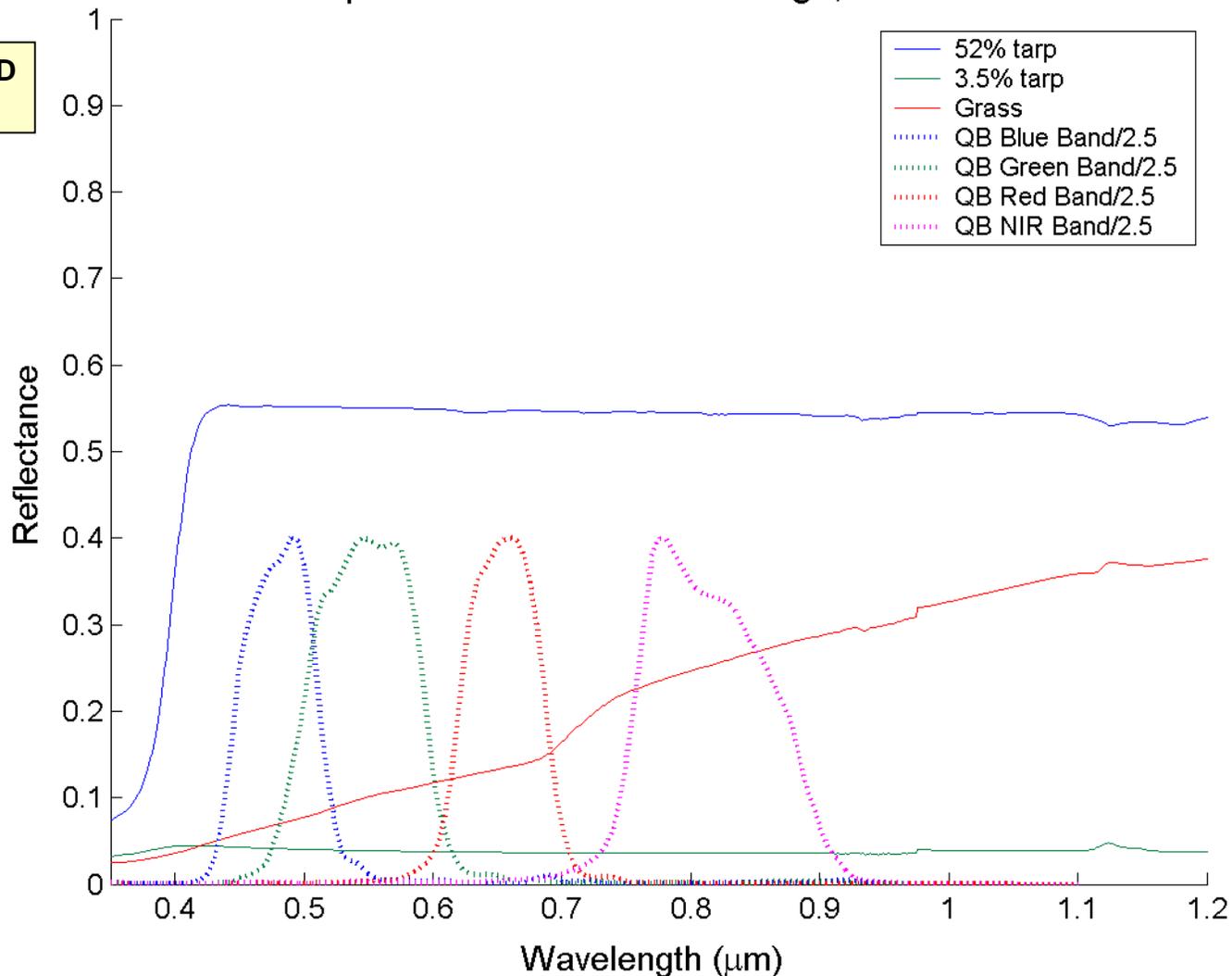
Spectroradiometer Data



Stennis Space Center

Spectral Albedo for Brookings, 7/20/02

Brookings, SD
July 20, 2002



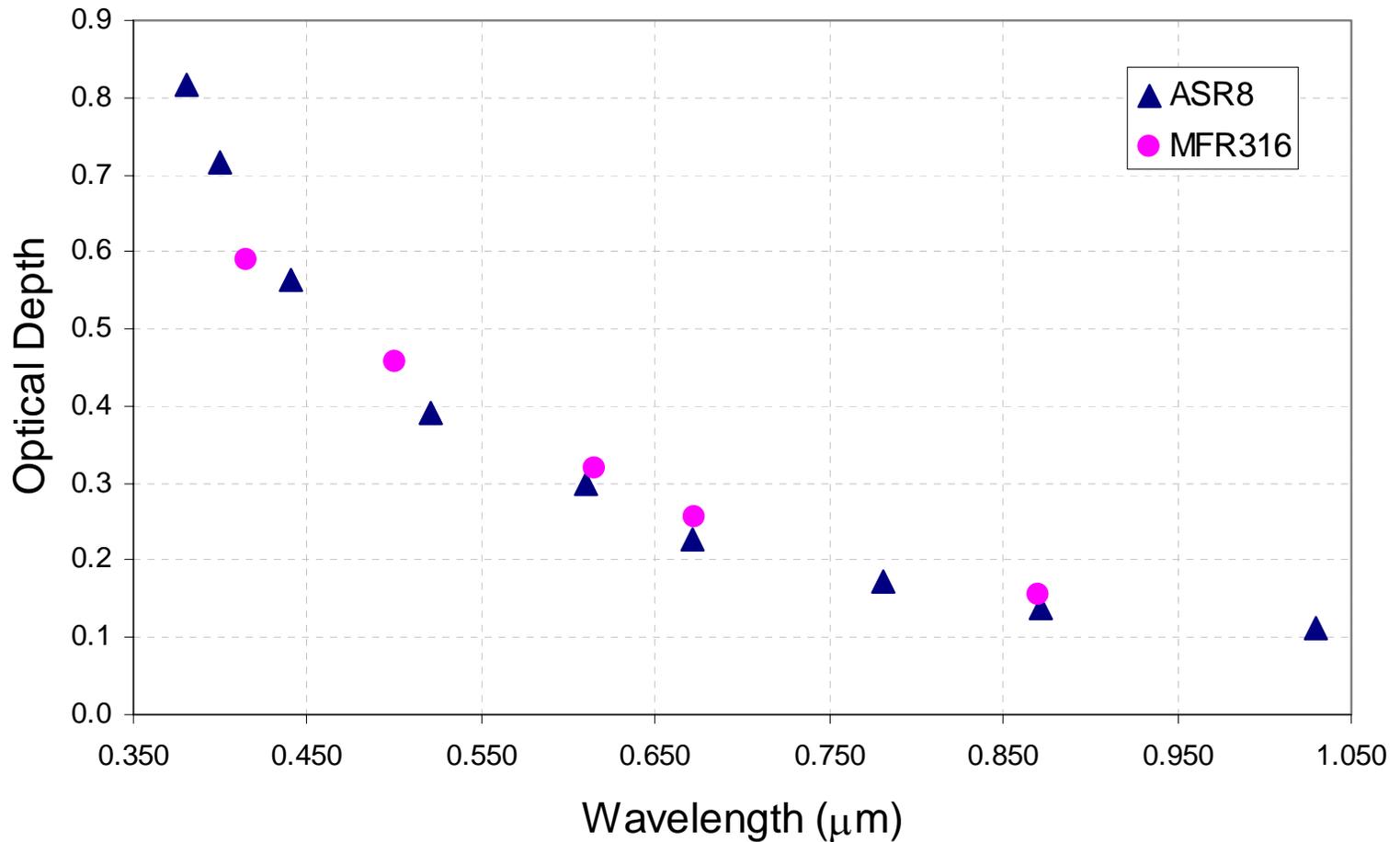


ASR/MFRSR Optical Depth Values

Stennis Space Center

Brookings, SD
July 20, 2002

Optical Depth for Brookings, July 20, 2002





DigitalGlobe Calibration Coefficients

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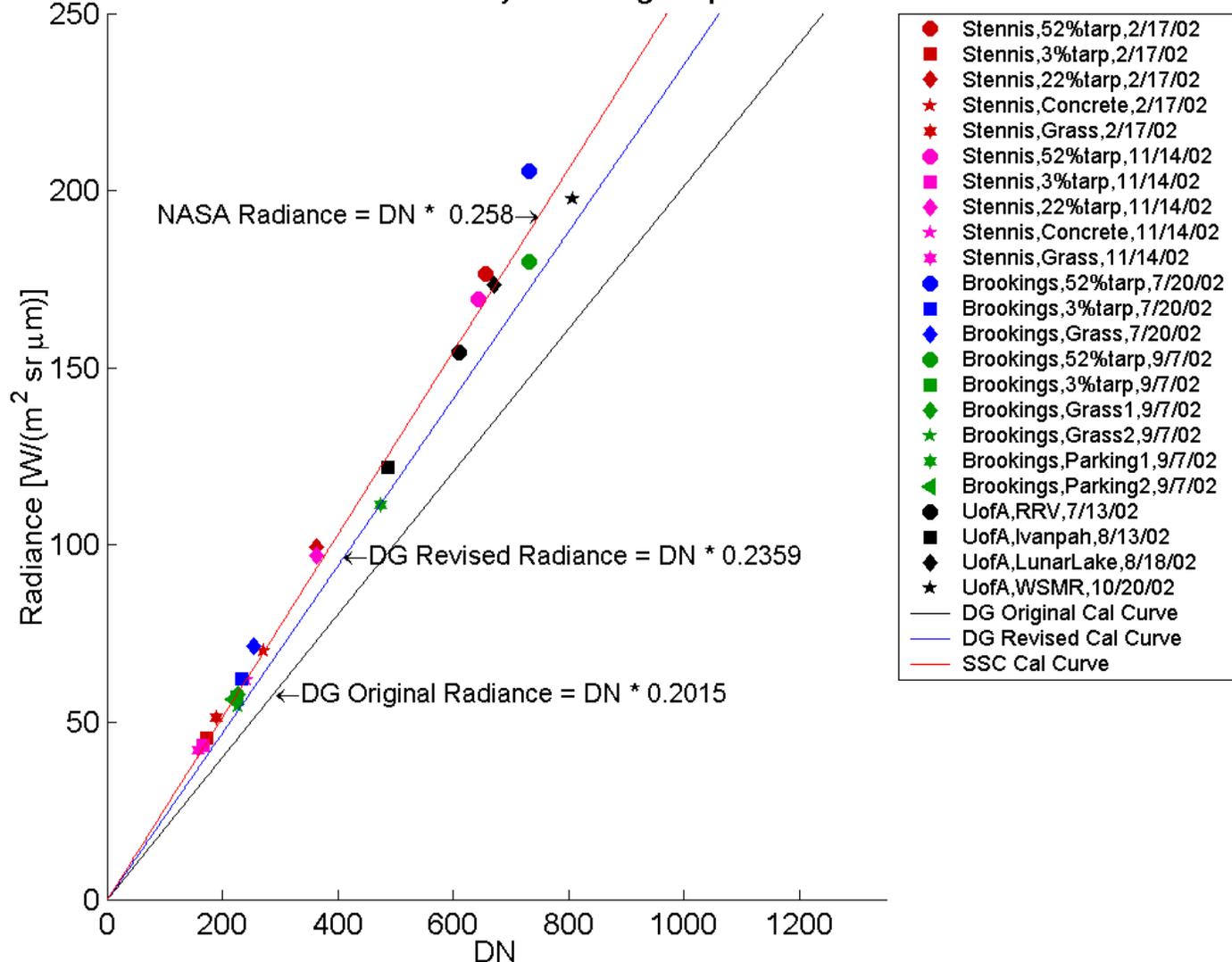
- DigitalGlobe publishes inband radiance calibration coefficients in the metadata files included with each image
 - For this study, NASA-generated coefficients were compared to DigitalGlobe average spectral radiance calibration coefficients.
 - Average spectral radiance coefficients can be computed for each band by dividing the inband coefficient by the width of the band
 - These average spectral radiance calibration coefficients are referred to as the “DigitalGlobe Original” coefficients
 - These coefficients are based on the overall system calibration of the QuickBird sensor
- DigitalGlobe provided the NASA team with a second set of calibration coefficients for comparison to NASA-generated coefficients
 - This set of coefficients has not been published by DigitalGlobe
 - This second set of average spectral radiance coefficients is referred to as the “DigitalGlobe Revised” coefficients
 - These coefficients are based on the subsystem (instrument minus telescope) calibration of the QuickBird sensor



QuickBird Blue Band Calibration Summary

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Blue Band Calibration Summary - Average Spectral Radiance

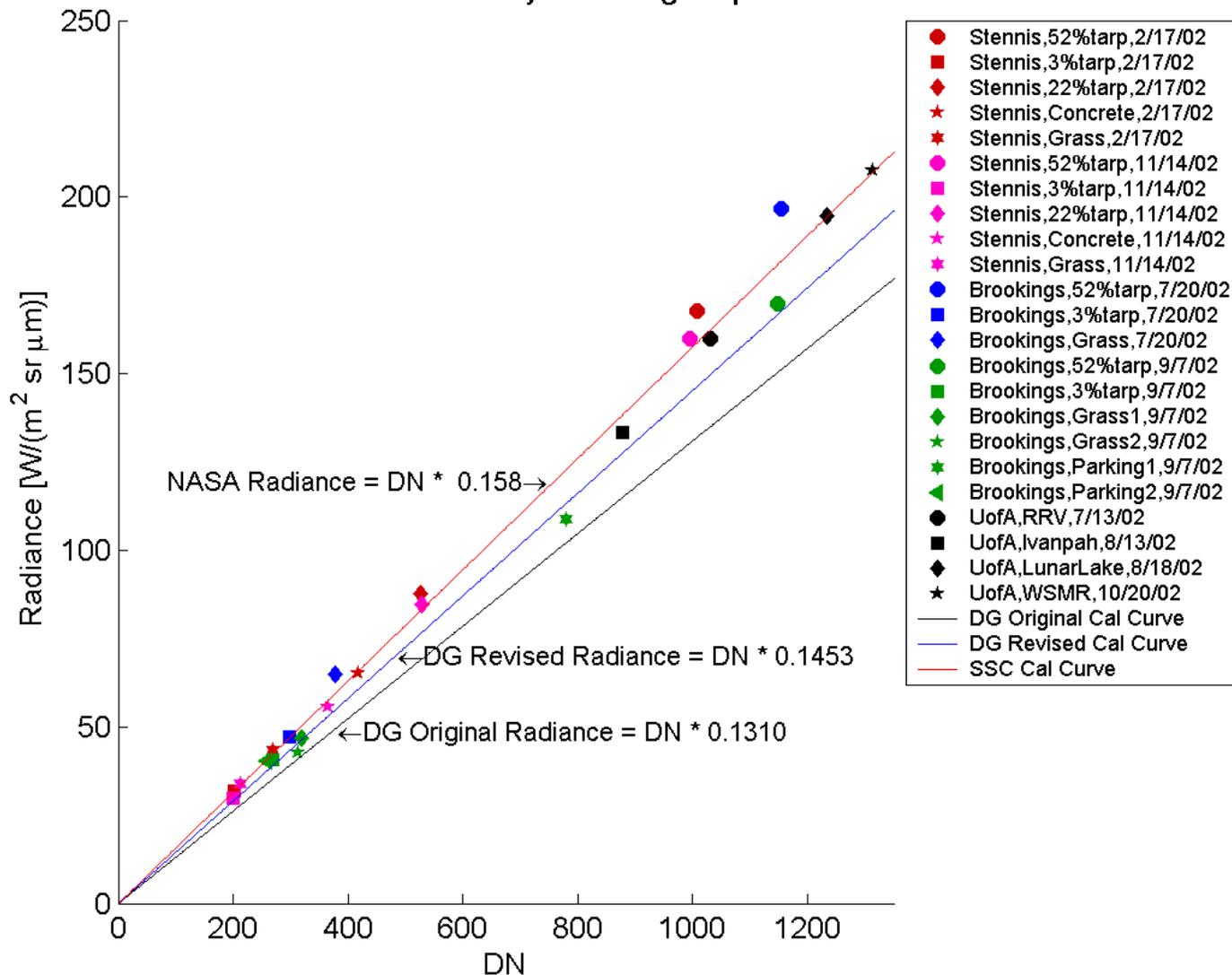


QuickBird Green Band Calibration Summary



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Green Band Calibration Summary - Average Spectral Radiance

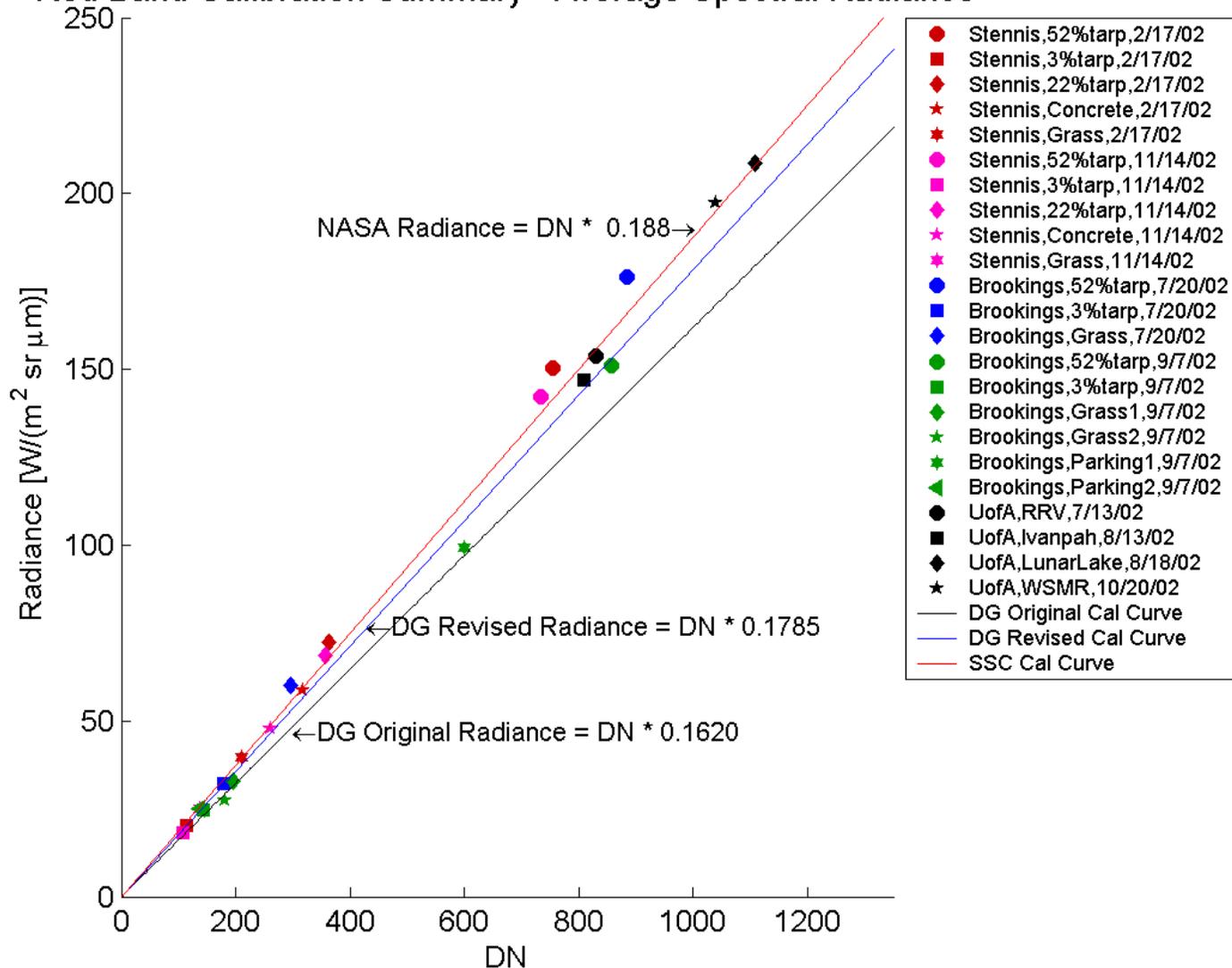




QuickBird Red Band Calibration Summary

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Red Band Calibration Summary - Average Spectral Radiance

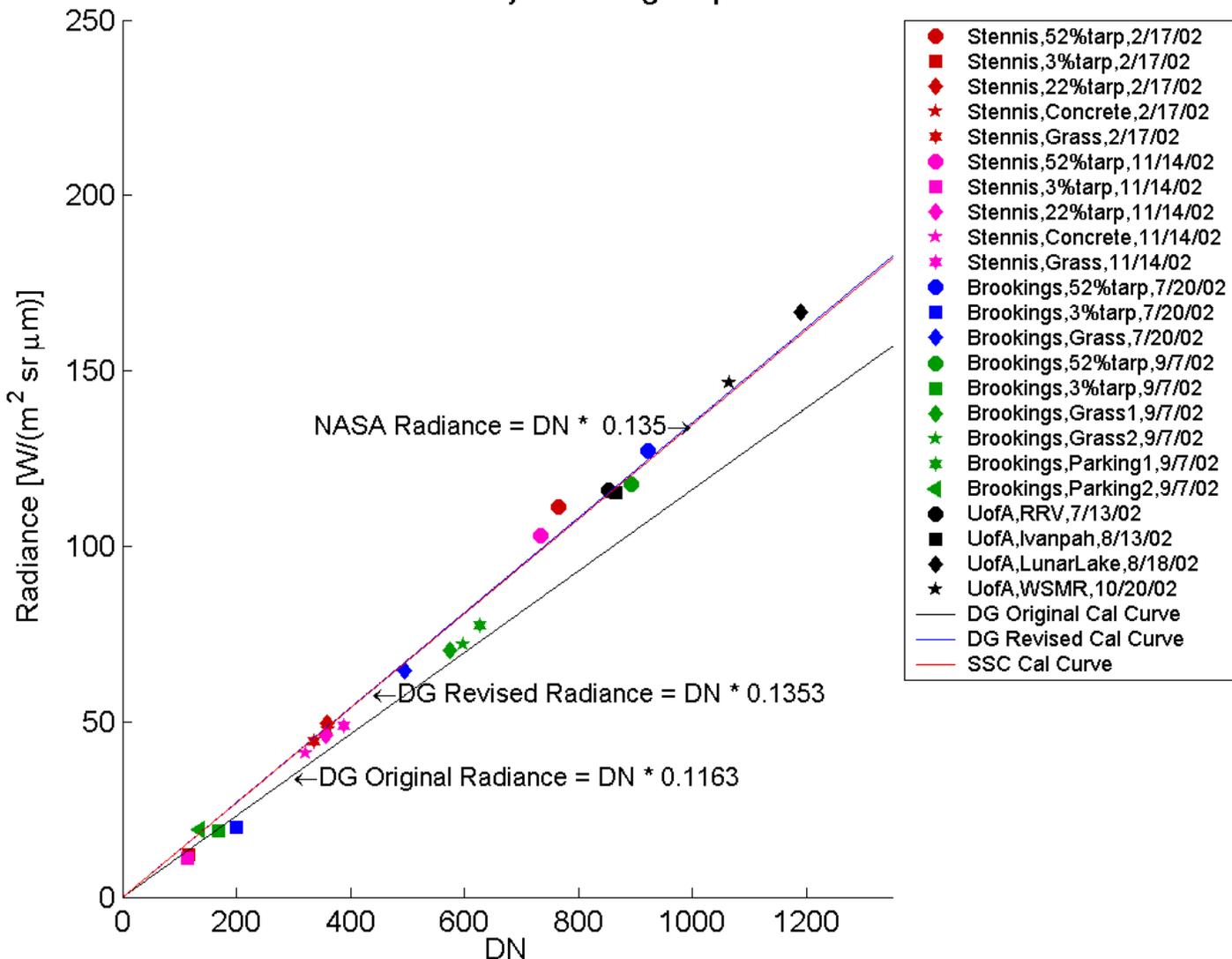




QuickBird NIR Band Calibration Summary

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NIR Band Calibration Summary - Average Spectral Radiance





QuickBird Radiometric Assessment

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Average Spectral Radiance Calibration Coefficients

Bandwidth FWHM (μm)	NASA Estimate ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	DigitalGlobe Original ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	% Difference
1 0.445 - 0.510	0.258	0.2015	21.9%
2 0.500 - 0.595	0.158	0.1310	16.9%
3 0.620 - 0.690	0.188	0.1620	13.7%
4 0.755 - 0.875	0.135	0.1163	13.7%

Percent difference is calculated by $\text{abs}(1 - \text{DigitalGlobe}/\text{NASA})$



QuickBird Radiometric Assessment

Stennis Space Center

Average Spectral Radiance Calibration Coefficients

Bandwidth FWHM (μm)	NASA Estimate ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	DigitalGlobe Revised ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	% Difference
1 0.445 - 0.510	0.258	0.2359	8.6%
2 0.500 - 0.595	0.158	0.1453	7.8%
3 0.620 - 0.690	0.188	0.1785	4.9%
4 0.755 - 0.875	0.135	0.1353	0.4%

Percent difference is calculated by $\text{abs}(1 - \text{DigitalGlobe}/\text{NASA})$



Summary

Stennis Space Center

- The “revised” average spectral radiance calibration coefficients provided by DigitalGlobe agree well with the NASA vicarious calibration
 - These results were obtained by two independent teams
- NASA Stennis Space Center will continue to assess QuickBird radiometry
 - A comprehensive error budget is being developed to include sun photometer calibration error, BRDF, reflectance measurement, and adjacency effect error