



Radiometric Characterization of the IKONOS, QuickBird, and OrbView-3 Sensors

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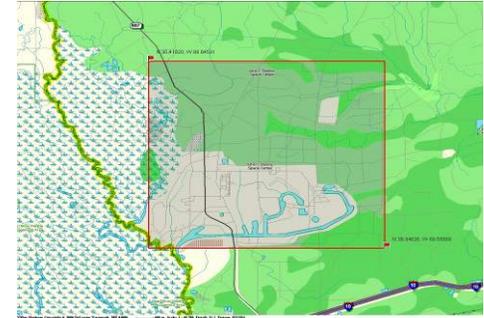
NASA Stennis Space Center, MS

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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
- **In-situ Instrumentation:** Analytical Spectral Devices FieldSpec® FR spectroradiometers, Yankee multifilter rotating shadowband radiometers (MFRSRs), automated solar radiometers (ASRs), novel hyperspectral sun photometer, Sippican® radiosonde, Yankee total sky imager, 20 m x 20 m radiometric tarps, 99% reflectance Spectralon® panels



General Scene



SSC Image Area
8.5 km x 8 km



OrbView-3 True-Color Imagery
March 12, 2005

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NASA SSC Target Field

Stennis Space Center

QuickBird Imagery
March 12, 2005
True-Color Pan-Sharpener





Wiggins, MS

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- **Site:** Rural area with a gravel pit sand site, large monoculture fields, and a cut-grass amateur golf course
- **Elevation:** 70 m – 85 m
- **Centerpoint:** 30.79° N, 89.06° W
- **In-situ Instrumentation:** Analytical Spectral Devices FieldSpec® FR spectroradiometers, Yankee MFRSRs, ASRs, Yankee total sky imager, 20 m x 20 m radiometric tarps, 99% reflectance Spectralon® panels



*IKONOS True-Color Imagery
March 24, 2005*

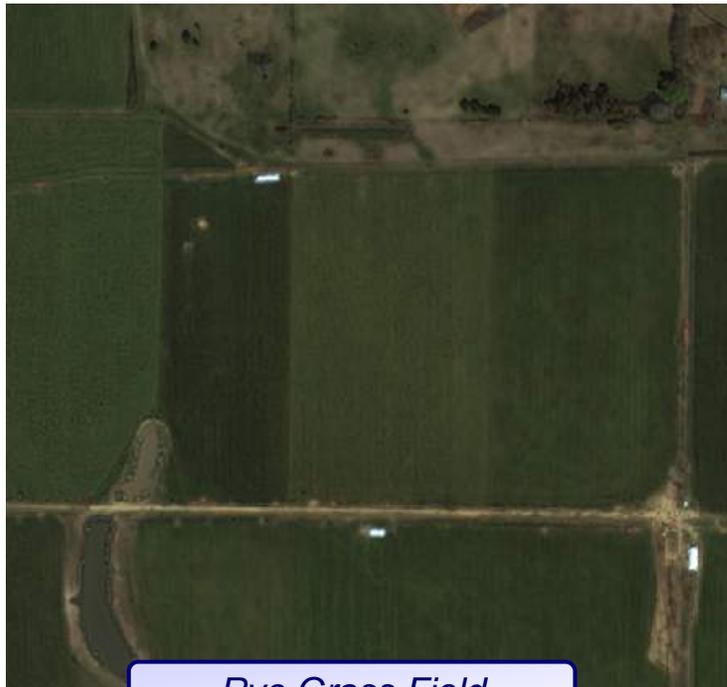
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Wiggins Target Fields

Stennis Space Center

*IKONOS Imagery
March 24, 2005
True-Color Pan-Sharpener*



Rye Grass Field

*Gravel Pit
Sand Site*



*Golf Course with
Radiometric Tarps*

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Park Falls, WI

Stennis Space Center

- **Site:** Heavily wooded rural area with a field containing an Aerosol Robotic Network (AERONET) site
- **Elevation:** 475 m
- **Centerpoint:** 45.95° N, 90.27° W
- ***In-situ* Instrumentation:** Analytical Spectral Devices FieldSpec® FR spectroradiometers, CIMEL Electronique automatic suntracking photometer, novel hyperspectral sun photometer, 20 m x 20 m radiometric tarps, 99% reflectance Spectralon® panels



General Scene



QuickBird True-Color Imagery
August 5, 2005

Includes material © DigitalGlobe™



Park Falls Target Field

Stennis Space Center



QuickBird Imagery
August 5, 2005
True-Color Pan-Sharpened



Includes material © DigitalGlobe™



Radiometric Tarps

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- Four 20 m x 20 m tarps with reflectance values of approximately 3.5%, 22%, 34%, and 52% within spectral measurement range
- Peak-to-peak variation in reflectance less than 10% within any 100 nm spectral band within spectral measurement range
- Less than 10% variation in reflectance values when measuring tarps from 10° to 60° off axis within spectral measurement range
- Spectral measurement range of 400 nm – 1050 nm
- Each side is straight to within ± 6.0 cm over the 20-m length
- Each tarp has 60 square witness samples measuring 30.5 cm x 30.5 cm

Manufactured by
MTL Systems, Inc. / Group VIII
Technology, Inc.



Radiometric Tarps

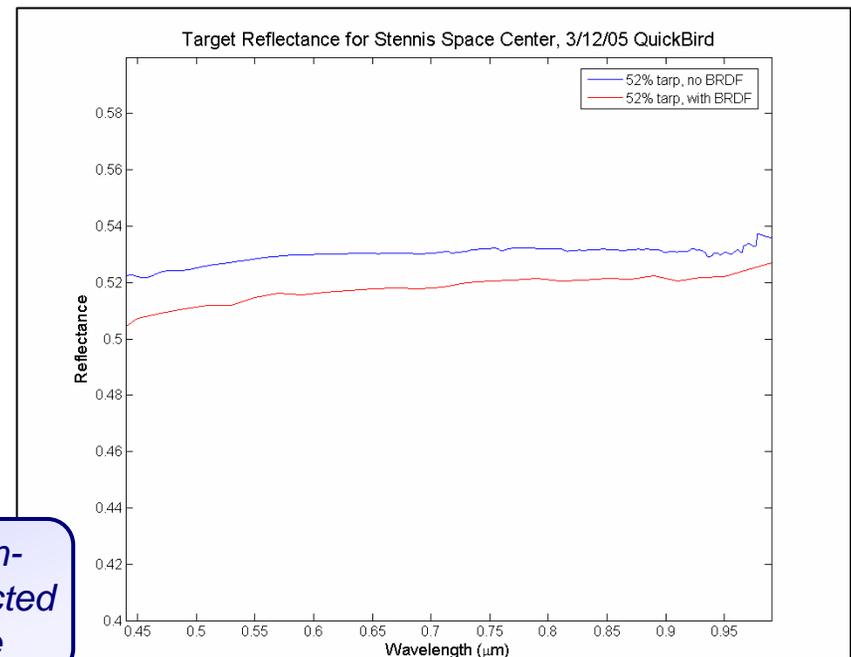
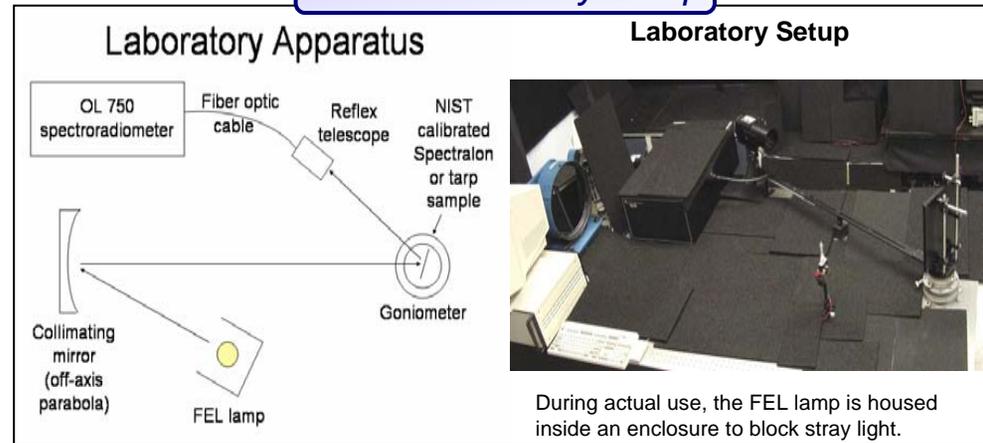


BRDF Correction

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BRDF Laboratory Setup

- Bidirectional Reflectance Distribution Function (BRDF) of radiometric tarp witness samples measured in laboratory
 - Witness samples removed from tarps after ground truth data collection
 - Sun and satellite geometry recreated in the laboratory to determine BRDF correction factors for each radiometric tarp
- Calculated correction factors incorporated into reflectance data files



Comparison of non-corrected and corrected target reflectance



SSC Calibration and Characterization of Spectroradiometers

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- NASA SSC maintains four Analytical Spectral Devices FieldSpec[®] FR spectroradiometers
 - Laboratory transfer radiometers
 - Ground surface reflectance for verification and validation (V&V) field collection activities
- Radiometric Calibration
 - National Institute of Standards and Technology (NIST)-calibrated integrating sphere serves as source with known spectral radiance
- Spectral Calibration
 - Laser and pen lamp illumination of integrating sphere
- Environmental Testing
 - Temperature stability tests performed in environmental chamber





Novel Hyperspectral Sun Photometer

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- Novel hyperspectral sun photometer is capable of acquiring measurements comparable to both ASRs and MFRSRs by making use of the laboratory radiometric calibration of the FieldSpec® FR spectroradiometers
 - Optical Depth/Transmission
 - Diffuse-to-Global Ratio
- Sun photometer developed with fewer limitations than current sun photometers, utilizing equipment already used in the field
 - Radiometrically calibrated FieldSpec® FR spectroradiometers
 - 99% reflectance Spectralon® panels
- Measurements are made only at the time of overpass, thus reducing the impact of a changing atmosphere on the calculation of optical depth
 - Resulted in a change to previously published OrbView-3 radiometric characterization

SSC 1/10/04 - 16:33 GMT				
	ASR 27	ASD	Difference	Percent Difference
Band	Generated	Generated	ASR-ASD	1 - (asd/asr)
380 nm	0.588	0.5982	-0.010	-1.74%
400 nm	0.495	0.4852	0.010	1.99%
440 nm	0.366	0.3216	0.044	12.14%
520 nm	0.224	0.1988	0.025	11.25%
610 nm	0.161	0.1563	0.005	2.91%
670 nm	0.108	0.1002	0.008	7.26%
780 nm	0.07	0.0691	0.001	1.33%
870 nm	0.049	0.0508	-0.002	-3.58%
RMS 1:8			0.019	

Sample Results



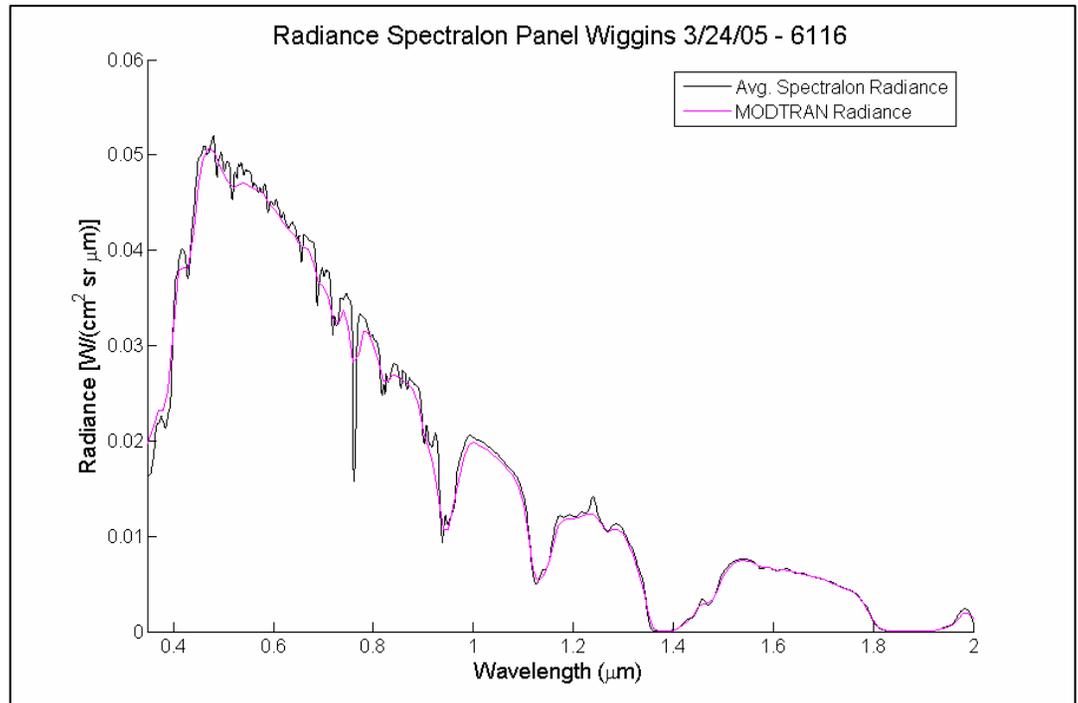
Novel Hyperspectral Sun Photometer Setup



Comparison to Spectralon Panel

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- Verification of parameters used to generate Moderate Resolution Transmittance (MODTRAN) at-sensor radiance estimate
 - Measuring the radiance of Spectralon® panel with a well-calibrated spectroradiometer is a way of measuring atmospheric global and diffuse irradiance
 - Use ground truth data and geometry modeling an ASD FieldSpec® FR spectroradiometer measuring a 99% reflectance Spectralon® panel as input to MODTRAN to predict radiance
 - Compare MODTRAN-calculated radiance to actual radiance measured from Spectralon® panel to verify the atmospheric model





IKONOS Radiometric Characterization

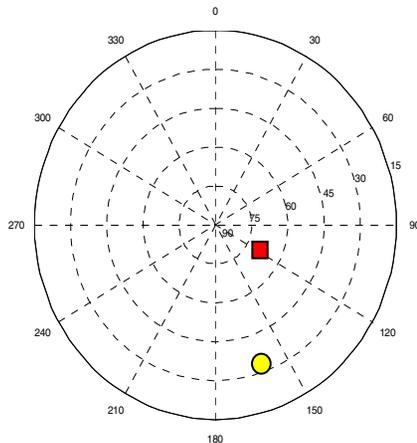


IKONOS Data Acquisitions

Stennis Space Center

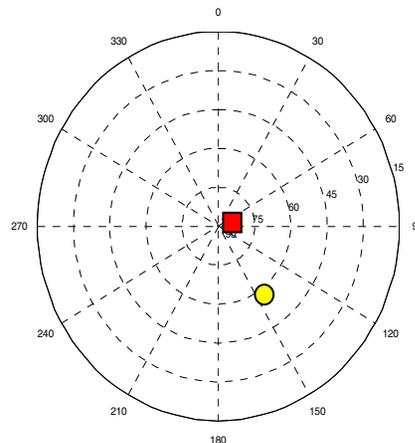
Site/Date	Overpass Time (UTC)	Satellite Elevation	Satellite Azimuth	Sun Elevation	Sun Azimuth
Stennis 12/15/04	16:45	68.9 deg	118.6 deg	34.0 deg	160.8 deg
Wiggins 3/24/05	16:50	86.3 deg	71.9 deg	56.3 deg	146.1 deg
Stennis 4/15/05	16:51	72.7 deg	25.4 deg	64.5 deg	138.8 deg

Standard imagery
Cubic Convolution resampling, MTF Off



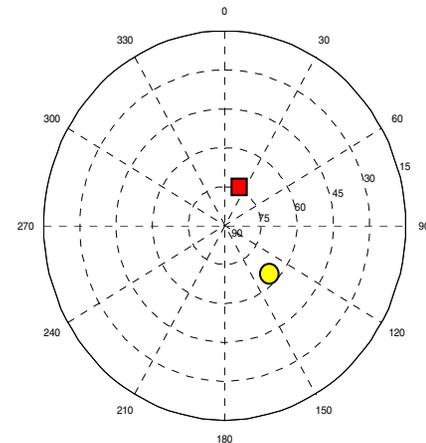
Stennis Space Center, MS, 12/15/04

● Sun
■ IKONOS



Wiggins, MS, 3/24/05

● Sun
■ IKONOS



Stennis Space Center, MS, 4/15/05

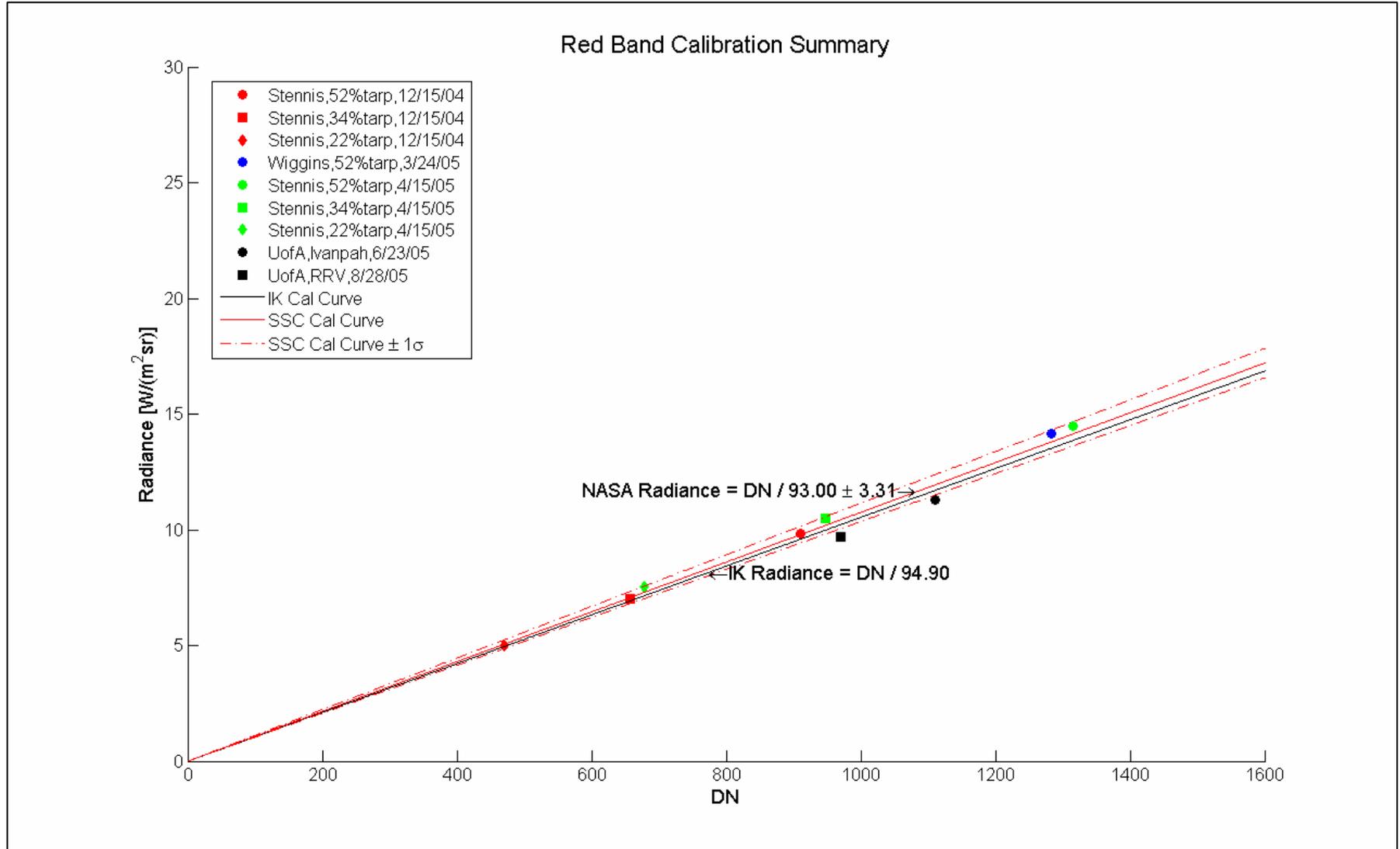
● Sun
■ IKONOS





IKONOS Sample Calibration Summary

Stennis Space Center





2004/2005 IKONOS Radiometric Assessment

Stennis Space Center

Inband Radiance Calibration Coefficients

Bandwidth FWHM (μm)	NASA Team Estimate [DN/(W/m² sr)]	IKONOS Provided [DN/(W/m²sr)]	% Difference
1 0.450 - 0.520	67.8 \pm 2.6	72.8	-7.4%
2 0.510 - 0.600	71.2 \pm 2.9	72.7	-2.1%
3 0.630 - 0.700	93.0 \pm 3.3	94.9	-2.0%
4 0.760 - 0.850	82.3 \pm 2.1	84.3	-2.4%

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



2004/2005 IKONOS Results Summary

Stennis Space Center

- The NASA team of University of Arizona, South Dakota State University, and NASA SSC produce consistent results
- The IKONOS calibration coefficients continue to agree well with the NASA team estimate (within 2.5% except for blue band)
- The NASA team will continue to assess IKONOS radiometric accuracy



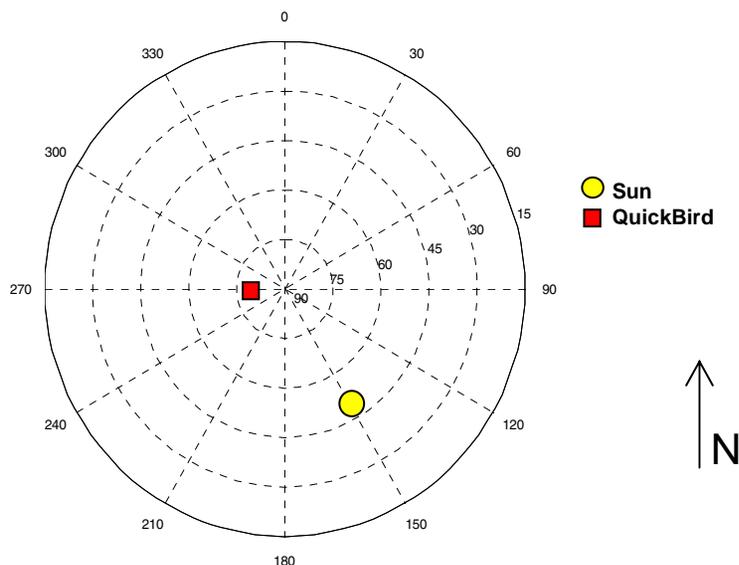
QuickBird Radiometric Characterization



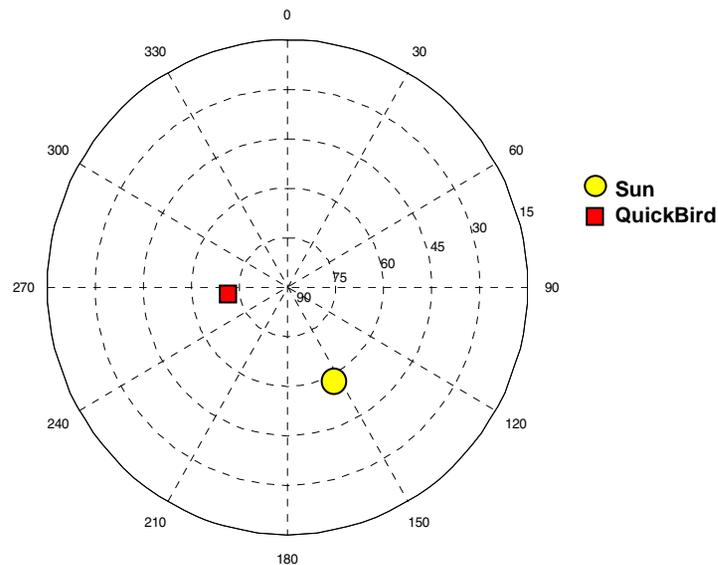
QuickBird Data Acquisitions

Stennis Space Center

Site/Date	Overpass Time (UTC)	Satellite Elevation	Satellite Azimuth	Sun Elevation	Sun Azimuth
Stennis 3/12/05	16:55	78 deg	270 deg	52.4 deg	149.2 deg
Standard imagery 4x4 Cubic Convolution resampling					
Park Falls 8/5/05	17:20	69.3 deg	261.6 deg	59.4 deg	157.4 deg
Standard imagery Nearest Neighbor resampling					



Stennis Space Center, MS, 3/12/05

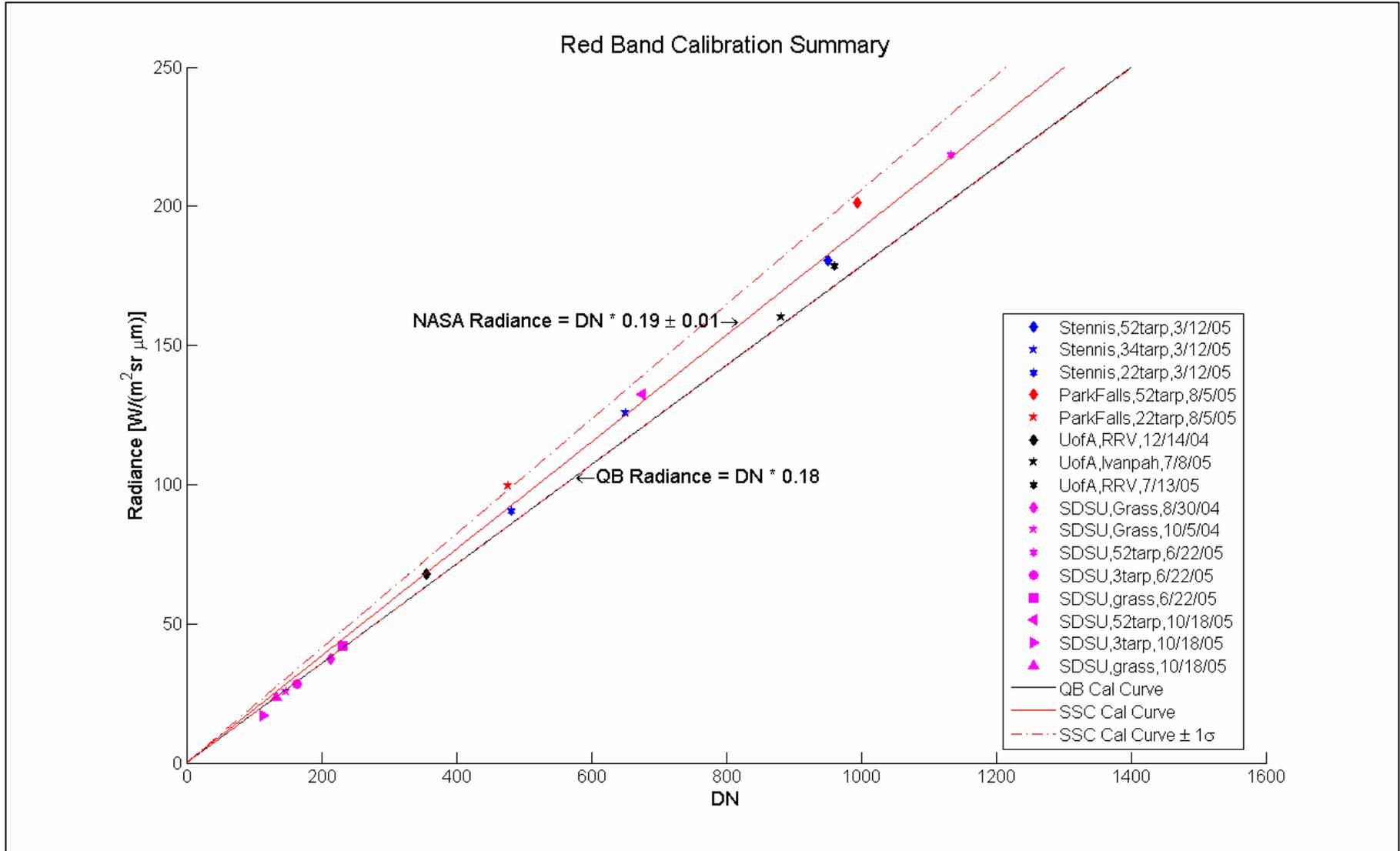


Park Falls, WI, 8/5/05



QuickBird Sample Calibration Summary

Stennis Space Center





2004/2005 QuickBird Radiometric Assessment

Stennis Space Center

Average Spectral Radiance Calibration Coefficients

Bandwidth FWHM (μm)	NASA Team Estimate ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	QuickBird Provided ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	% Difference
1 0.445 - 0.510	0.26 ± 0.02	0.236	9.2%
2 0.500 - 0.595	0.16 ± 0.01	0.145	9.4%
3 0.620 - 0.690	0.19 ± 0.01	0.179	5.8%
4 0.755 - 0.875	0.14 ± 0.01	0.135	3.6%

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



2004/2005 QuickBird Results Summary

Stennis Space Center

- The NASA team of University of Arizona, South Dakota State University, and NASA SSC produce consistent results
- The QuickBird calibration coefficients continue to agree reasonably well with the NASA team estimate (within 10%)
- The NASA team will continue to assess QuickBird radiometric accuracy



OrbView-3 Radiometric Characterization

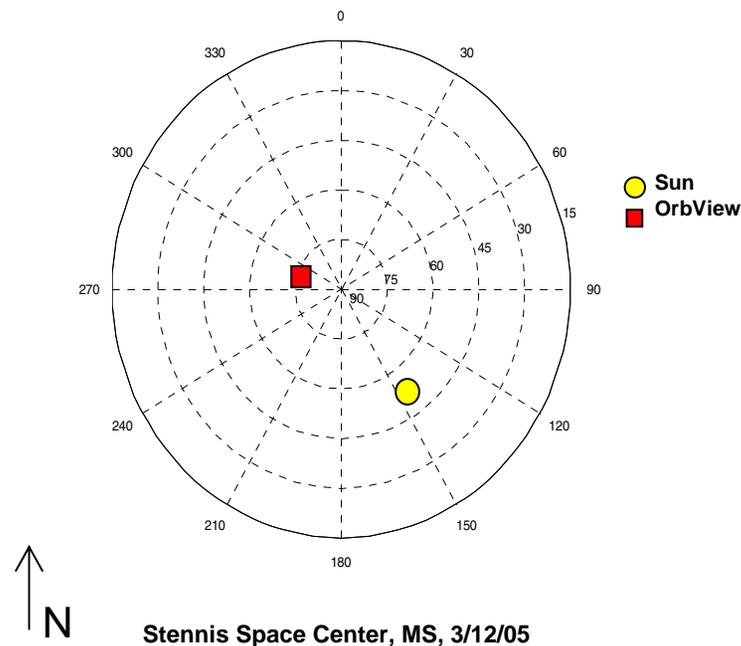


OrbView-3 Data Acquisitions

Stennis Space Center

Site/Date	Overpass Time (UTC)	Satellite Elevation	Satellite Azimuth	Sun Elevation	Sun Azimuth
Stennis 3/12/05	16:53	76.1 deg	283.8 deg	52.0 deg	148.6 deg

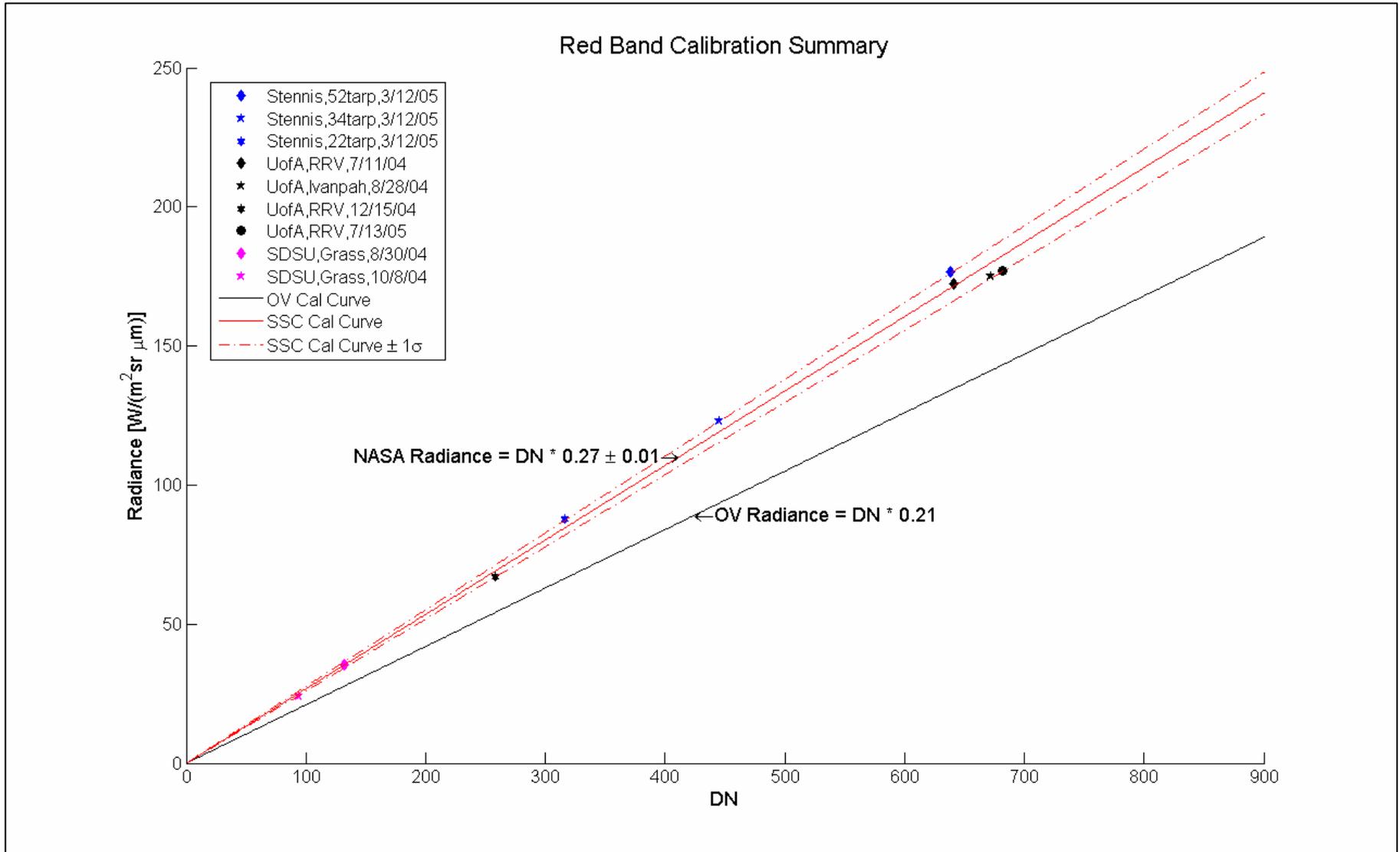
Basic imagery





OrbView-3 Sample Calibration Summary

Stennis Space Center





2004/2005 OrbView-3 Radiometric Assessment

Stennis Space Center

Average Spectral Radiance Calibration Coefficients

Bandwidth FWHM (μm)	NASA Team Estimate ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	OrbView Provided ($\text{W}/\text{m}^2 \text{ sr } \mu\text{m DN}$)	% Difference
1 0.450 - 0.520	0.35 ± 0.02	0.269	23.1%
2 0.520 - 0.600	0.31 ± 0.01	0.249	19.7%
3 0.625 - 0.695	0.27 ± 0.01	0.210	22.2%
4 0.760 - 0.900	0.18 ± 0.00	0.142	21.1%

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



2004/2005 OrbView-3 Results Summary

Stennis Space Center

- The NASA team of University of Arizona, South Dakota State University, and NASA SSC produce consistent results
- The OrbView calibration coefficients do not appear to agree well with the NASA team estimate (~20% difference)
- Discussions with GeoEye™ (formerly ORBIMAGE®) personnel are ongoing to update the calibration coefficients
- The NASA team will continue to assess OrbView radiometric accuracy



Contributors

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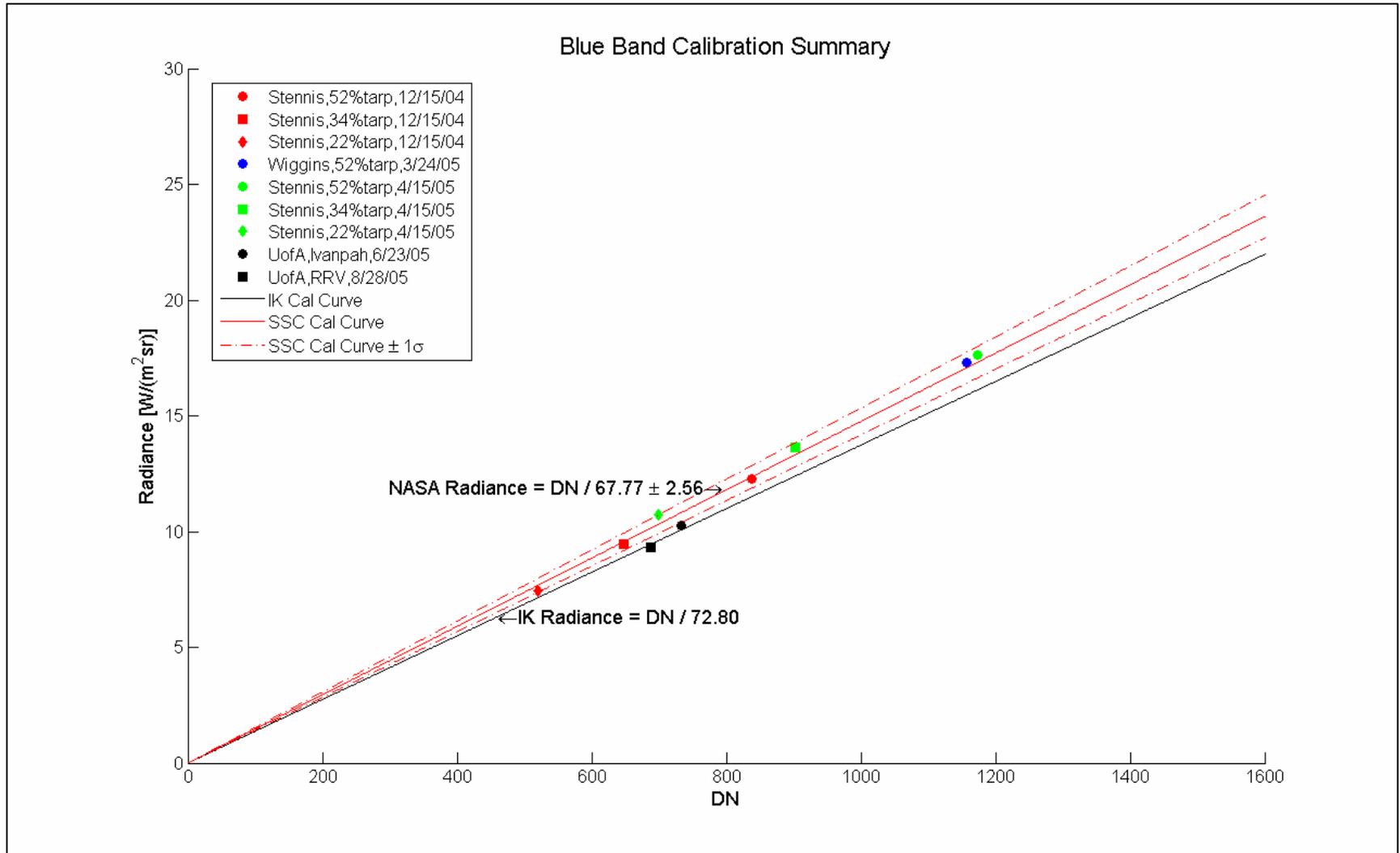


Back-up

IKONOS Blue Band Calibration Summary



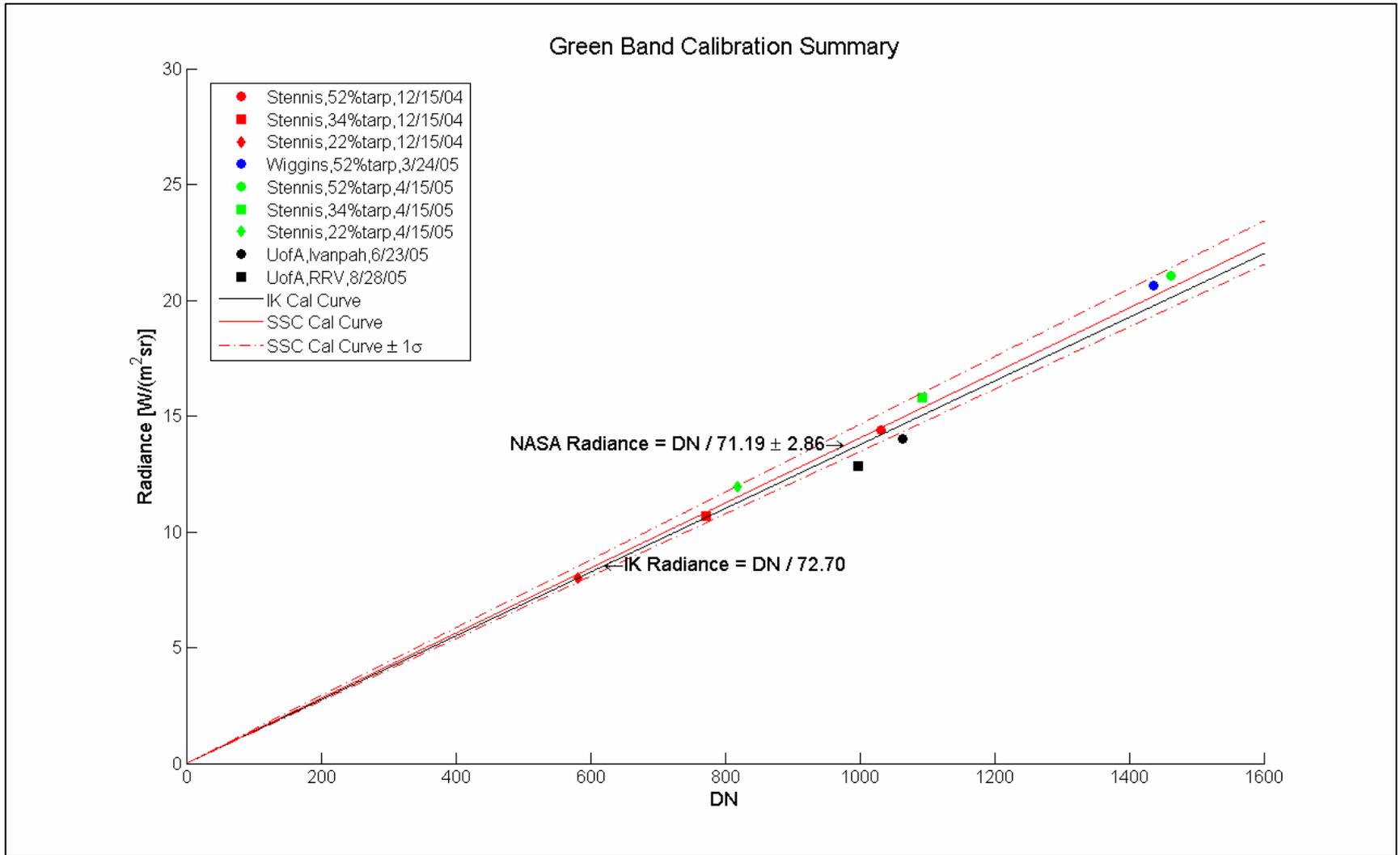
Stennis Space Center



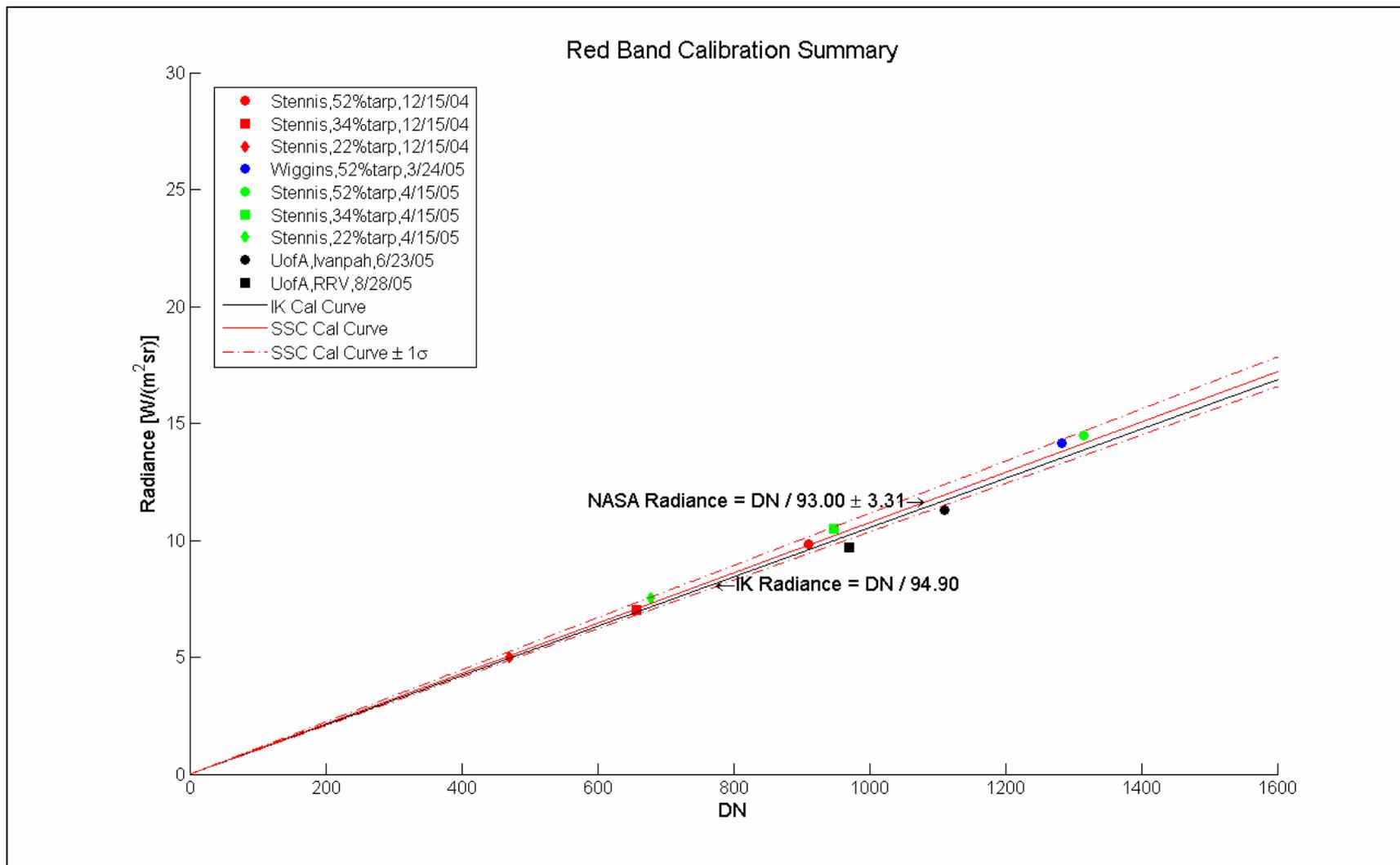
IKONOS Green Band Calibration Summary



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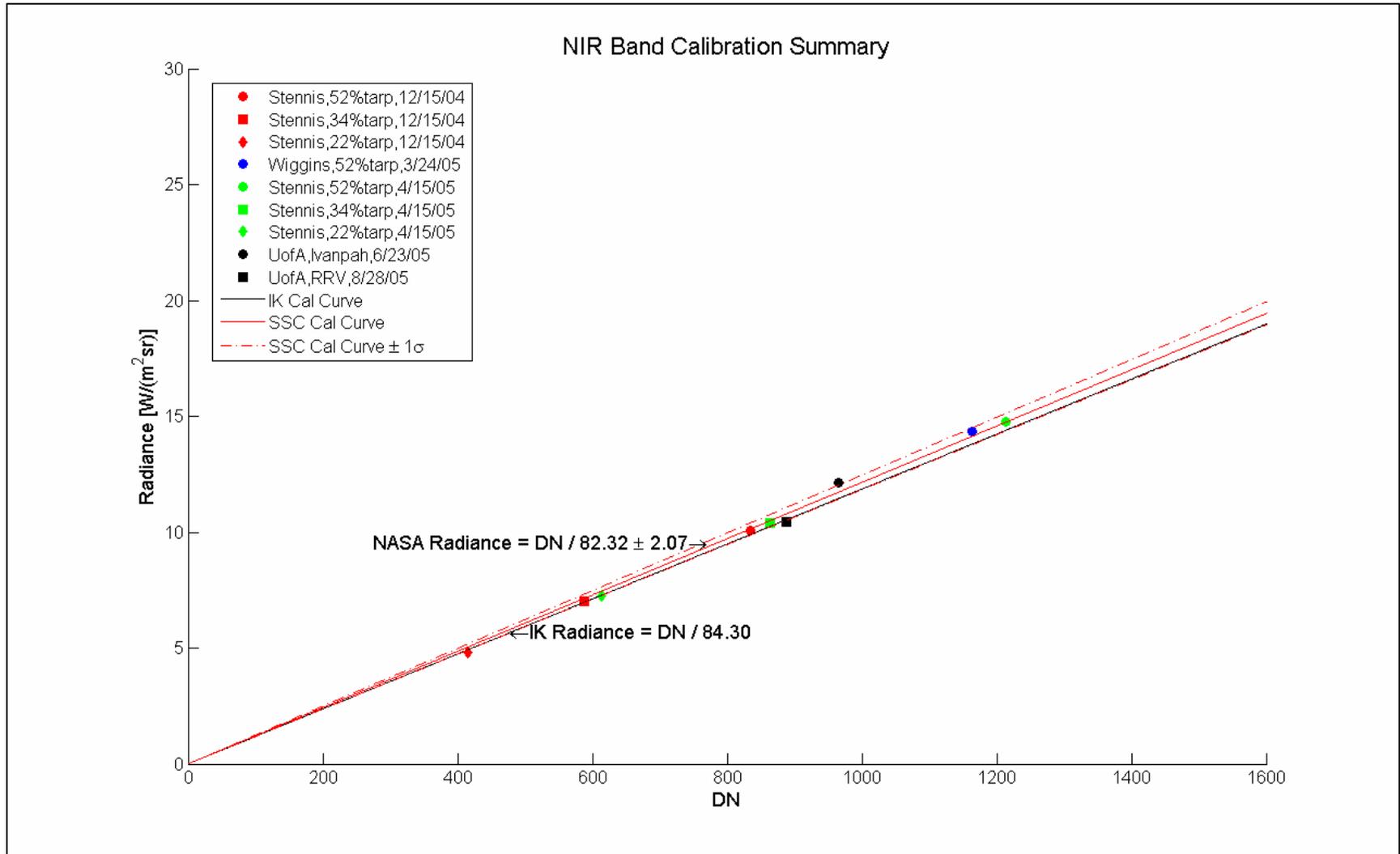
IKONOS Red Band Calibration Summary



IKONOS NIR Band Calibration Summary



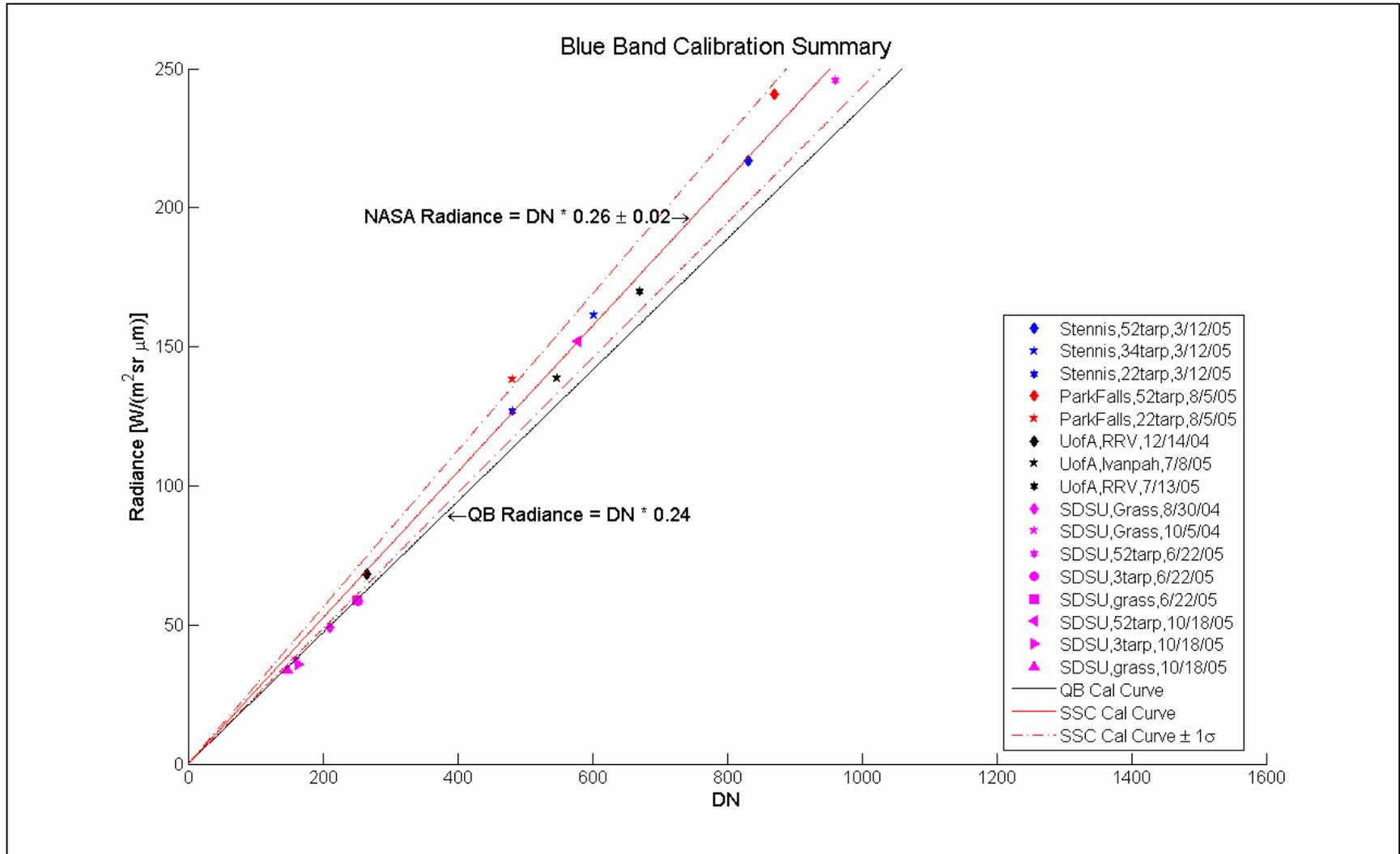
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QuickBird Blue Band Calibration Summary

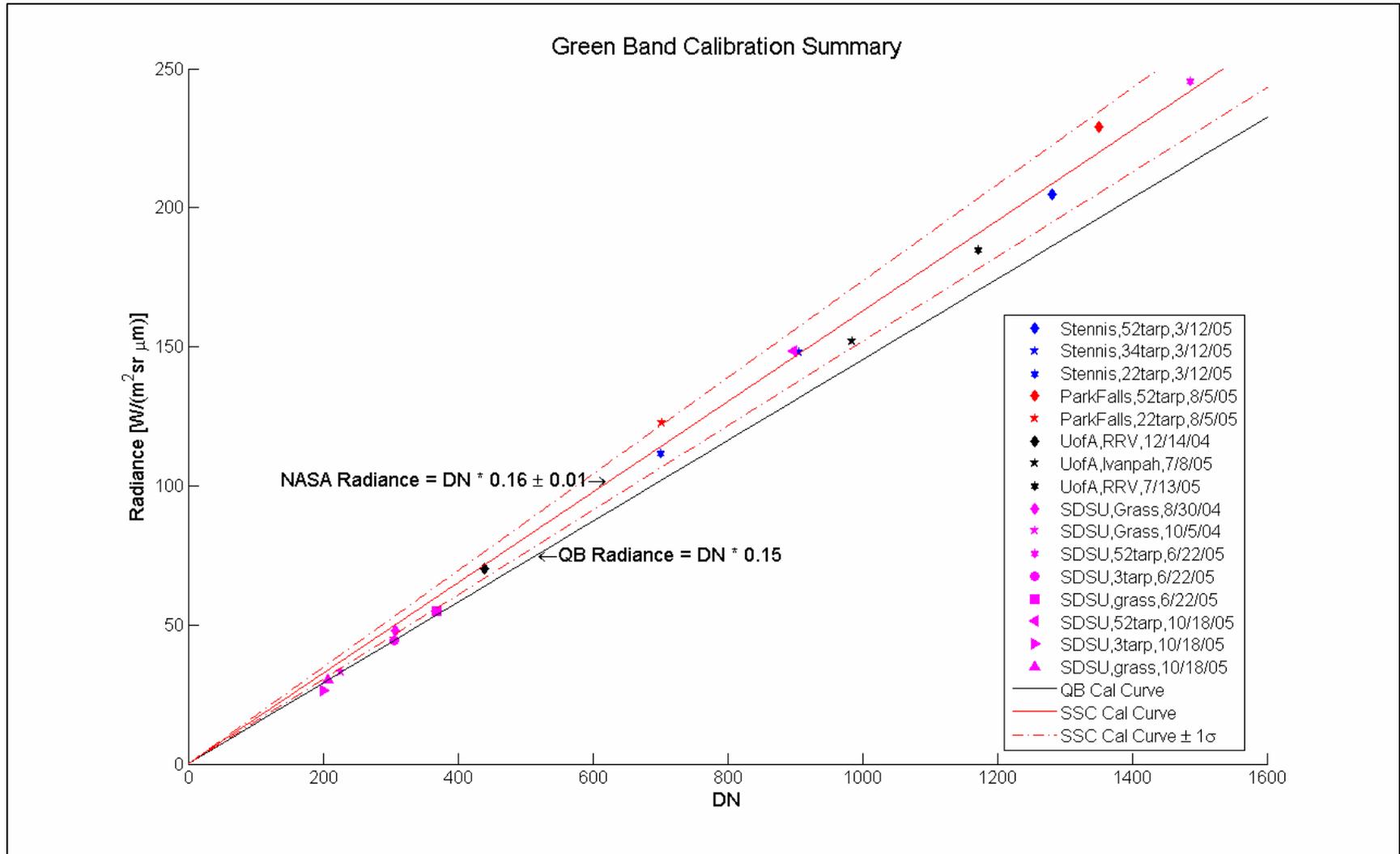
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QuickBird Green Band Calibration Summary

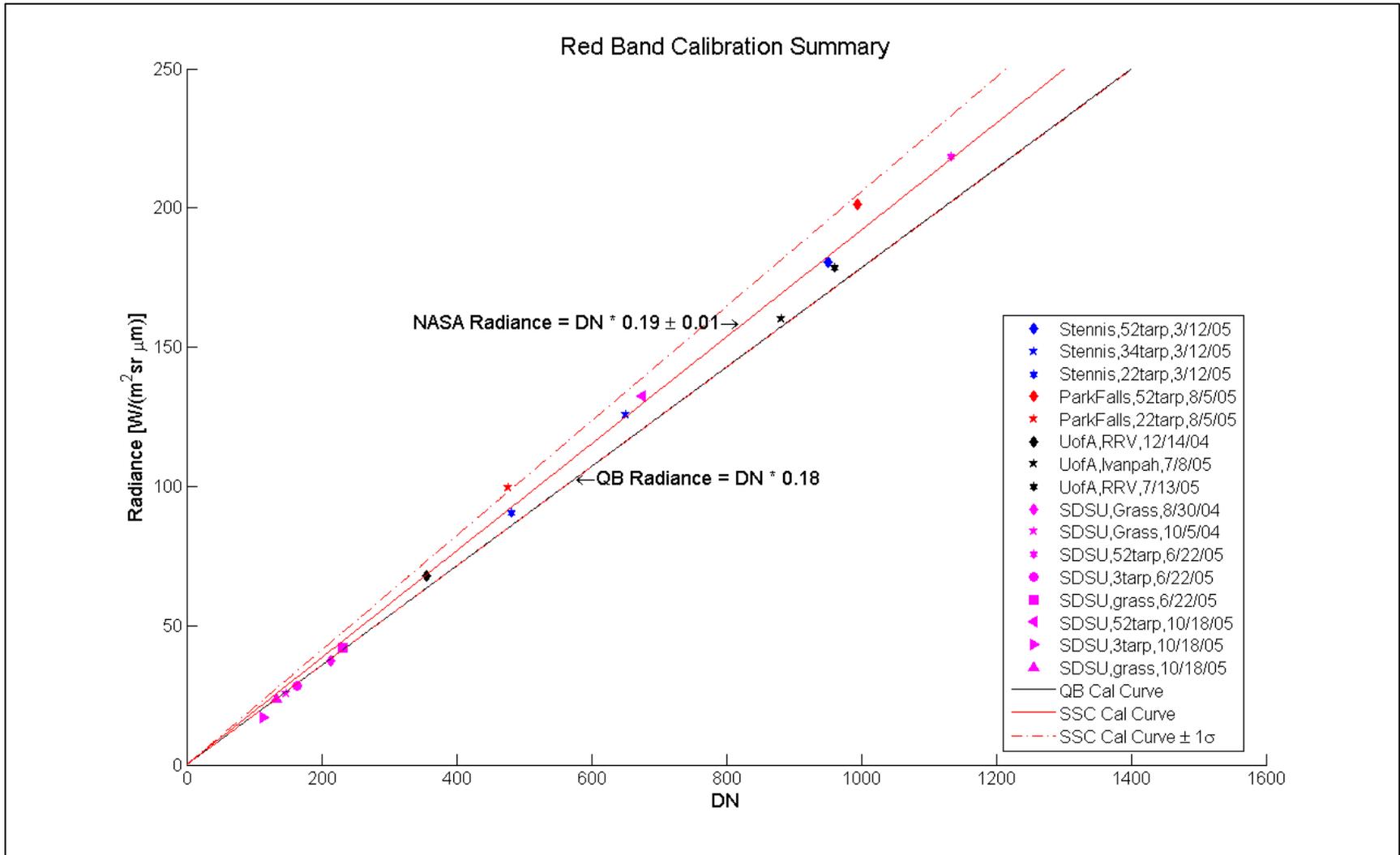
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QuickBird Red Band Calibration Summary



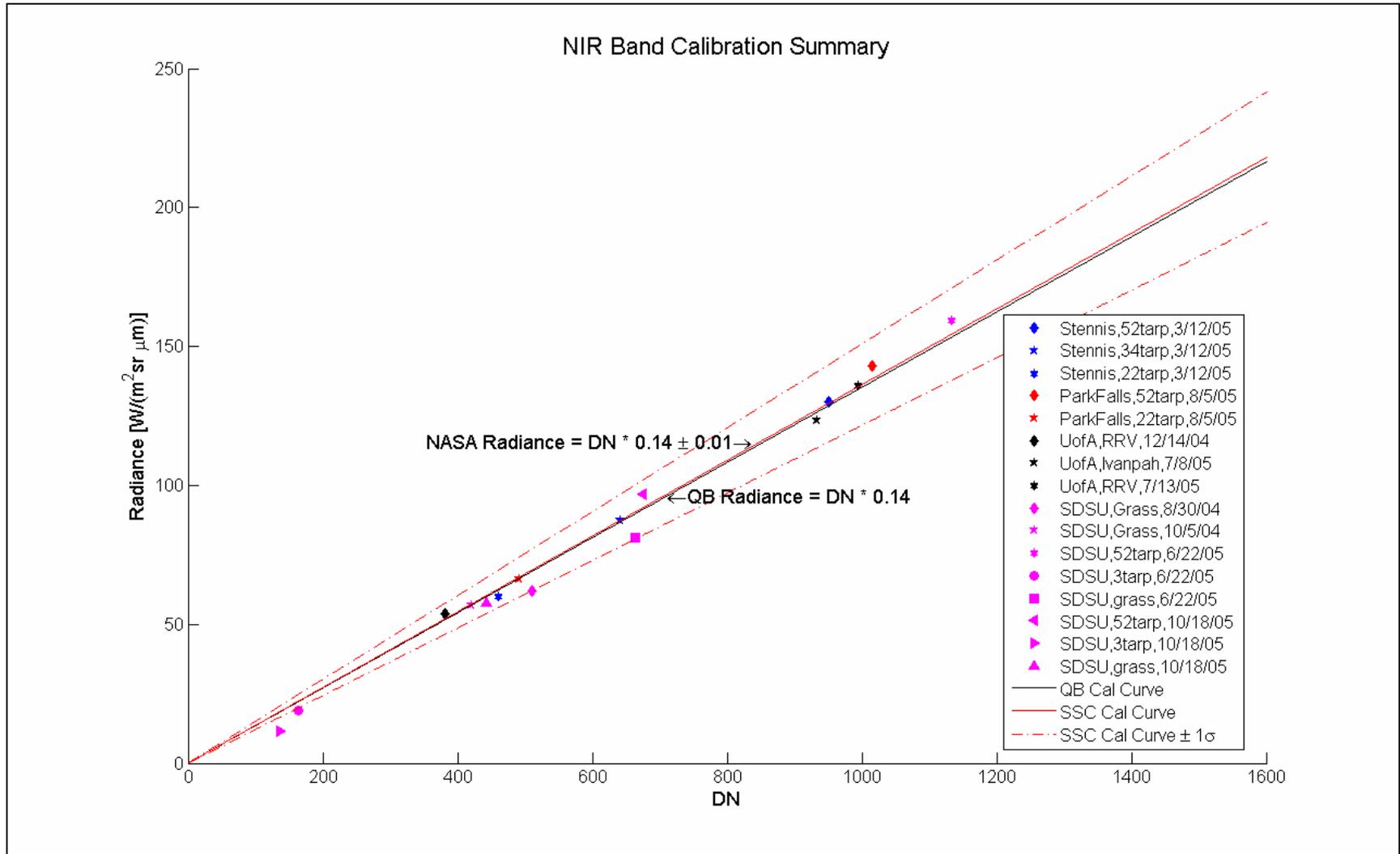
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QuickBird NIR Band Calibration Summary



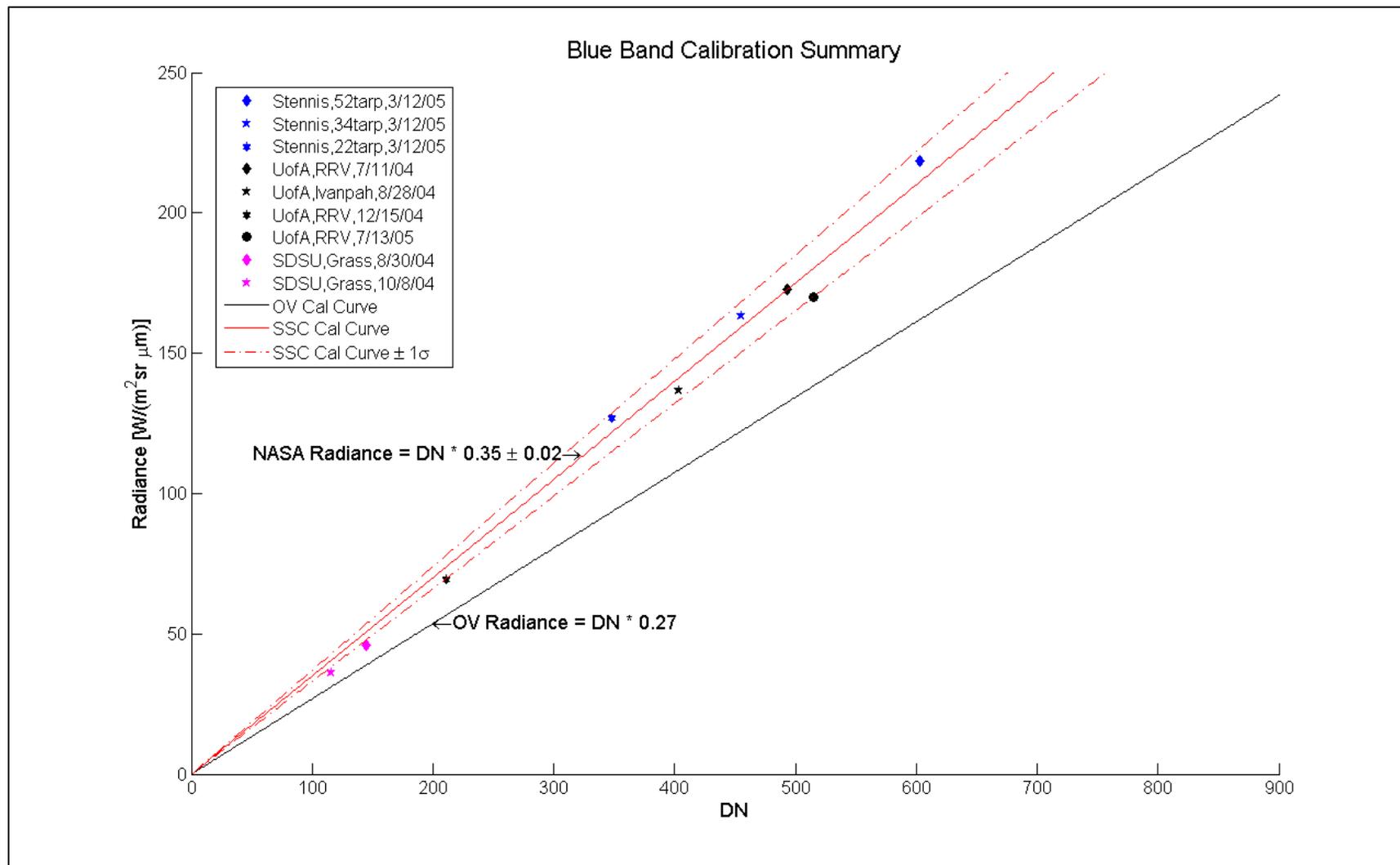
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OrbView-3 Blue Band Calibration Summary

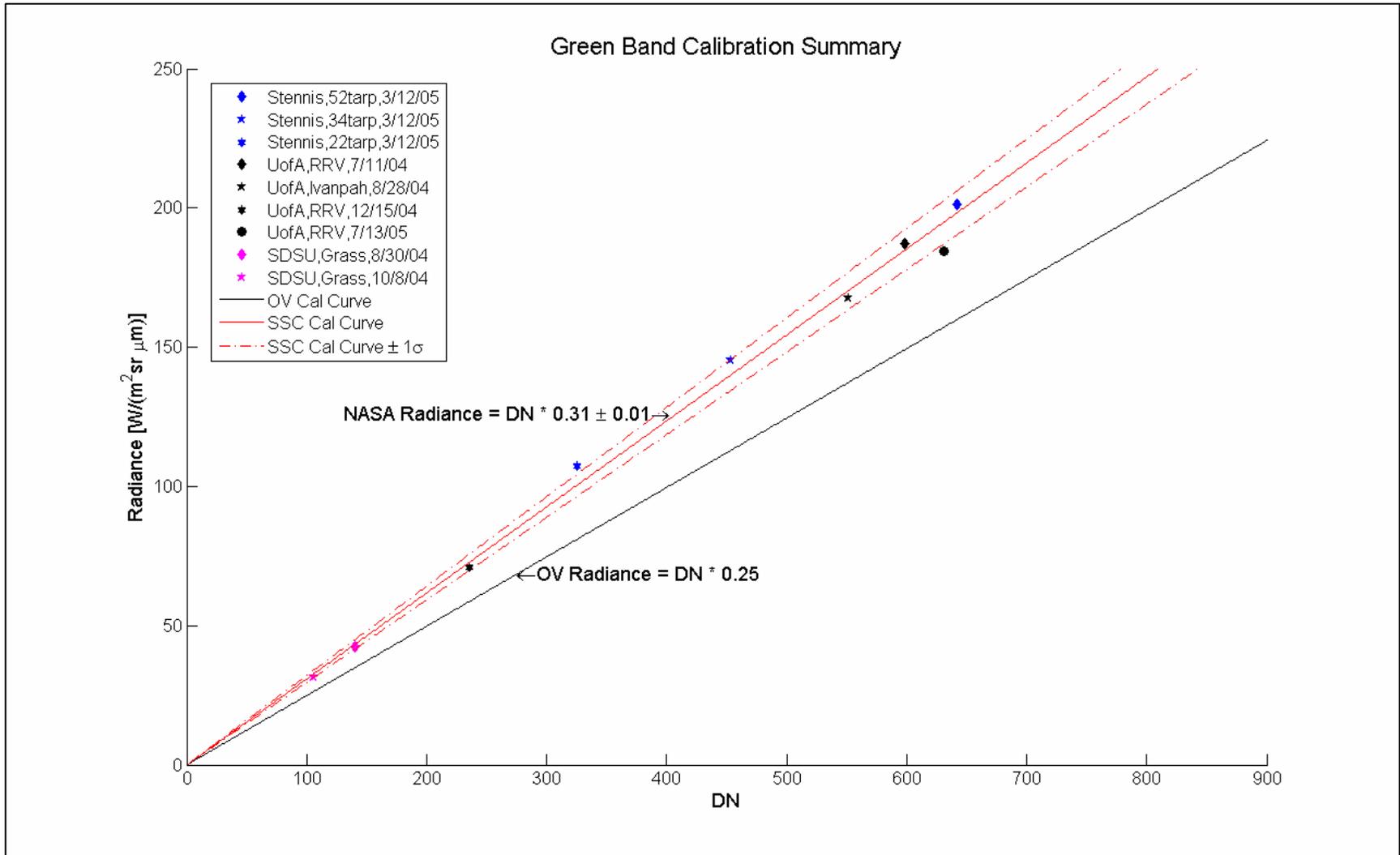
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OrbView-3 Green Band Calibration Summary

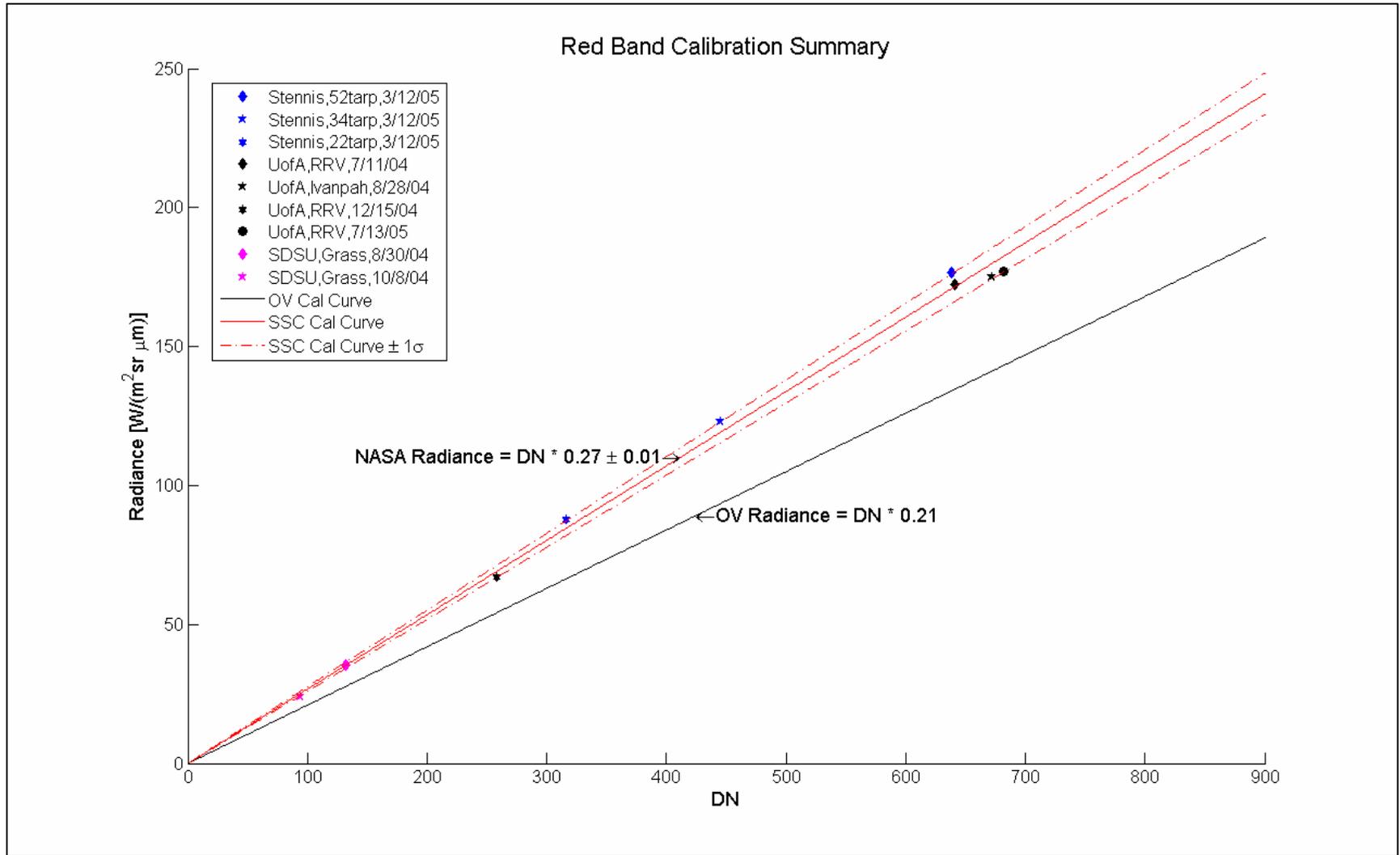
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OrbView-3 Red Band Calibration Summary



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OrbView-3 NIR Band Calibration Summary



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