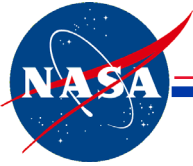


# **Radiometric Characterization of the IKONOS, QuickBird, and OrbView-3 Sensors**

**Kara Holekamp**

Science Systems and Applications, Inc.  
John C. Stennis Space Center, MS 39529  
228-688-3840  
[kara.holekamp@ssc.nasa.gov](mailto:kara.holekamp@ssc.nasa.gov)

2006 Civil Commercial Imagery Evaluation Workshop  
Laurel, Maryland, USA  
March 14–16, 2006



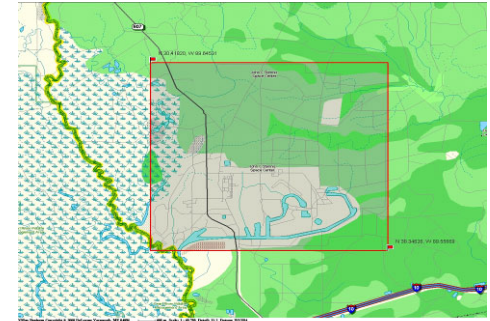
# NASA Stennis Space Center, MS

Stennis Space Center

- **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

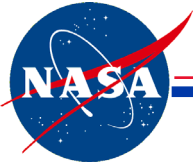


SSC Image Area  
8.5 km x 8 km



OrbView-3 True-Color Imagery  
March 12, 2005

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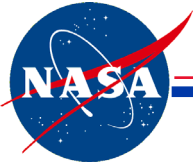
# NASA SSC Target Field

Stennis Space Center

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



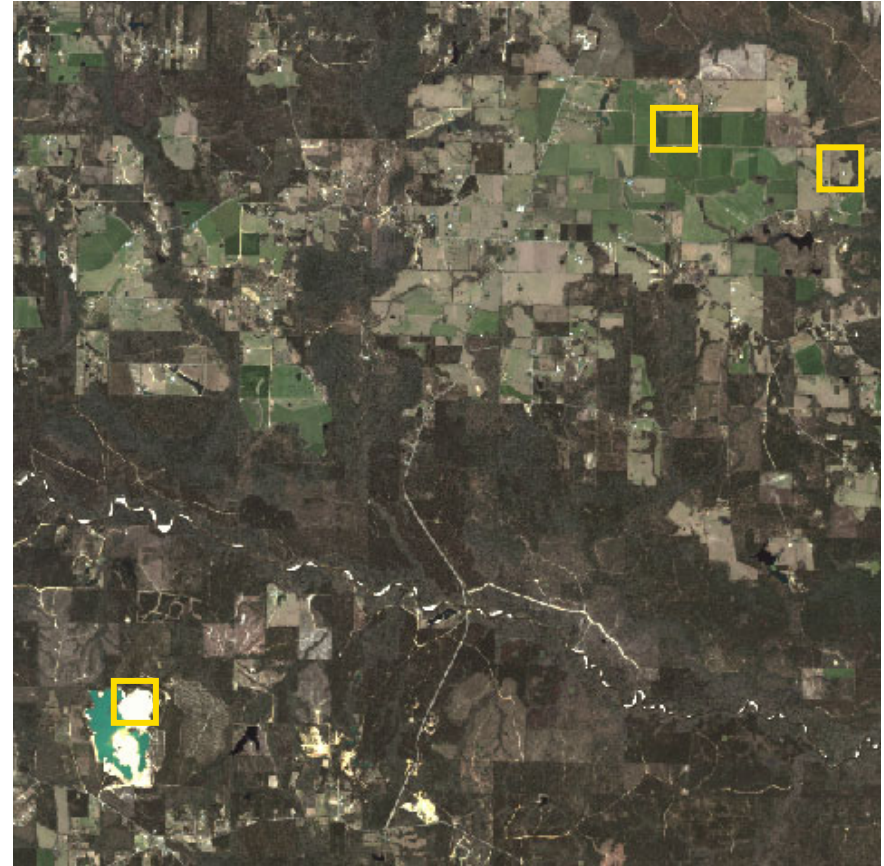
Includes material © DigitalGlobe™  
2006 Civil Commercial Imagery Evaluation Workshop, Laurel, MD



# Wiggins, MS

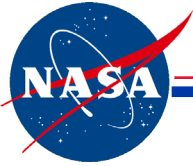
Stennis Space Center

- **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*

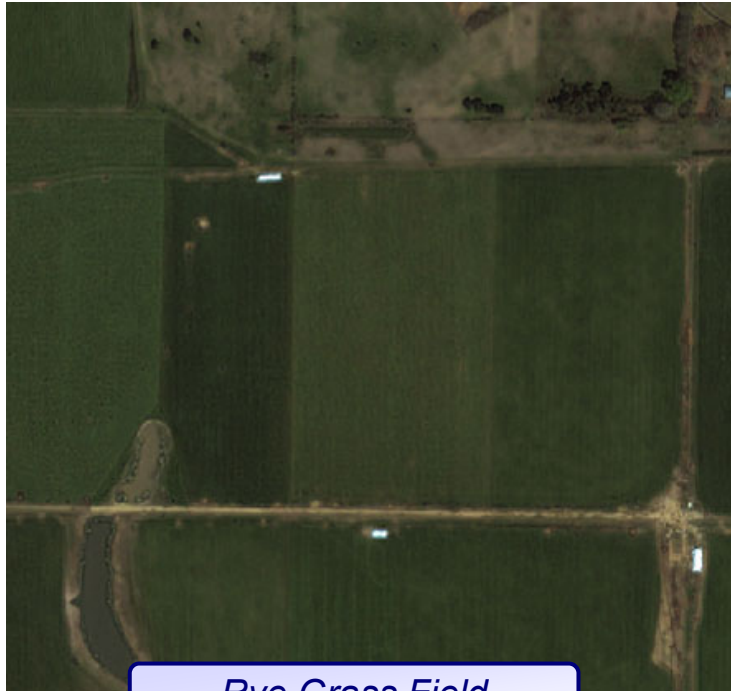
Includes material ©  
Space Imaging, LLC



# Wiggins Target Fields

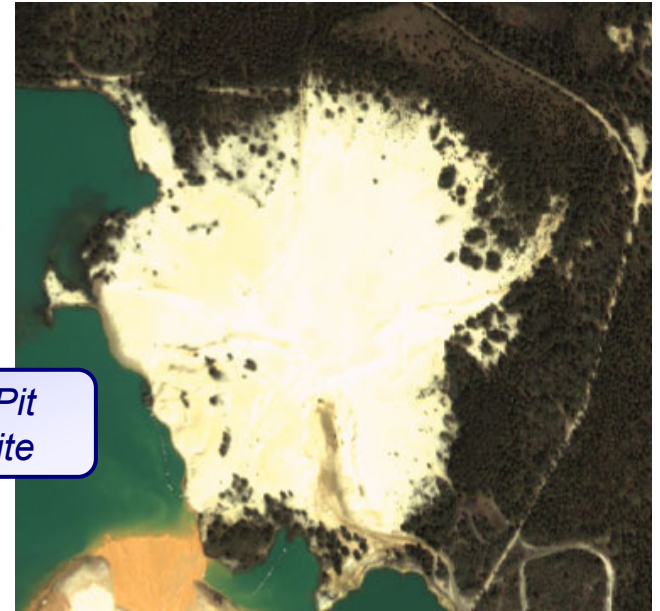
Stennis Space Center

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



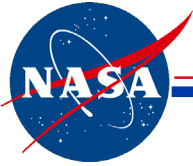
*Rye Grass Field*

*Gravel Pit  
Sand Site*



*Golf Course with  
Radiometric Tarps*

Includes material ©  
Space Imaging, LLC



# 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

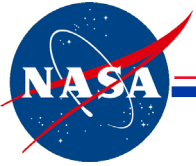


General Scene



QuickBird True-Color Imagery  
August 5, 2005

Includes material © DigitalGlobe™

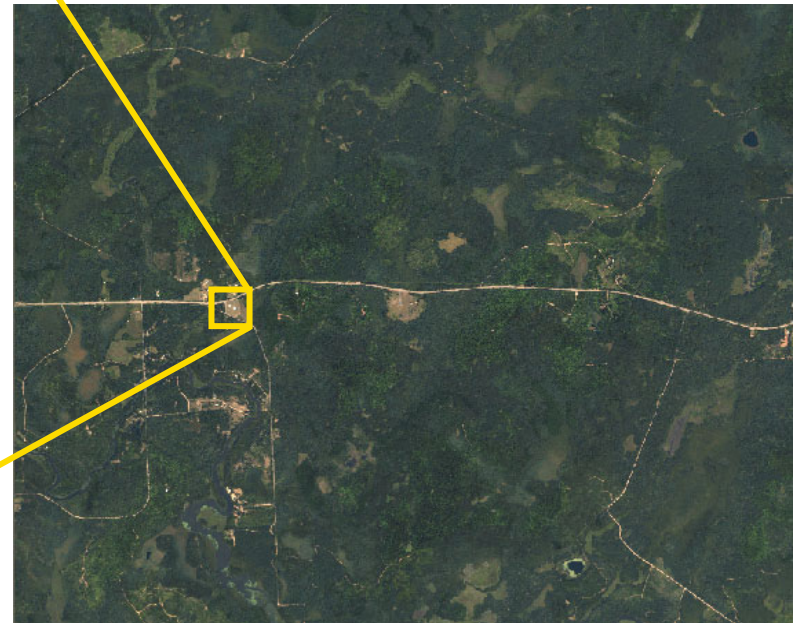


# Park Falls Target Field

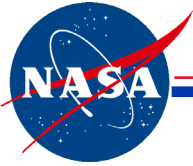
Stennis Space Center



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



Includes material © DigitalGlobe™



# Radiometric Tarps

Stennis Space Center

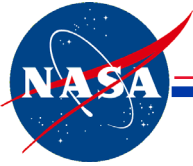
- Four 20 m x 20 m tarps with reflectance values of approximately 3.5%, 22%, 34%, and 52% within spectral measurement range
- Peak-to-peak variation in reflectance less than 10% within any 100 nm spectral band within spectral measurement range
- Less than 10% variation in reflectance values when measuring 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  $\pm 6.0$  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





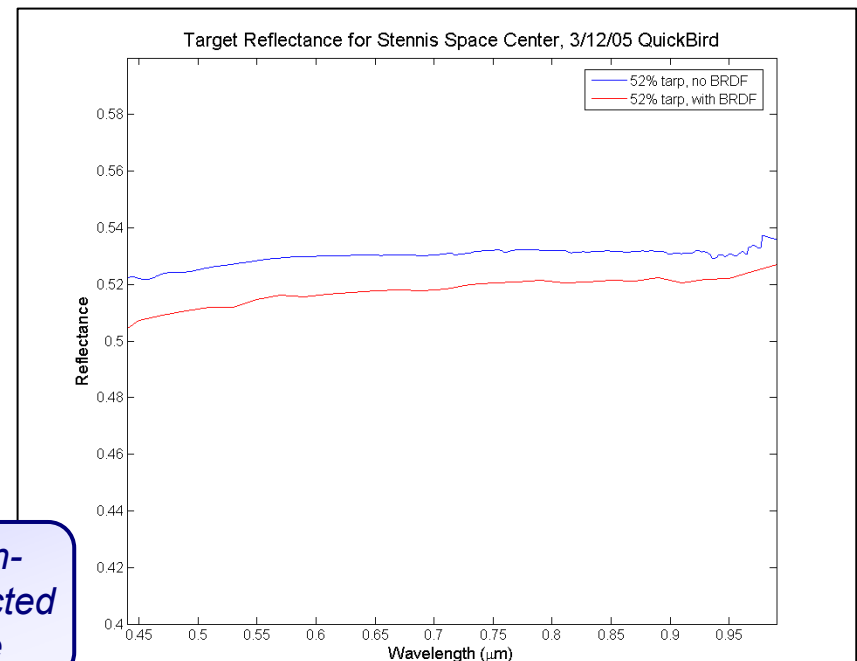
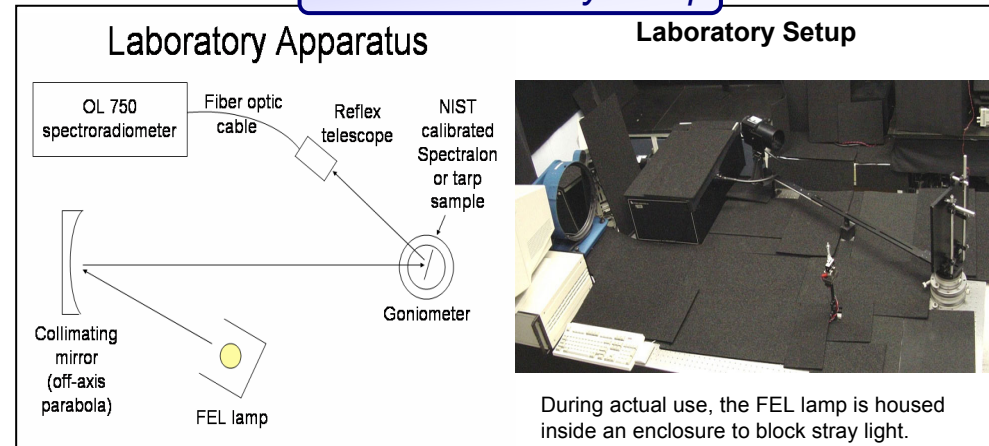


# BRDF Correction

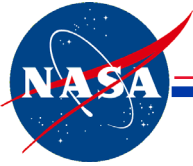
Stennis Space Center

## 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



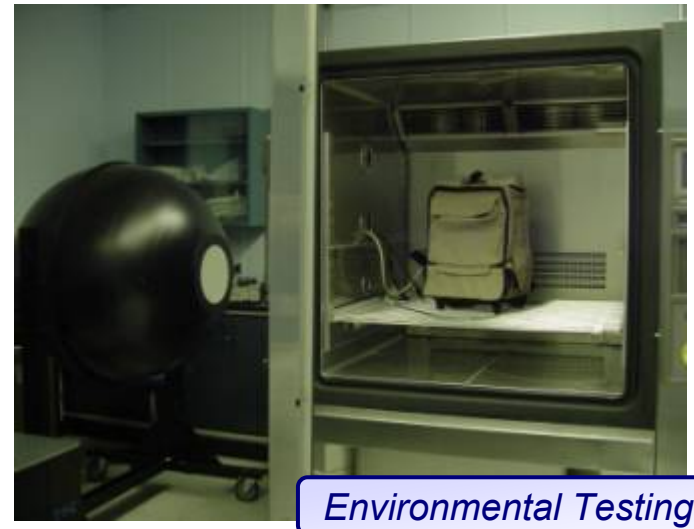
*Comparison of non-corrected and corrected target reflectance*

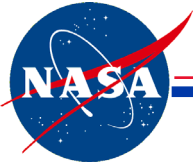


# SSC Calibration and Characterization of Spectroradiometers

Stennis Space Center

- 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

Stennis Space Center

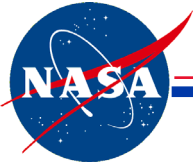
- Novel hyperspectral sun photometer is capable of acquiring measurements comparable to both ASRs and MFRSRs by making use of the laboratory radiometric calibration of the FieldSpec FR spectroradiometers
  - Optical Depth/Transmission
  - Diffuse-to-Global Ratio
- Sun photometer developed with fewer 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*



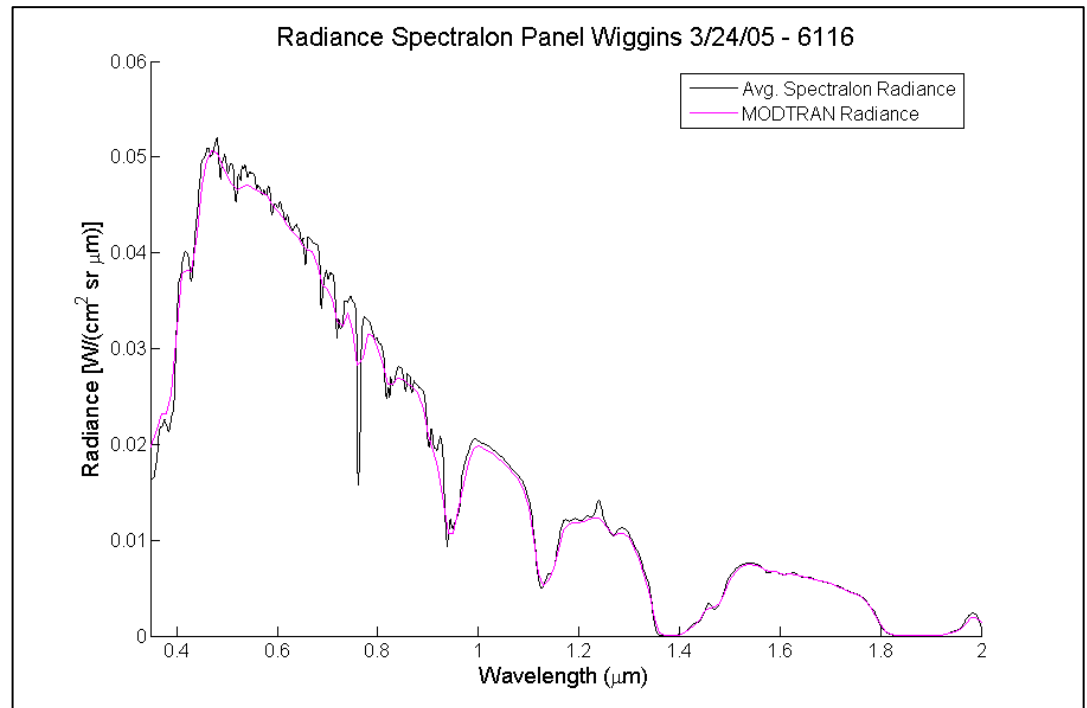
*Novel Hyperspectral Sun Photometer Setup*

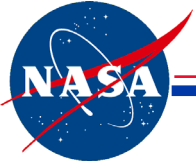


# Comparison to Spectralon Panel

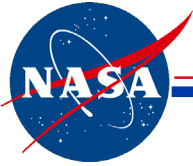
Stennis Space Center

- 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**

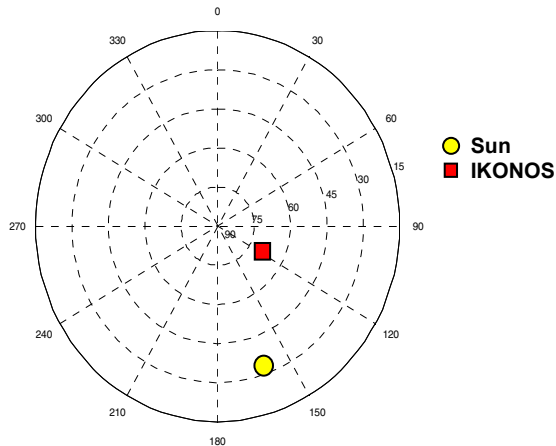


# IKONOS Data Acquisitions

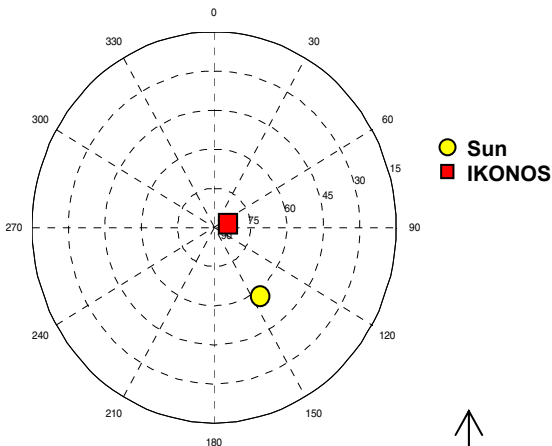
Stennis Space Center

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

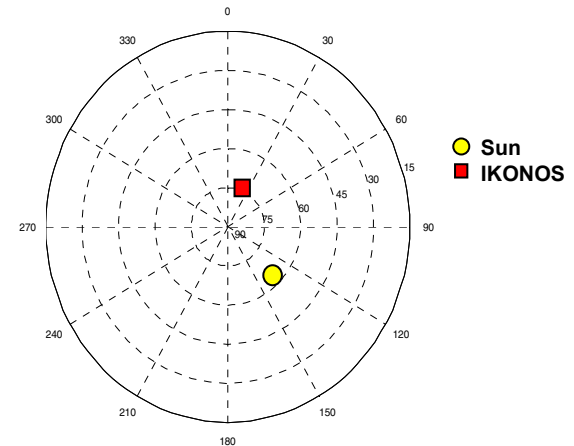
Standard imagery  
Cubic Convolution resampling, MTF Off



Stennis Space Center, MS, 12/15/04

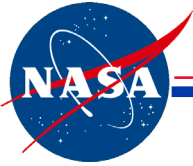


Wiggins, MS, 3/24/05



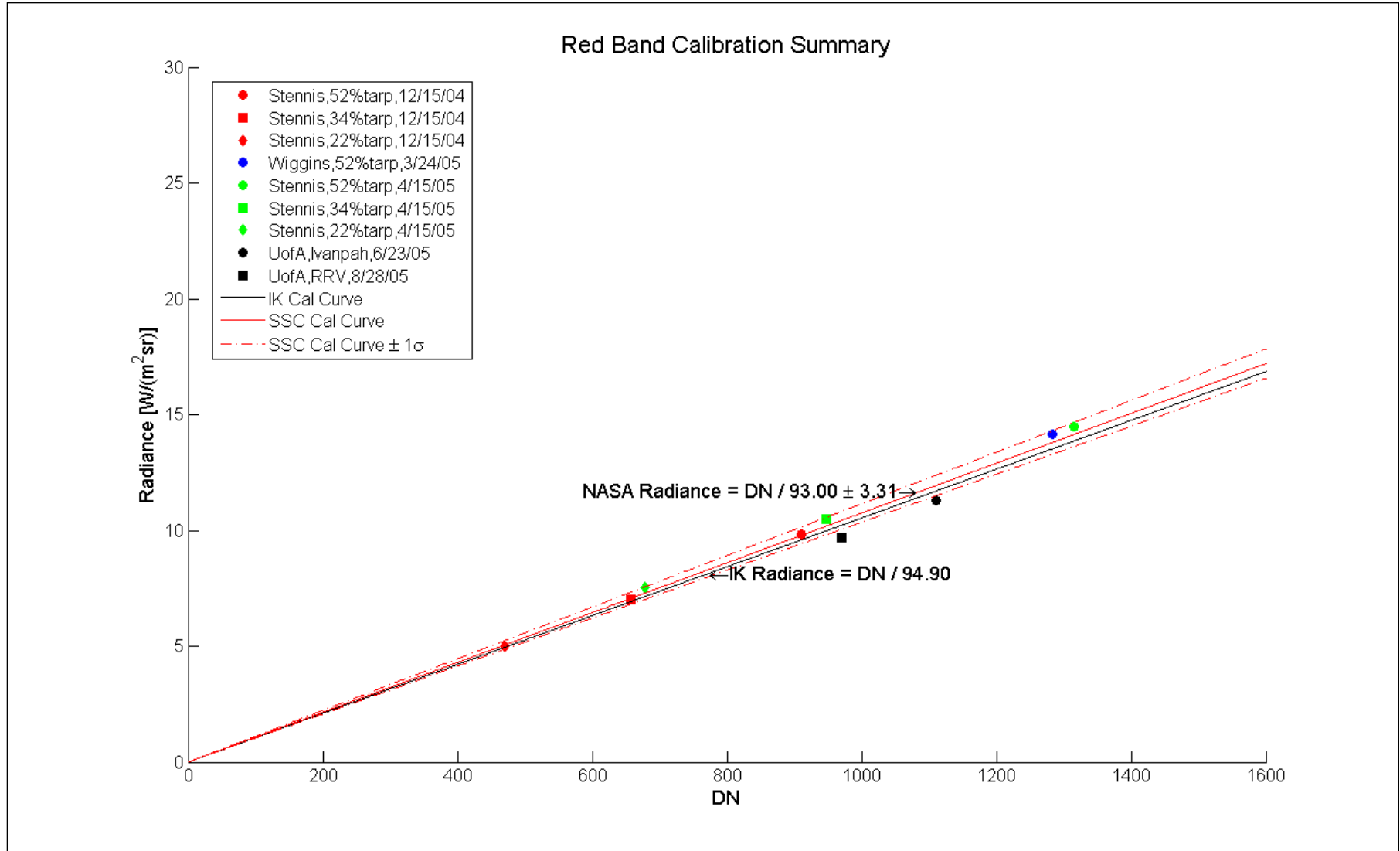
Stennis Space Center, MS, 4/15/05

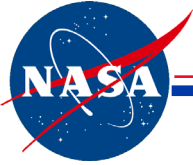




# IKONOS Sample Calibration Summary

Stennis Space Center





# 2004/2005 IKONOS Radiometric Assessment

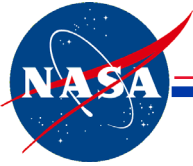
Stennis Space Center

## Inband Radiance Calibration Coefficients

Bandwidth FWHM ( $\mu\text{m}$ )	NASA Team Estimate [DN/(W/m <sup>2</sup> sr)]	IKONOS Provided [DN/(W/m <sup>2</sup> sr)]	% 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  $(1 - \text{IKONOS}/\text{NASA Mean})$

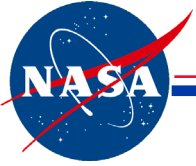




# 2004/2005 IKONOS Results Summary

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

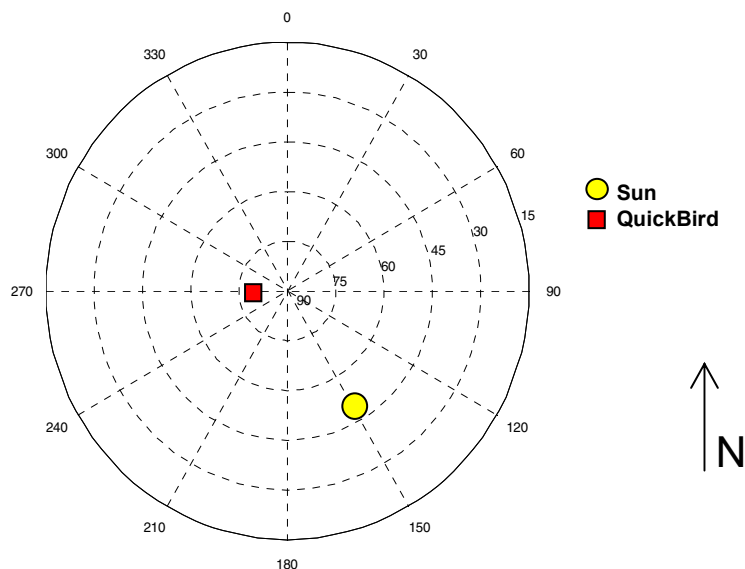
Stennis Space Center

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

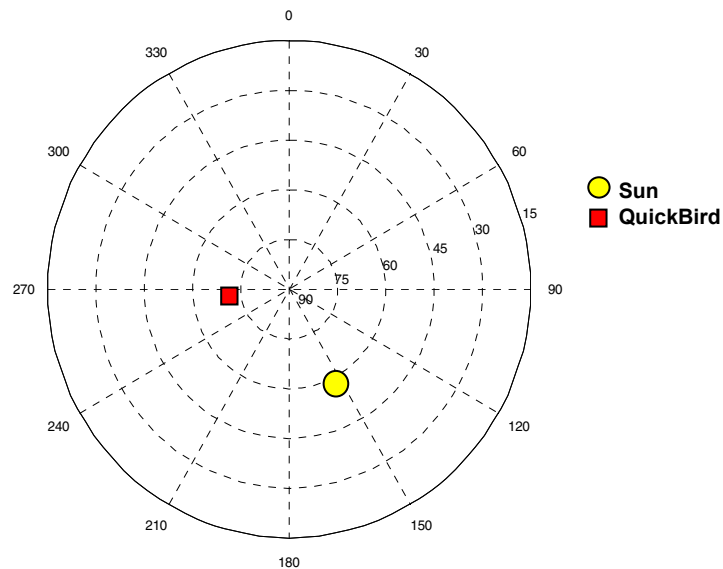
Standard imagery  
4x4 Cubic Convolution resampling

Park Falls 8/5/05	17:20	69.3 deg	261.6 deg	59.4 deg	157.4 deg
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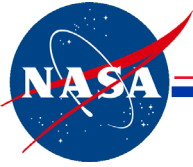
Standard imagery



Stennis Space Center, MS, 3/12/05

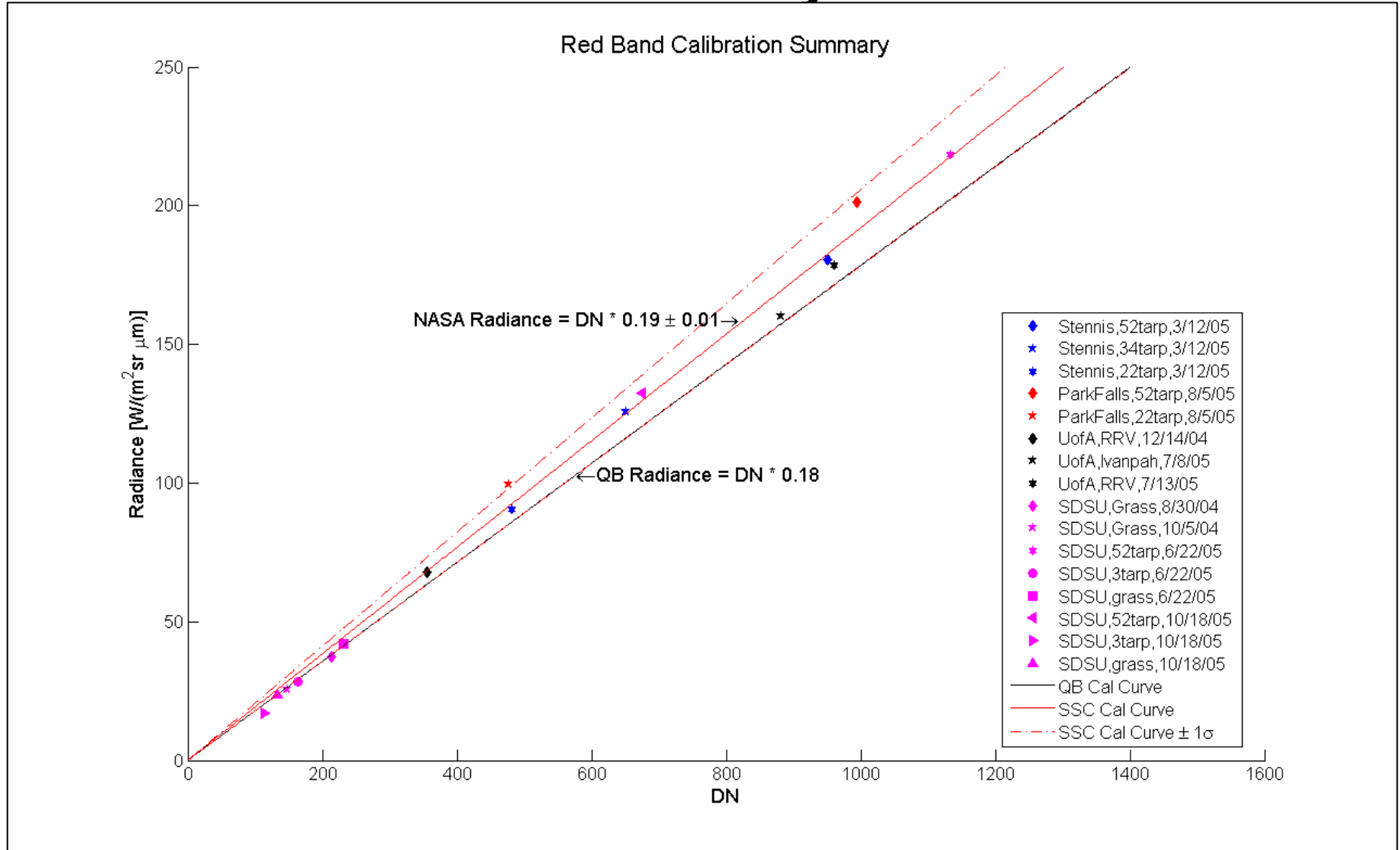


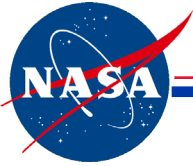
Park Falls, WI, 8/5/05



# QuickBird Sample Calibration Summary

Stennis Space Center





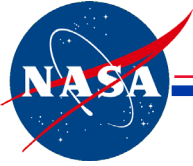
# 2004/2005 QuickBird Radiometric Assessment

Stennis Space Center

## Average Spectral Radiance Calibration Coefficients

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

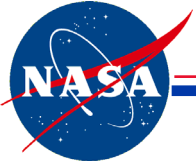
Percent difference is calculated by  $(1 - \text{QuickBird}/\text{NASA Mean})$



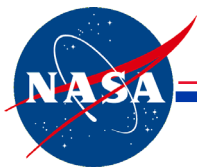
# 2004/2005 QuickBird Results Summary

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**

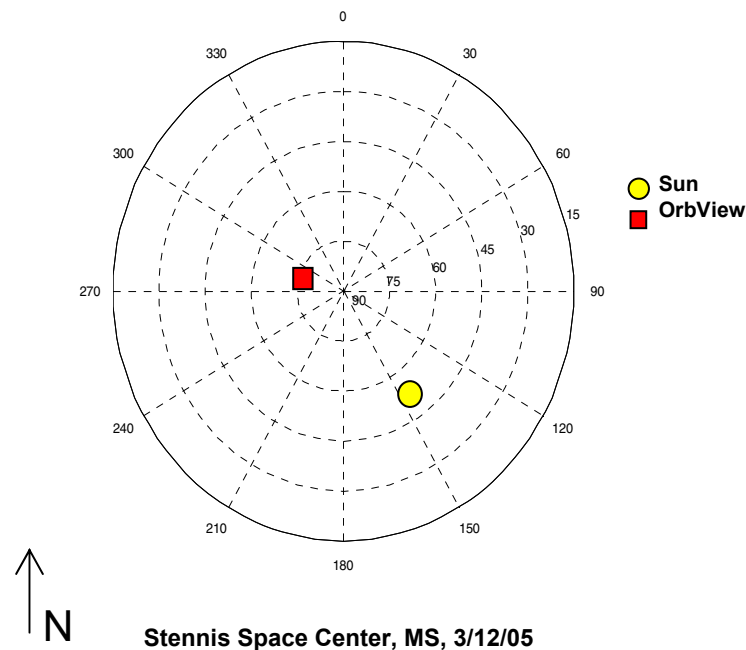


# OrbView-3 Data Acquisitions

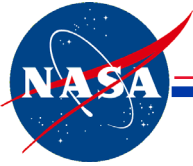
Stennis Space Center

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

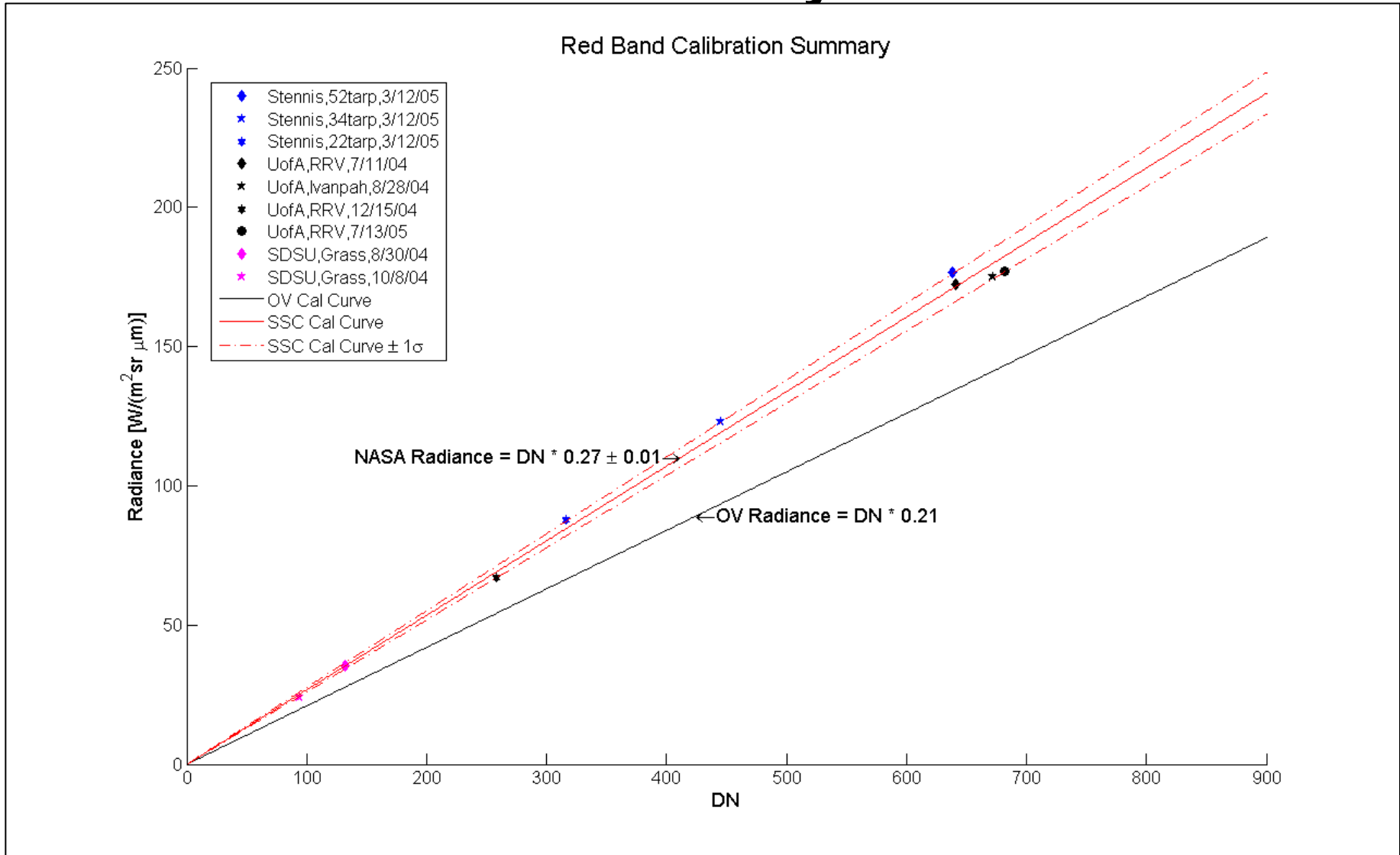


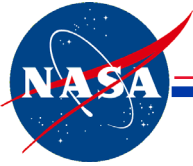




# OrbView-3 Sample Calibration Summary

Stennis Space Center





# 2004/2005 OrbView-3 Radiometric Assessment

Stennis Space Center

## Average Spectral Radiance Calibration Coefficients

Bandwidth FWHM ( $\mu\text{m}$ )	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	$0.35 \pm 0.02$	0.269	23.1%
2 0.520 - 0.600	$0.31 \pm 0.01$	0.249	19.7%
3 0.625 - 0.695	$0.27 \pm 0.01$	0.210	22.2%
4 0.760 - 0.900	$0.18 \pm 0.00$	0.142	21.1%

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

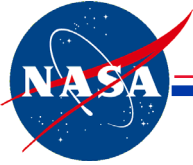


# 2004/2005 OrbView-3 Results

Stennis Space Center

## Summary

- 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 as to the cause of the differences
- The NASA team will continue to assess OrbView radiometric accuracy



# Contributors

Stennis Space Center

## **NASA, Stennis Space Center**

Troy Frisbie

Thomas Stanley

## **Science Systems and Applications, Inc.**

Slawomir Blonski

Mary Pagnutti

Robert E. Ryan

Brennan Grant

Kenton Ross

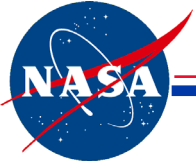
Steve Tate

Kelly Knowlton

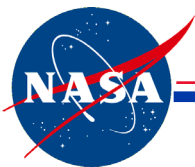
## **Computer Sciences Corporation**

Ronald Vaughan

*Participation in this work by Science Systems and Applications, Inc., and by Computer Sciences Corporation was supported by NASA at the John C. Stennis Space Center, Mississippi, under Task Order NNS04AB54T.*

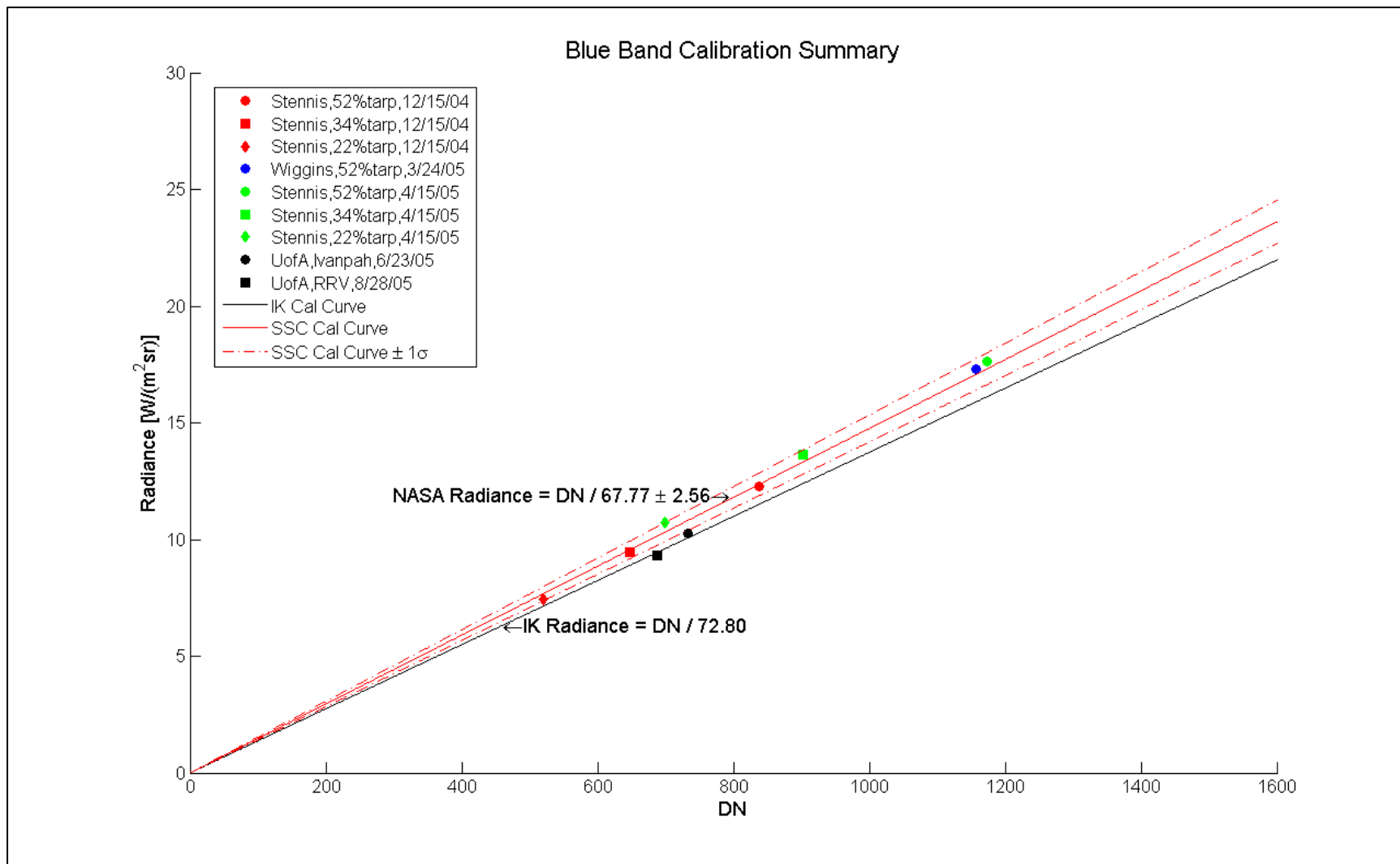


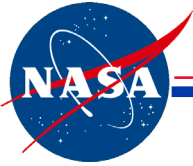
# Back-up



# IKONOS Blue Band Calibration Summary

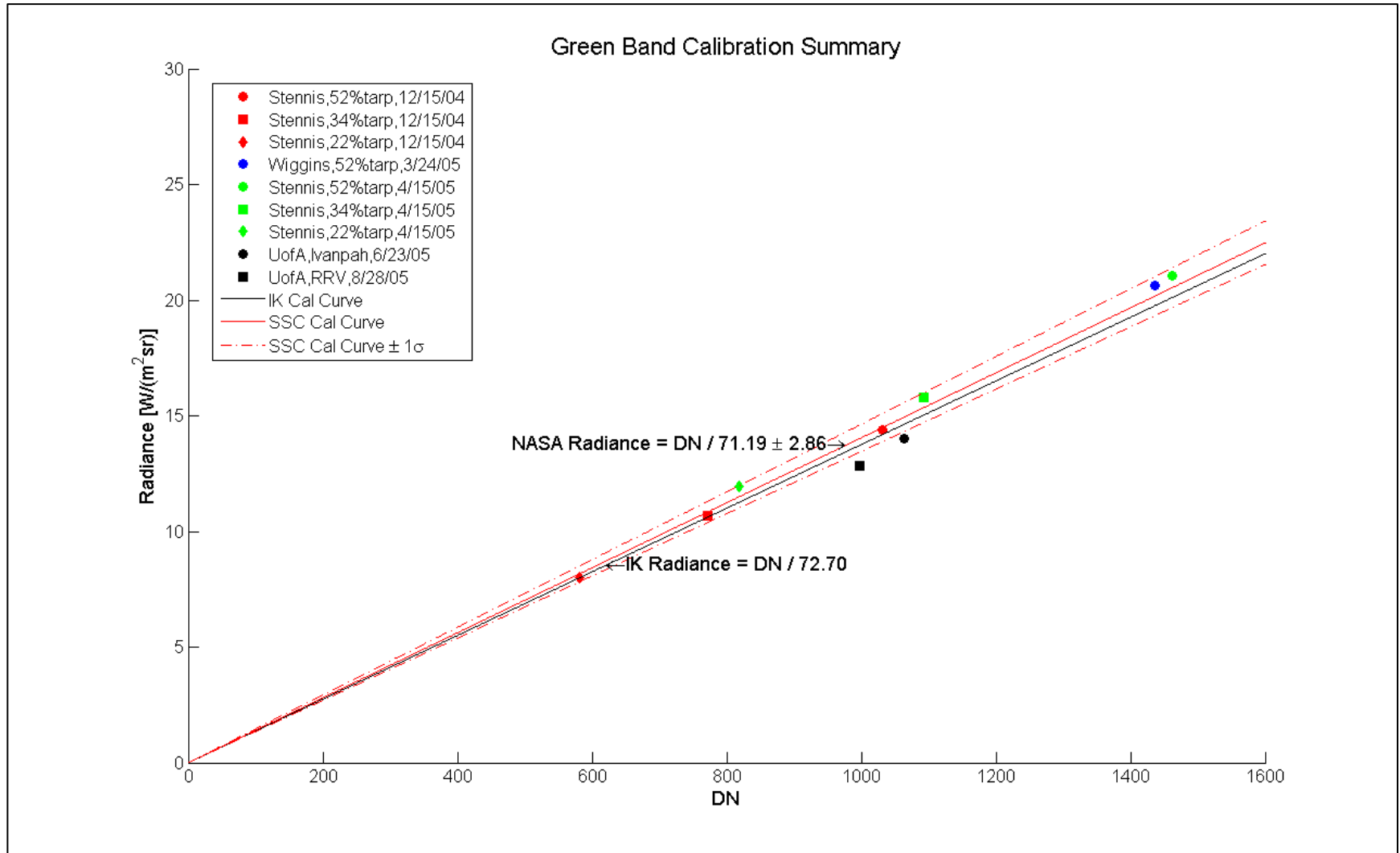
Stennis Space Center

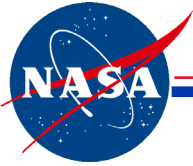




# IKONOS Green Band Calibration Summary

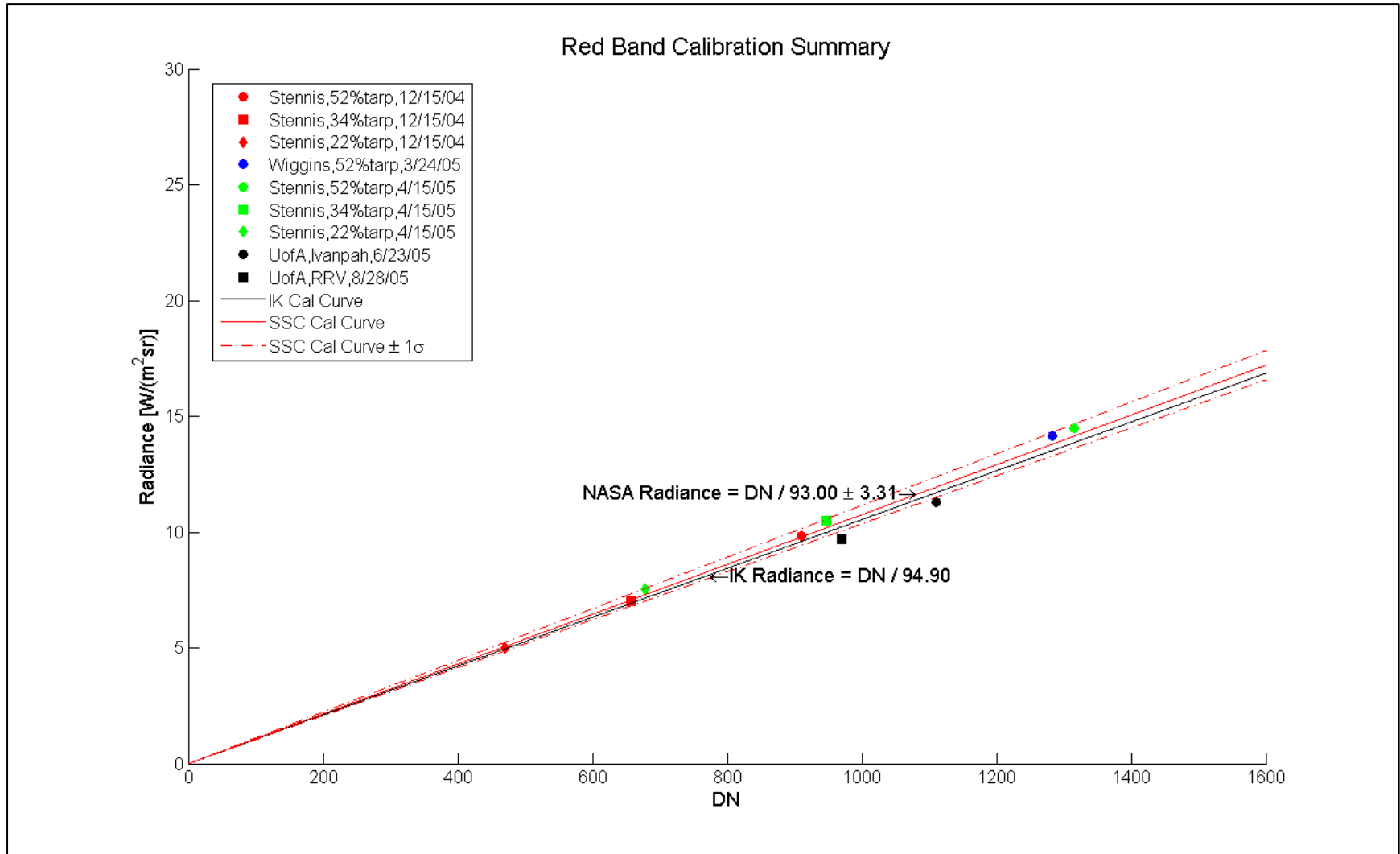
Stennis Space Center



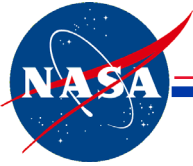


# IKONOS Red Band Calibration Summary

Stennis Space Center

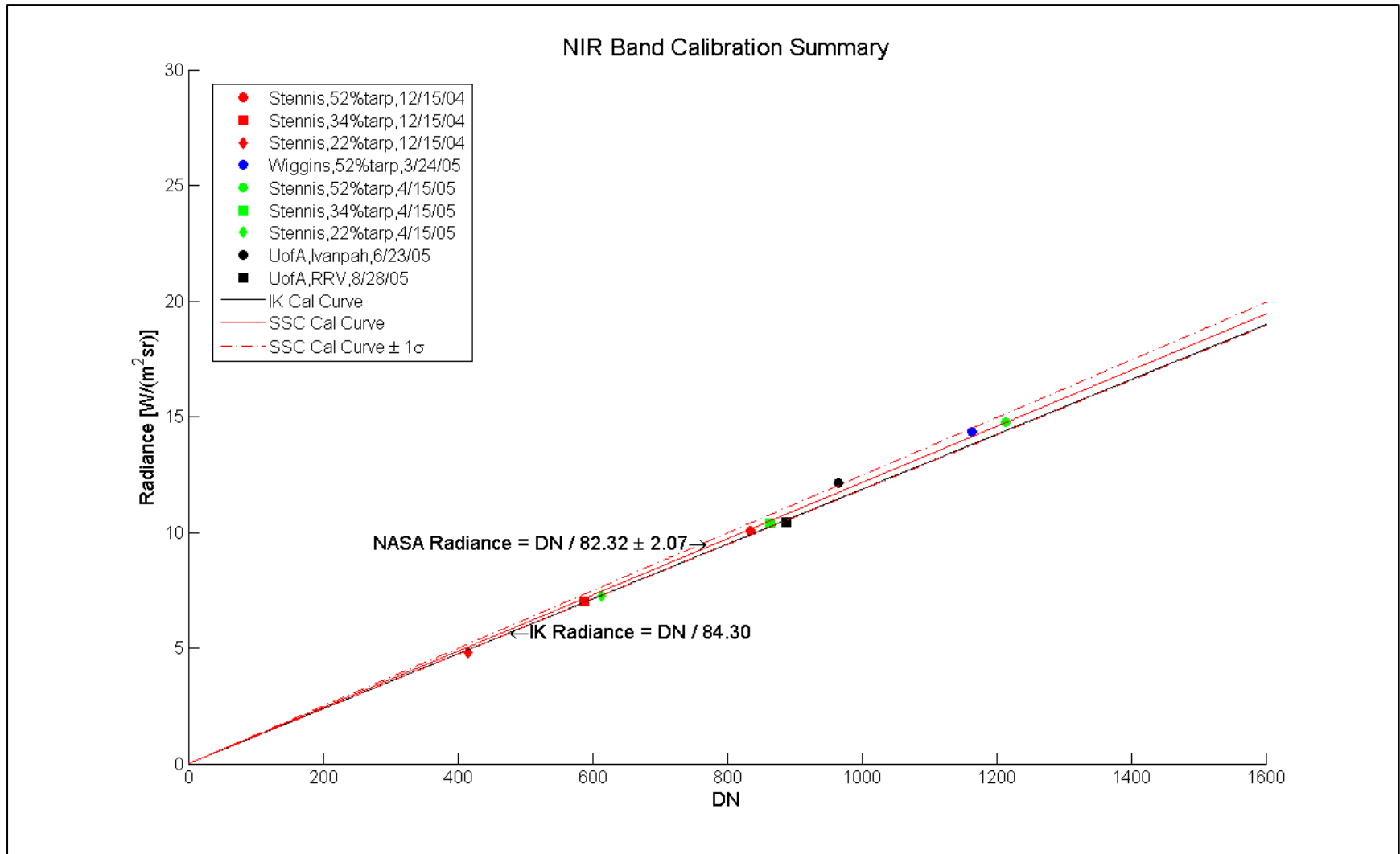


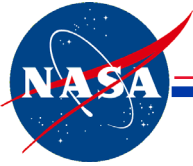




# IKONOS NIR Band Calibration Summary

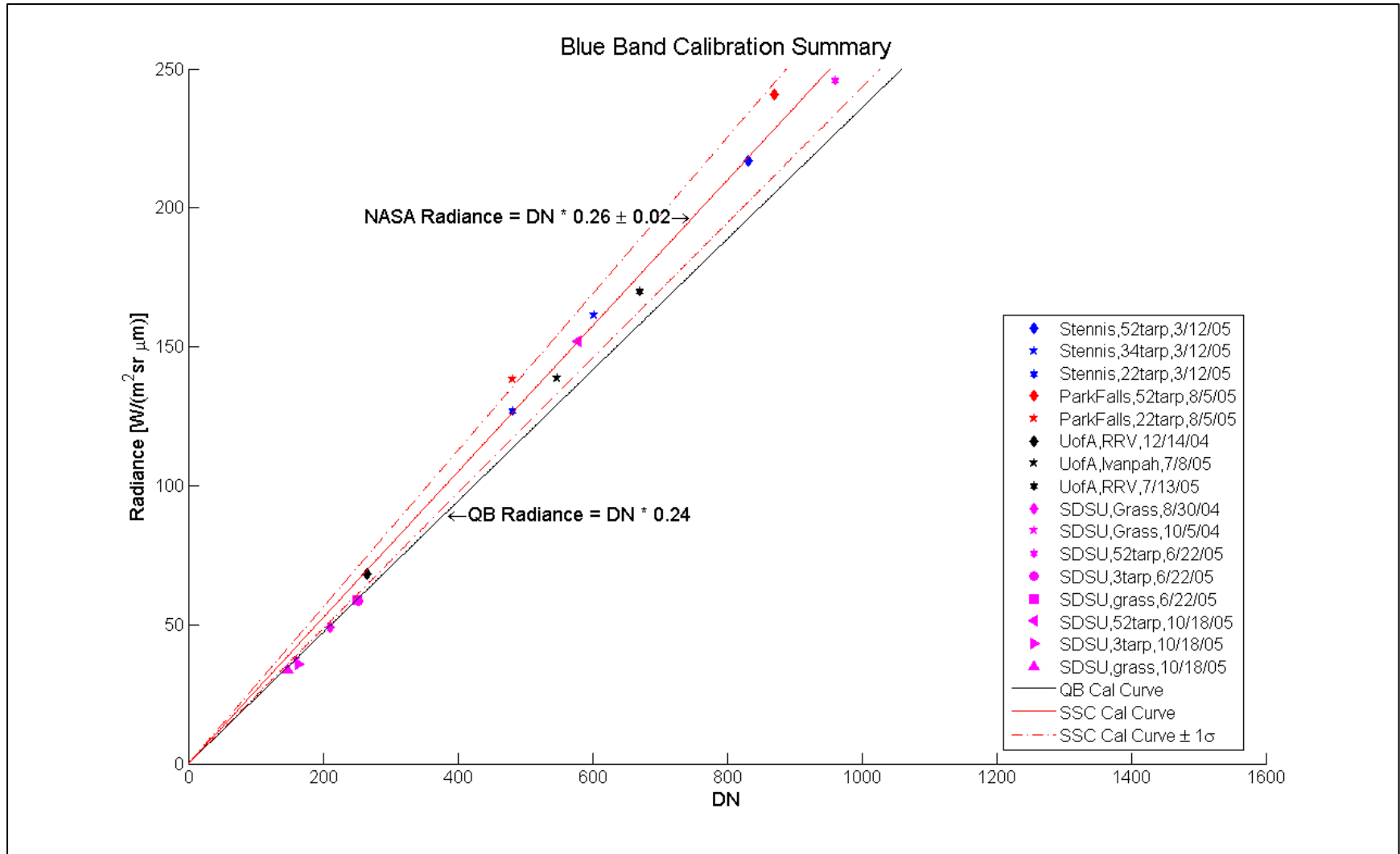
Stennis Space Center

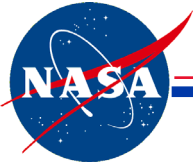




# QuickBird Blue Band Calibration Summary

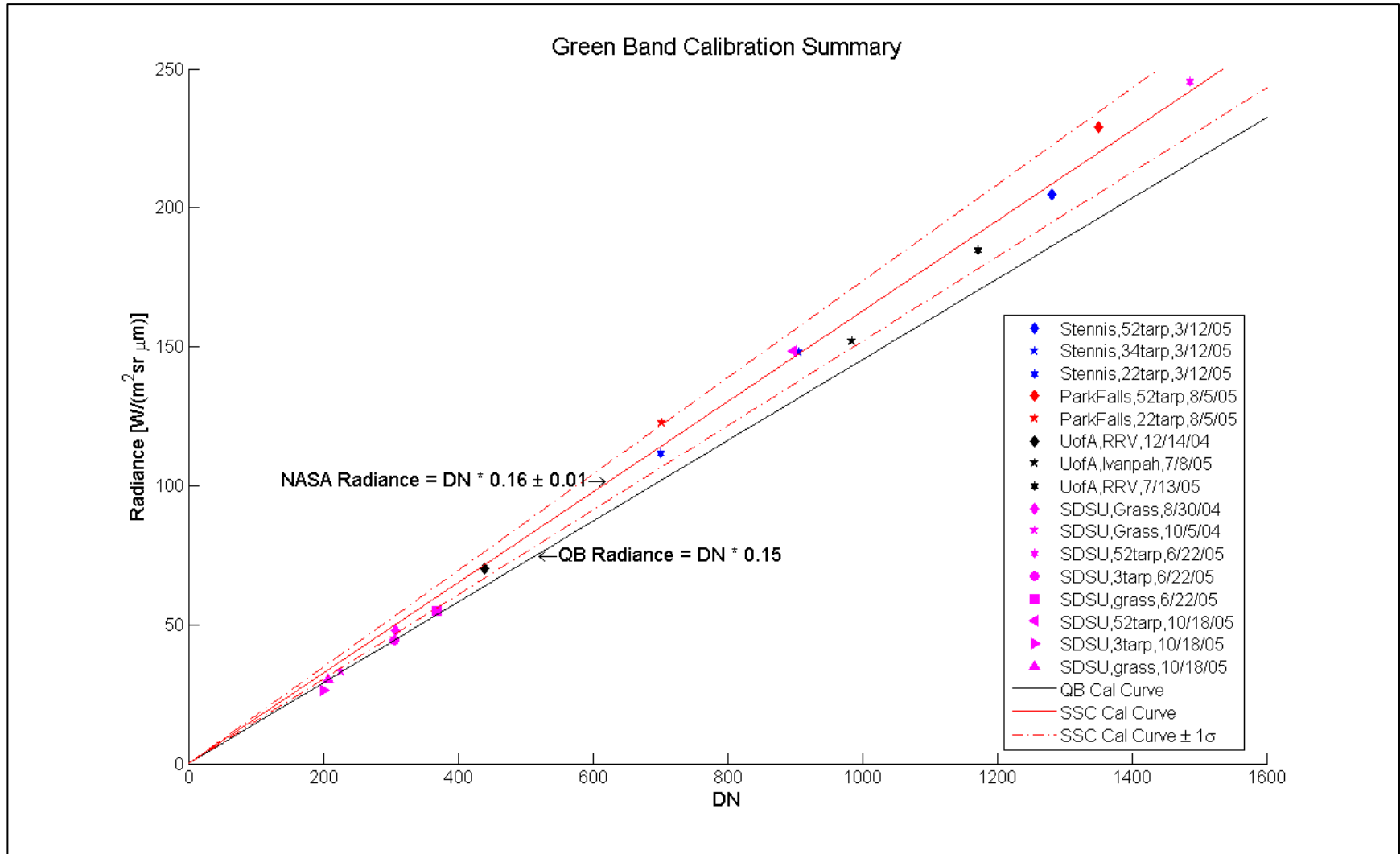
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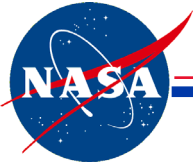




# QuickBird Green Band Calibration Summary

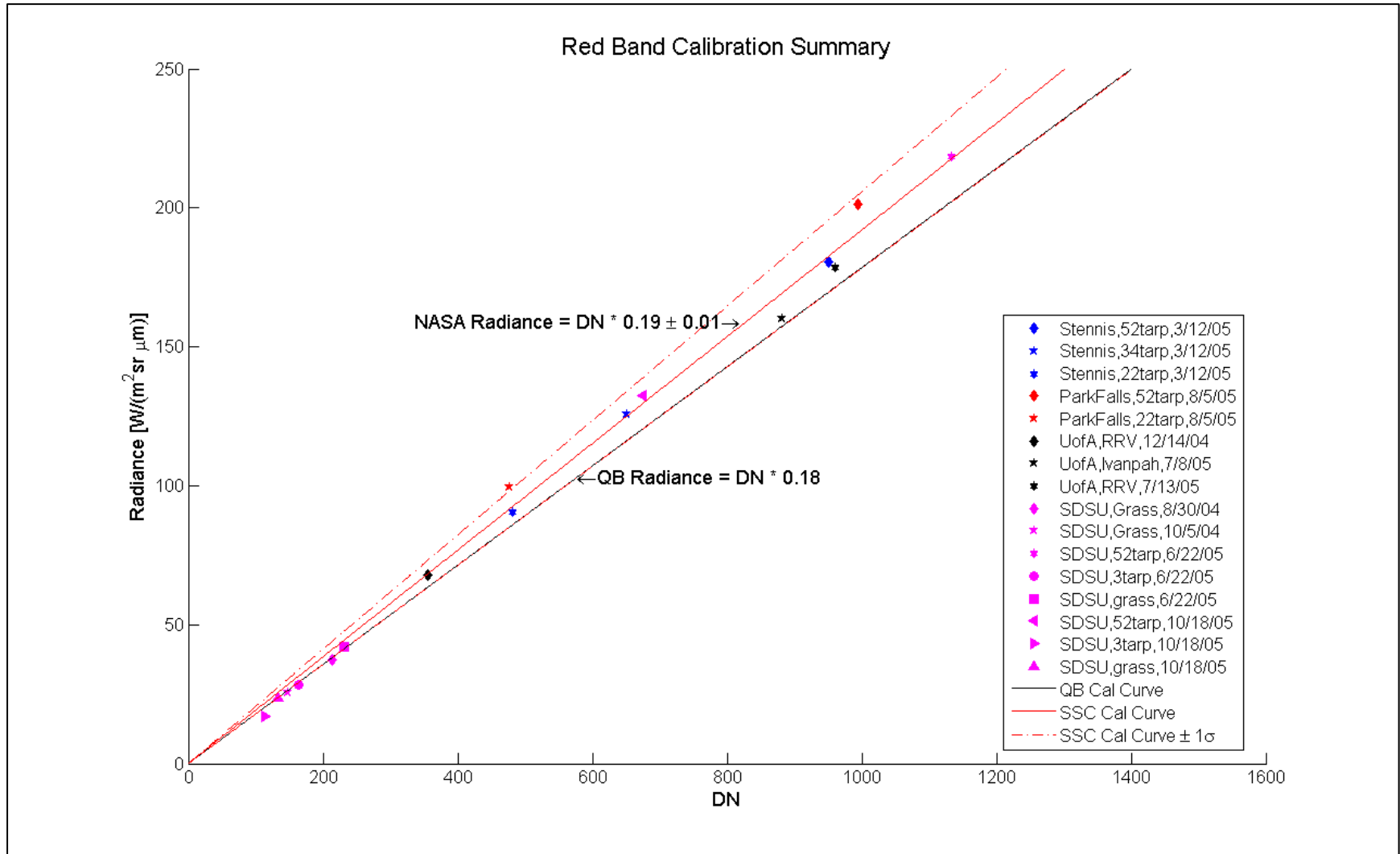
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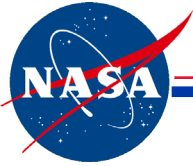




# QuickBird Red Band Calibration Summary

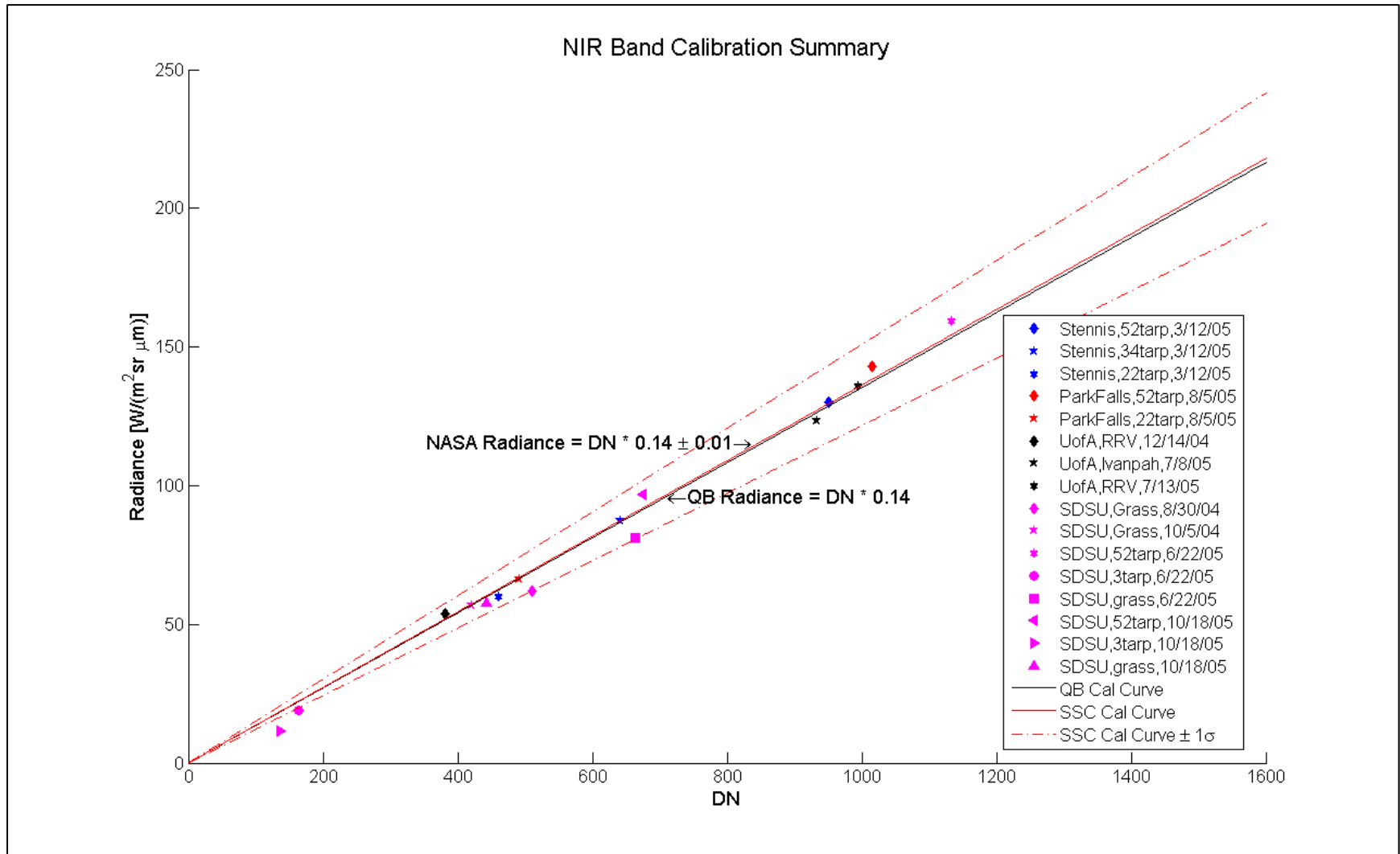
Stennis Space Center

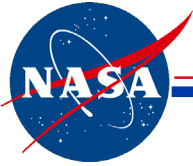




# QuickBird NIR Band Calibration Summary

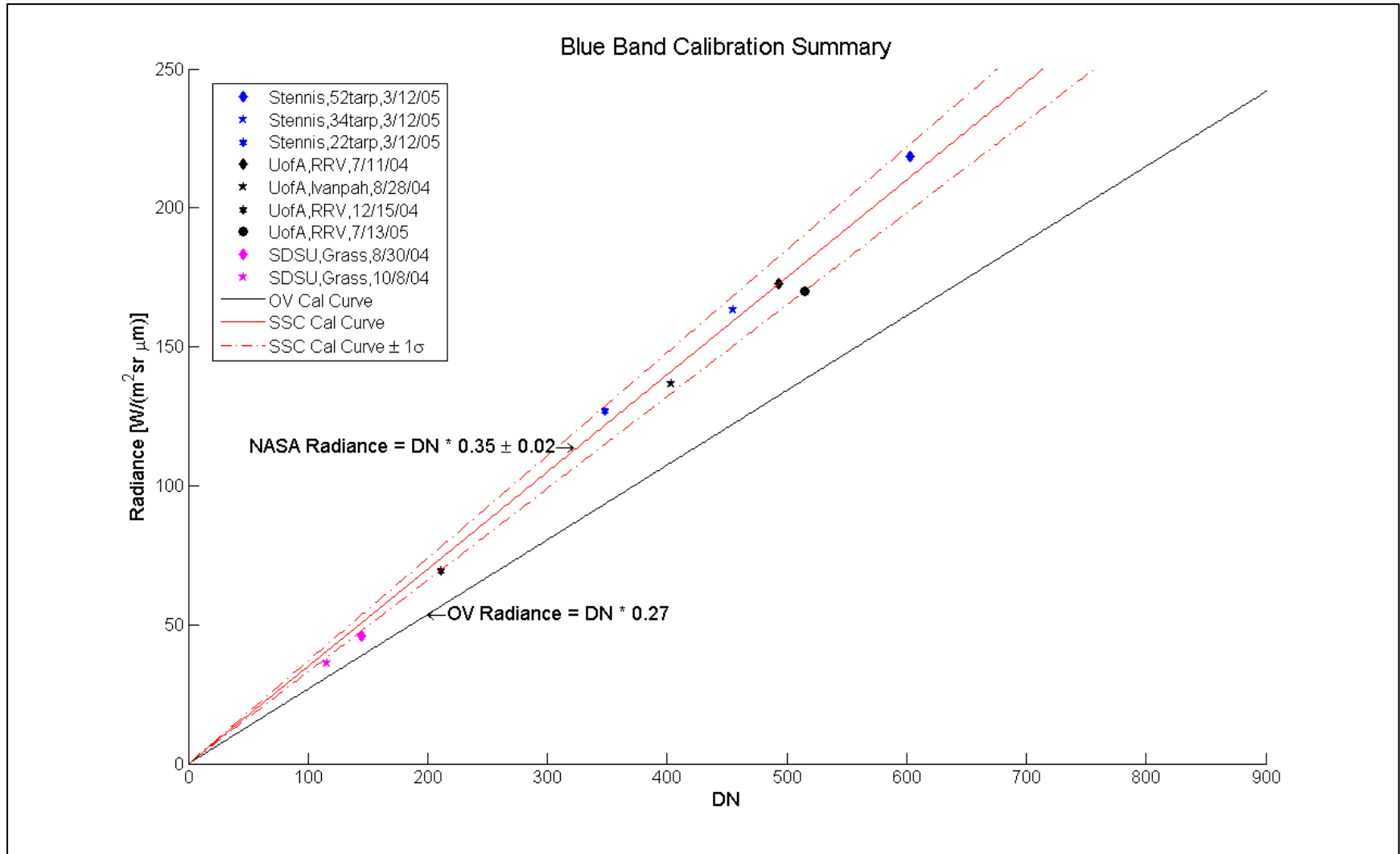
Stennis Space Center

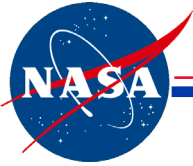




# OrbView-3 Blue Band Calibration Summary

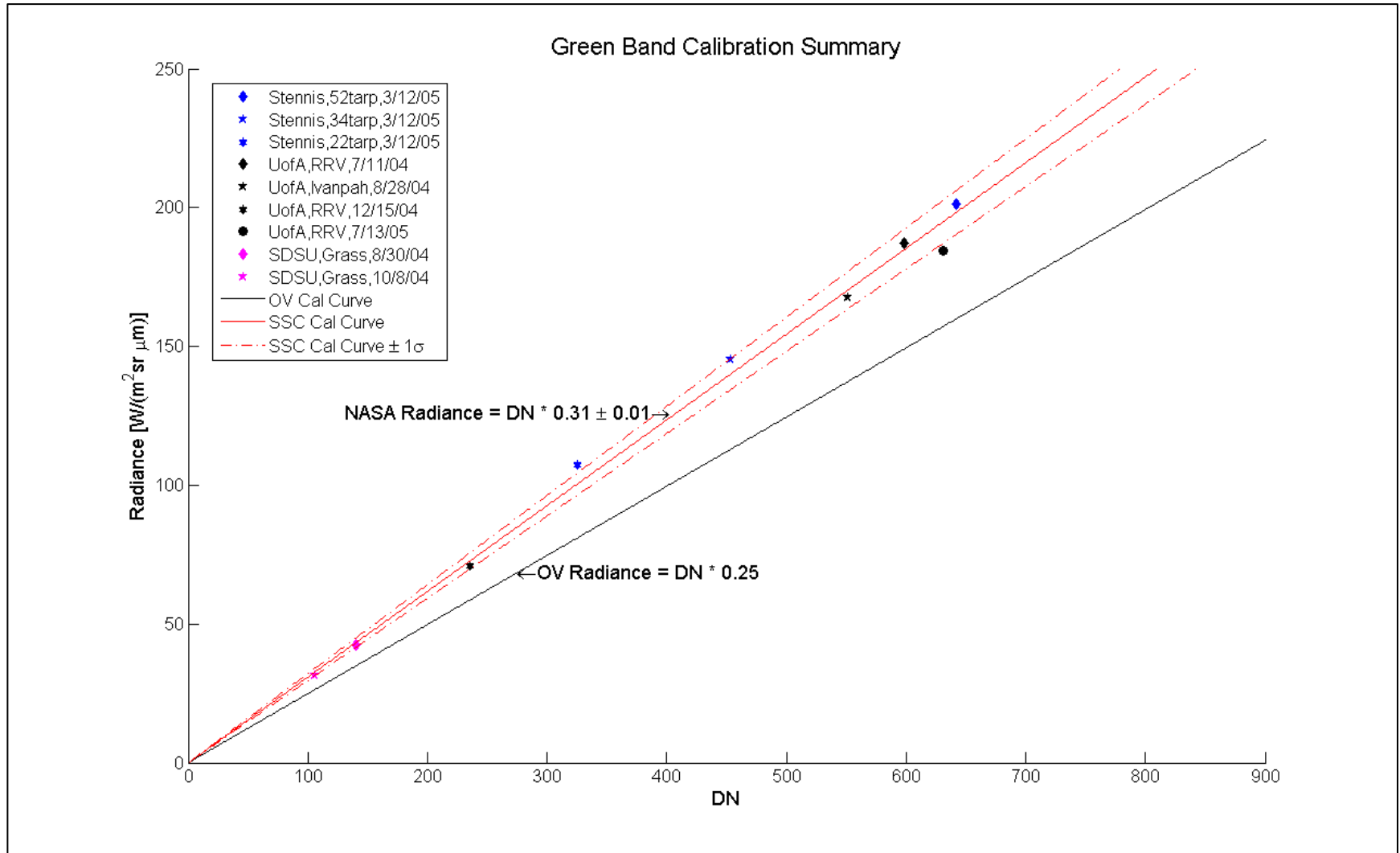
Stennis Space Center

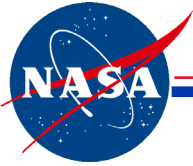




# OrbView-3 Green Band Calibration Summary

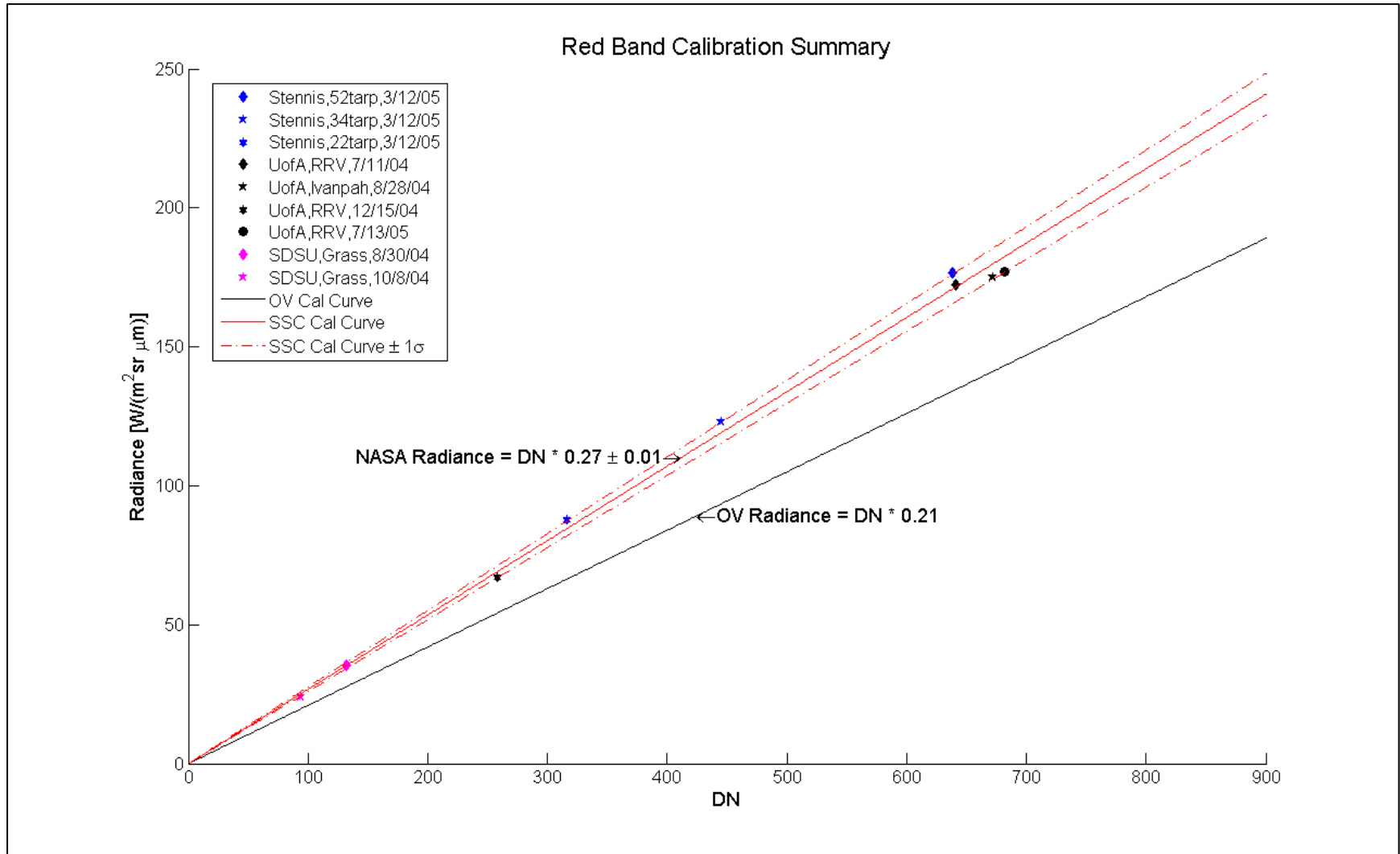
Stennis Space Center



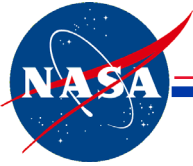


# OrbView-3 Red Band Calibration Summary

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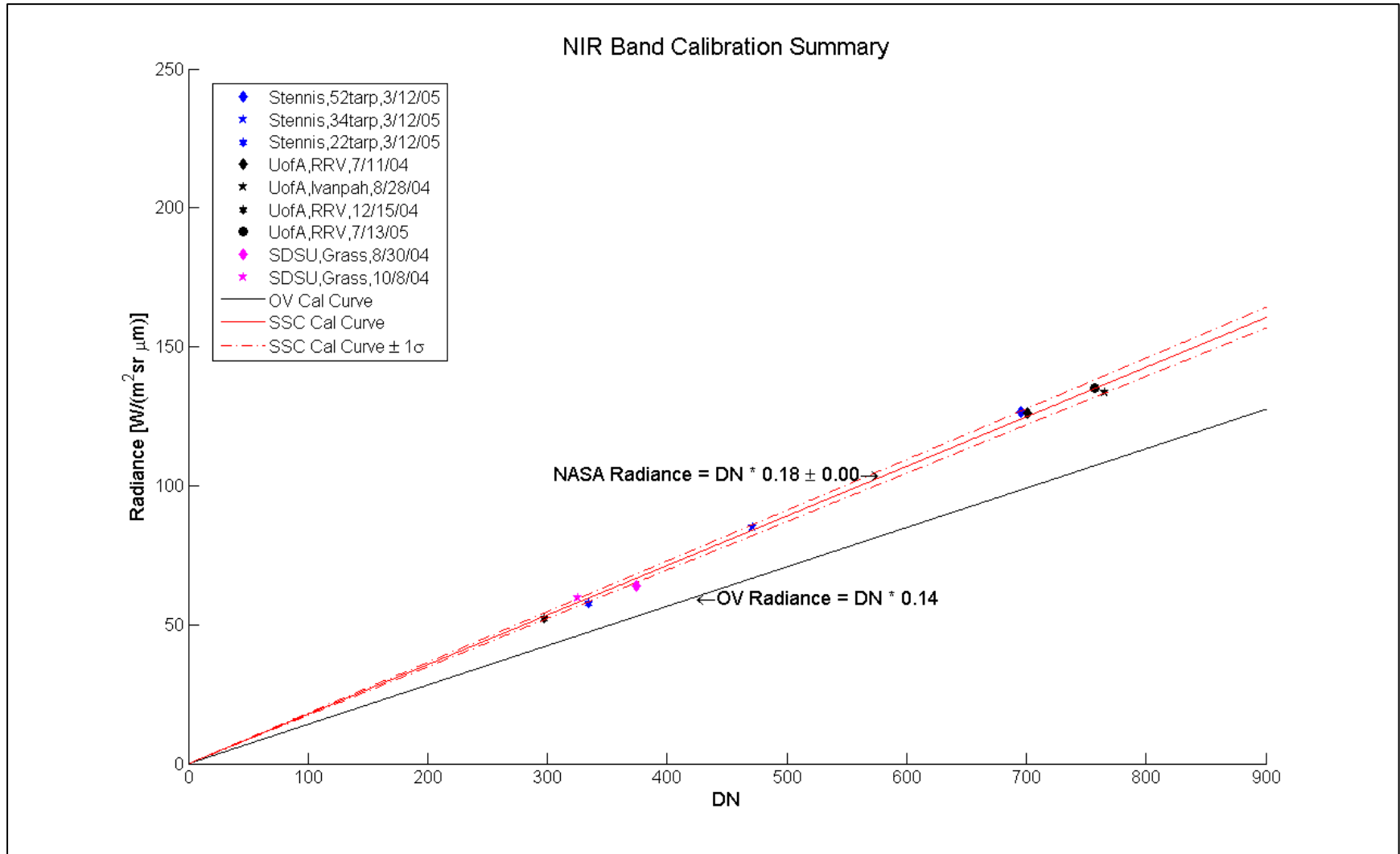






# OrbView-3 NIR Band Calibration Summary

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**REPORT DOCUMENTATION PAGE**

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<b>6. AUTHOR(S)</b> Kara Holekamp (1)				<b>5d. PROJECT NUMBER</b> SWR C15C-JC15-00	
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<b>14. ABSTRACT</b> Radiometric calibration of commercial imaging satellite products is required to ensure that science and application communities can better understand their properties. Inaccurate radiometric calibrations can lead to erroneous decisions and invalid conclusions and can limit intercomparisons with other systems. To address this calibration need, satellite at-sensor radiance values were compared to those estimated by each independent team member to determine the sensor's radiometric accuracy. The combined results of this evaluation provide the user community with an independent assessment of these commercially available high spatial resolution sensors' absolute calibration values.					
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