Stennis Space Center

QuickBird Panchromatic Imagery: Spatial Resolution Evaluation

Slawomir Blonski

Lockheed Martin Space Operations – Stennis Programs
NASA Stennis Space Center, MS 39529
Telephone: 228-688-1944
e-mail: slawomir.blonski@ssc.nasa.gov

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Kara Holekamp
Charles Smith
Mary Pagnutti
Robert Ryan

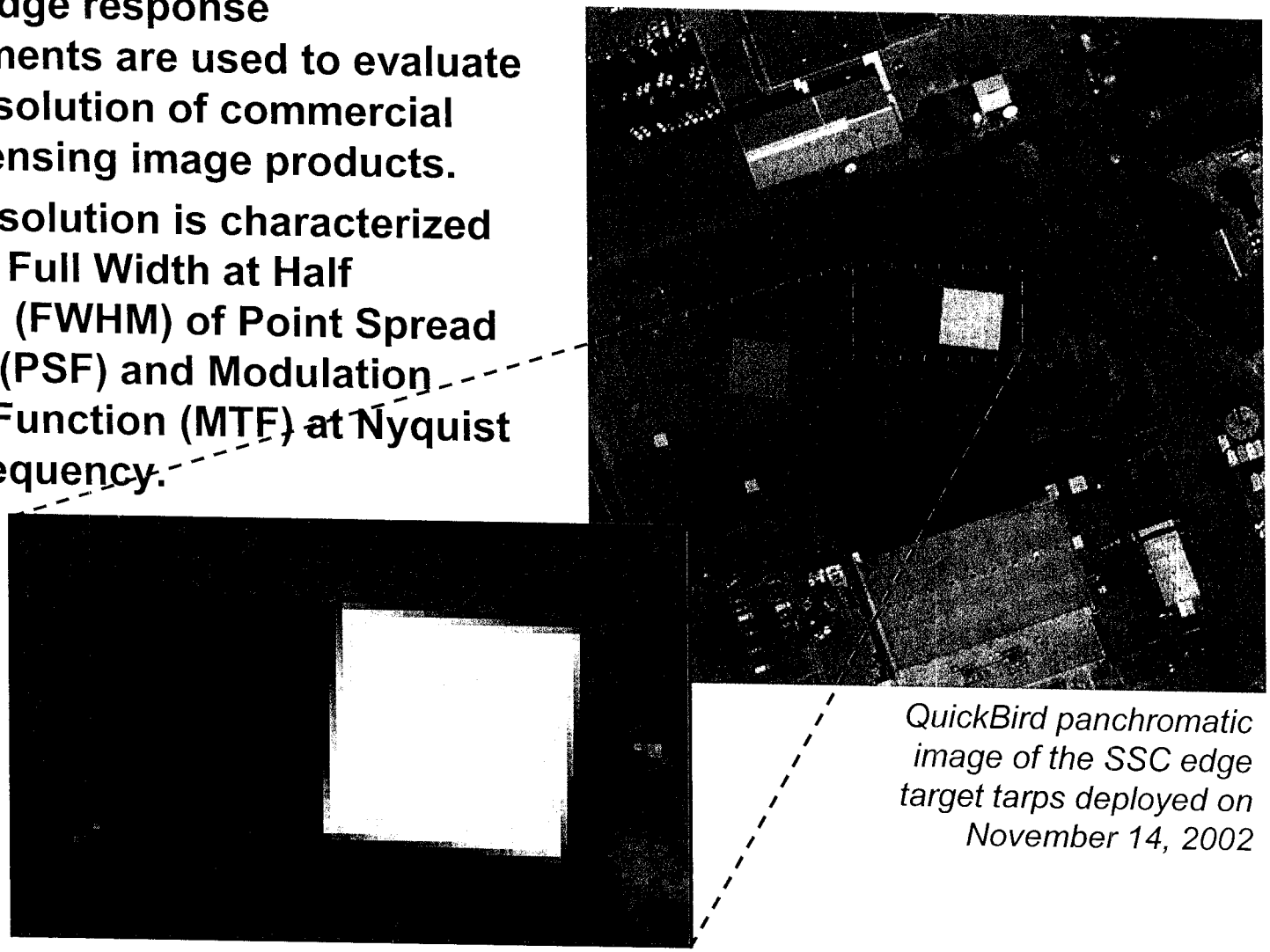
Lockheed Martin Space Operations – Stennis Programs
Stennis Space Center, Mississippi

Vicki Zanoni

NASA Earth Science Applications Directorate
Stennis Space Center, Mississippi

SSC Edge Targets

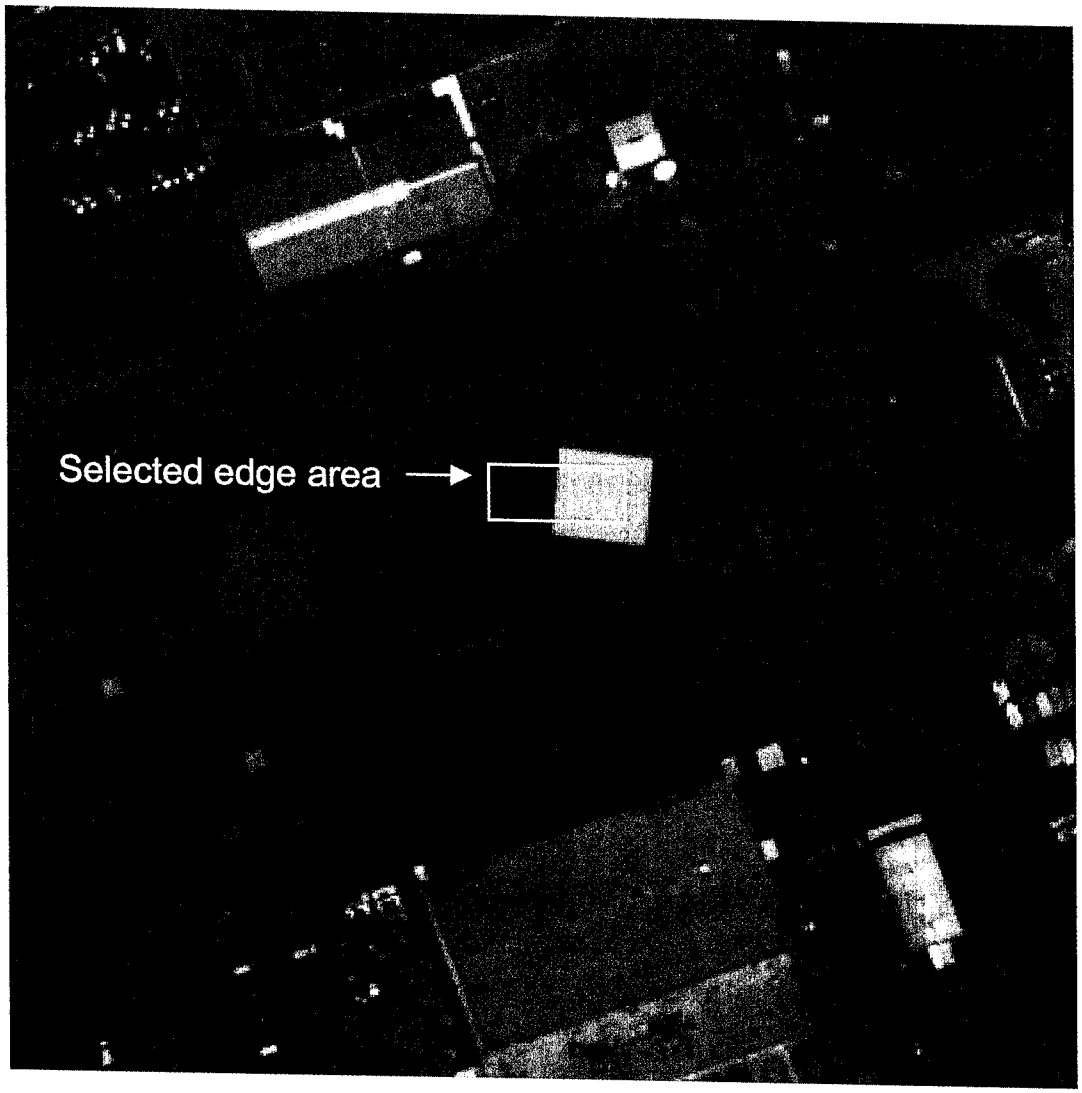
- In-flight edge response measurements are used to evaluate spatial resolution of commercial remote sensing image products.
- Spatial resolution is characterized with both Full Width at Half Maximum (FWHM) of Point Spread Function (PSF) and Modulation Transfer Function (MTF) at Nyquist spatial frequency.



QuickBird panchromatic image of the SSC edge target tarps deployed on November 14, 2002

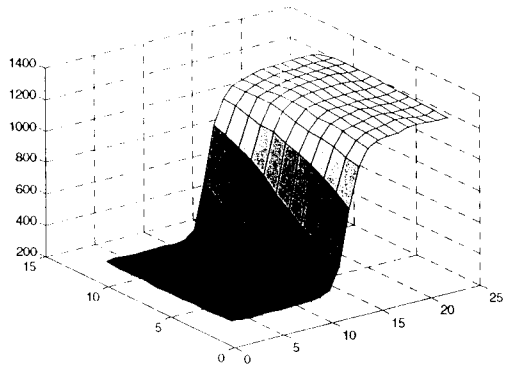
Edge Response Selection

- Rectangular area of the edge target image is selected for the edge response analysis.
- Effects of the adjacent surfaces (grass) must be avoided.
- Uniformity of the edge target panels is still the greatest challenge.

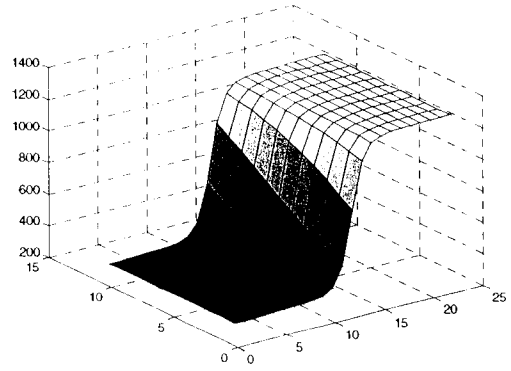


Edge Response Analysis

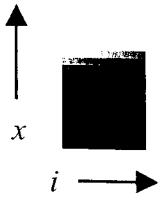
- Selected edge area includes a set of edge responses, each with an edge position shifted by a fraction of a pixel from an adjacent response.



Actual intensity in the edge area



Best fit with the sigmoidal functions

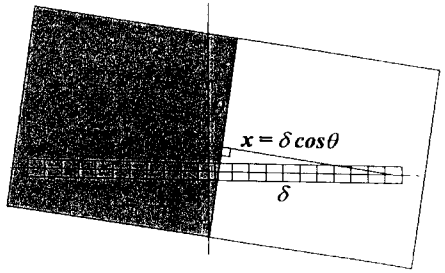


- **Nonlinear least-square fit of a two-dimensional function that is a linear combination of three sigmoidal functions.**

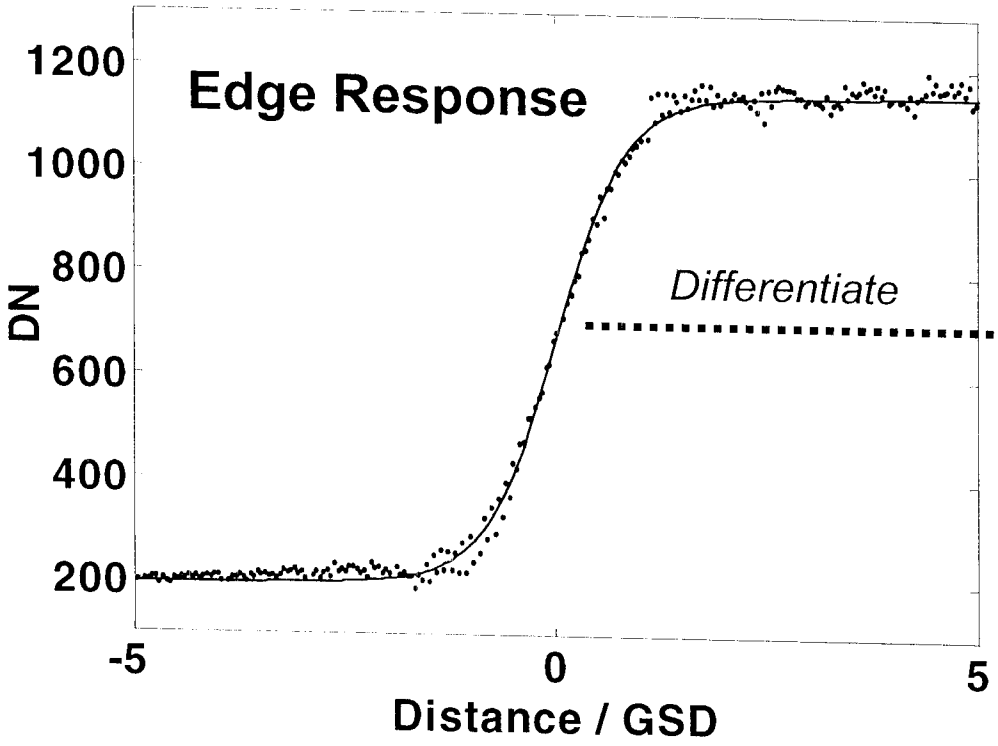
$$e_i(x) = d + \sum_{k=1}^{3} \frac{a_k}{1 + \exp\left[\dfrac{b_1 \Delta i + b_2 - x}{c_k}\right]}$$

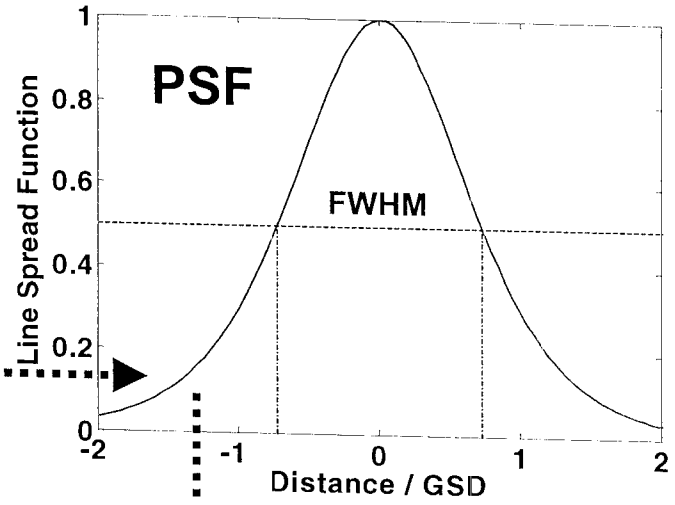
- Optimized parameters: a_1, a_2, a_3, b_1, b_2, c_1, c_2, c_3, d
- Position and orientation of the edge, described by parameters b_1 and b_2, are found *simultaneously* with the parameters characterizing spatial resolution (c_1, c_2, and c_3)
- Measured edge tilt: $\theta = \tan^{-1}(b_1)$
- Distance is scaled by cosine of the edge tilt angle:

$$x = \delta \cos\theta$$

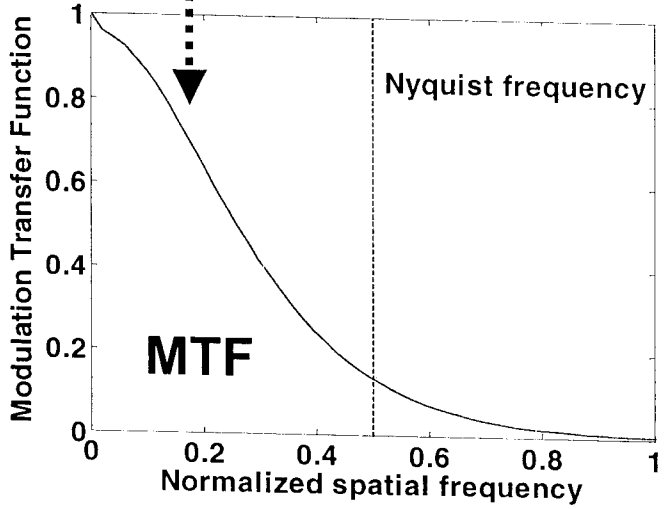


PSF and MTF Derivation





Fourier Transform



- Finding position and orientation of the edge allows for shifting of the edge responses to a single reference location so that all the edge points are aligned.
- Superimposing all the shifted edge responses creates a new edge response with a finer spatial sampling.
- Optimized edge response is generated with arbitrary spatial resolution from the best-fit parameters.

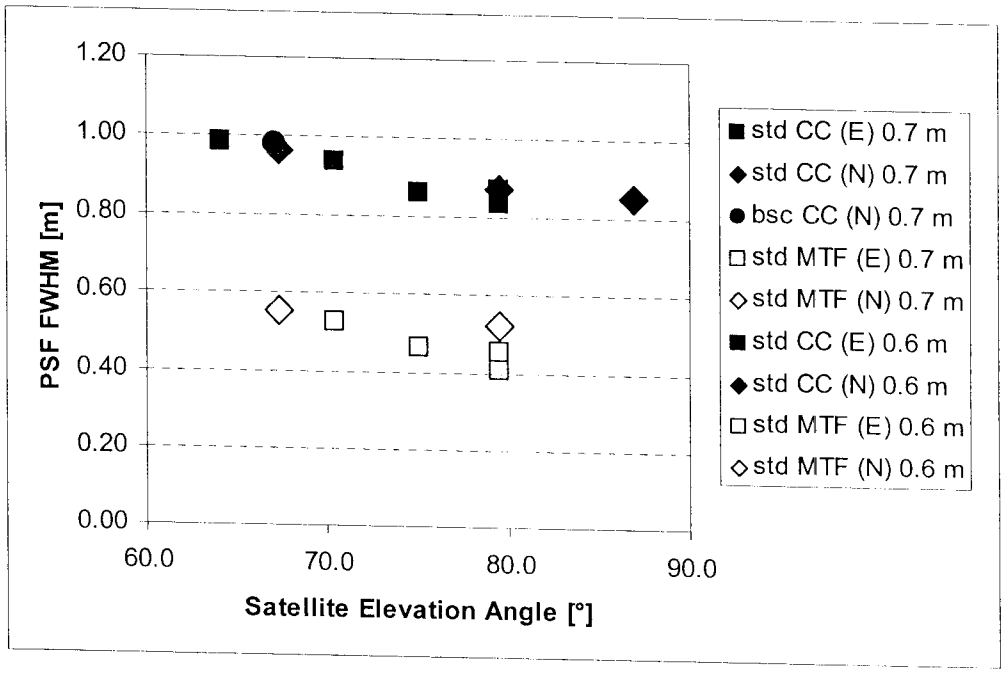
QuickBird Image Acquisitions

Date	Location	Product GSD (m)	Satellite Elevation Angle (°)	Satellite Azimuth Angle (°)
17-Feb-02	Stennis Space Center, MS	0.7	67.3	10.5
20-Jul-02	Brookings, SD	0.7	64.1	349.8
25-Aug-02	Brookings, SD	0.7	70.4	332.7
7-Sep-02	Brookings, SD	0.7	75.0	191.2
14-Nov-02	Stennis Space Center, MS	0.6	79.5	275.7
2-Apr-03	Stennis Space Center, MS	0.6	86.9	243.4

Standard (and one basic) image products georeferenced using Cubic Convolution (CC) and Modulation Transfer Function (MTF) resampling.

Point Spread Function

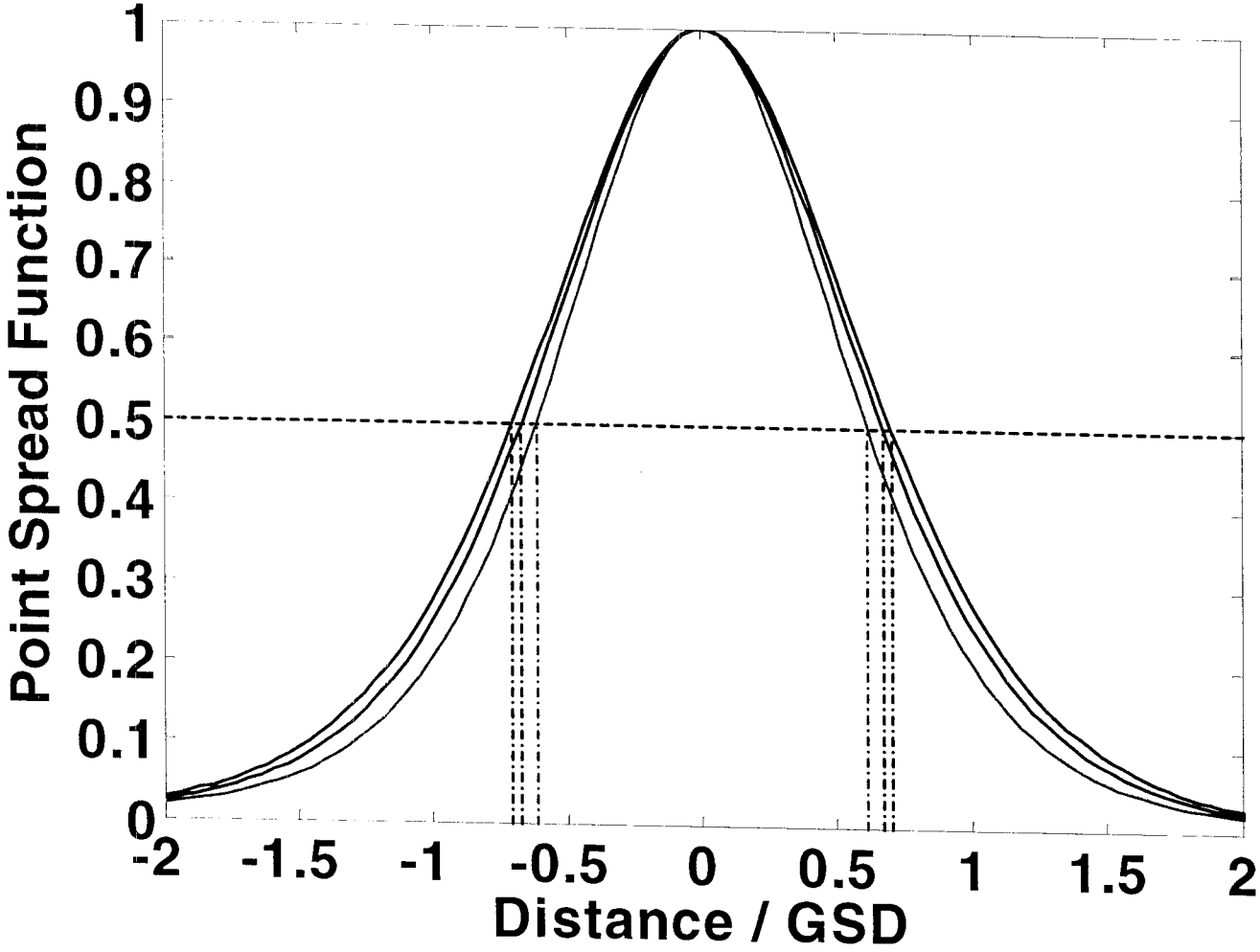
- FWHM of PSF measures extent of spatial response for single pixel.
- For QuickBird images with CC resampling, PSF FWHM is approximately equal to 1.3-1.4 × GSD.
- Resampling to smaller GSD only slightly improves (reduces) the extent of spatial response.
- MTF resampling improves spatial resolution by the factor of ~2, but noise and overshoots increase.



(E) = Easting (horizontal) direction

(N) = Northing (vertical) direction

PSF Comparison



GSD = 0.7 m

FWHM =

0.98 m ***20-Jul-02***

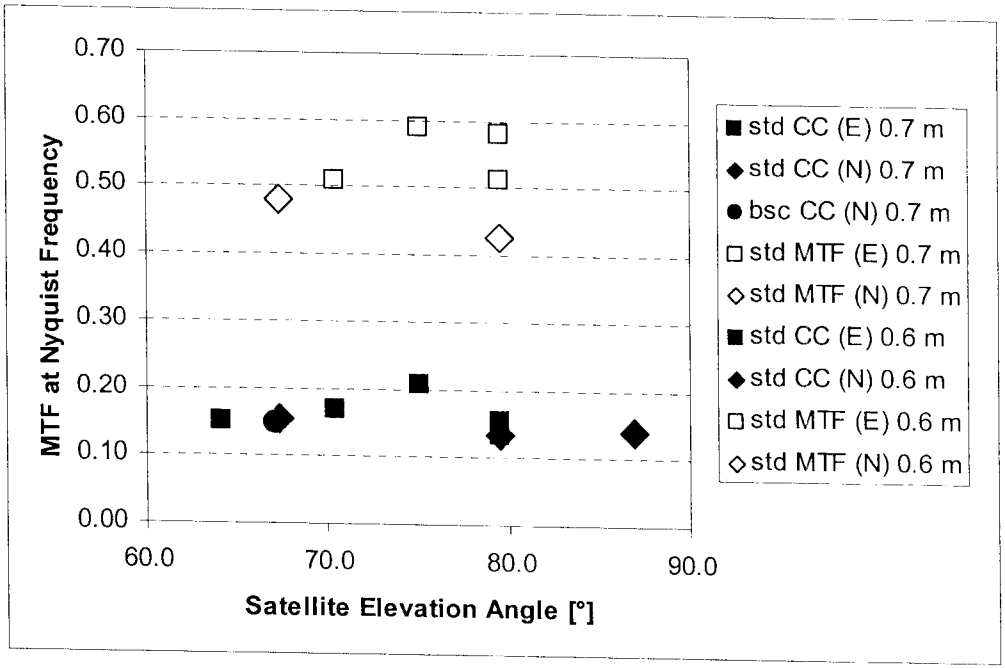
0.94 m ***25-Aug-02***

0.86 m ***7-Sep-02***

Relatively small PSF differences

Modulation Transfer Function

- MTF values at Nyquist spatial frequency exceed NASA Scientific Data Purchase contract requirements for QuickBird image products created with CC as well as with MTF resampling.
- MTF resampling creates images with higher values of MTF at Nyquist frequency (boost).
- Resampling image products to smaller GSD (0.6 m vs. 0.7 m) reduces value of MTF at Nyquist frequency, but NASA requirements are still fulfilled.



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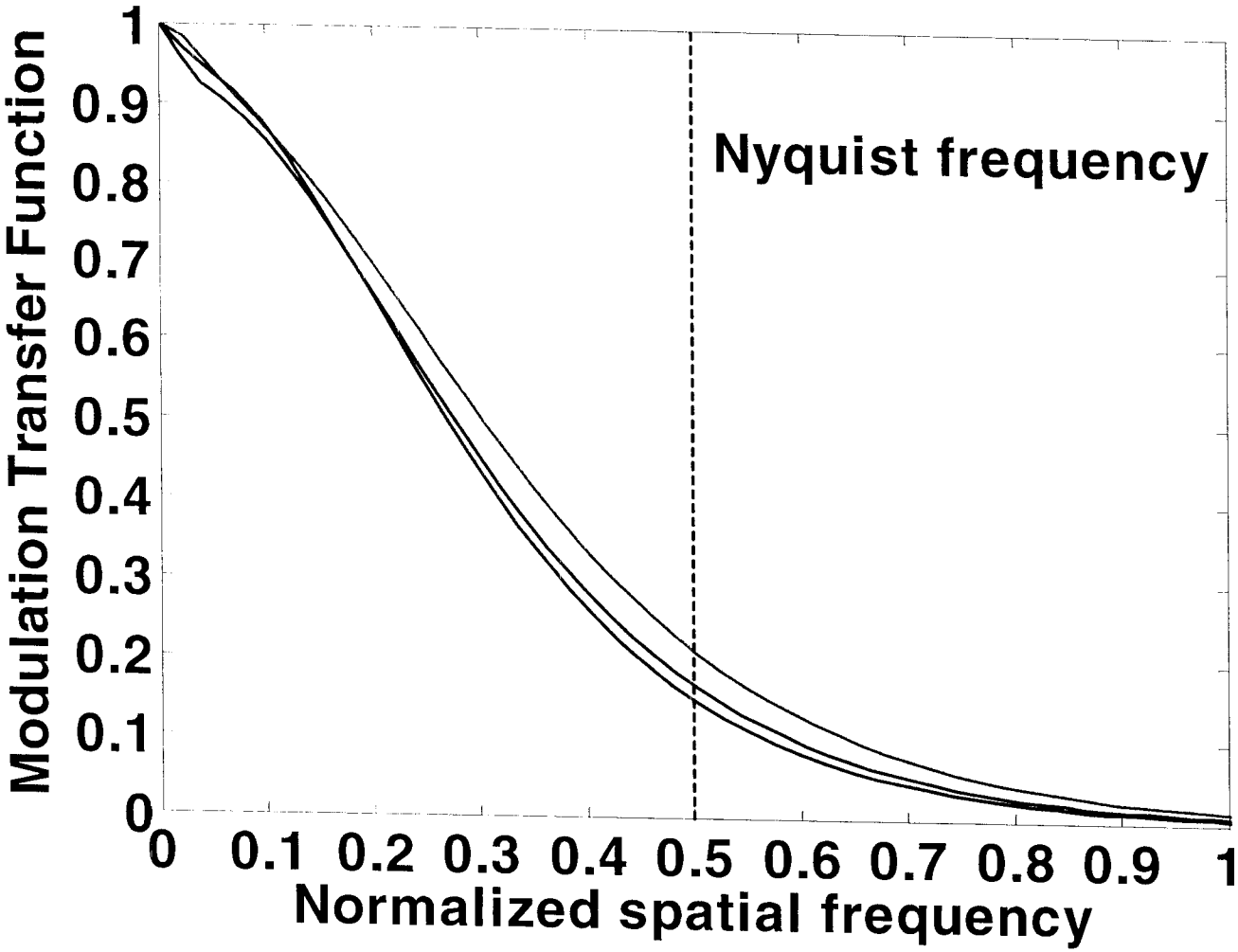
MTF Comparison



Nyquist frequency = 0.7 m^{-1}

$MTF_{Nyquist}$ =

0.15	*20-Jul-02*
0.17	*25-Aug-02*
0.21	*7-Sep-02*

Larger MTF differences

Resampling: MTF vs. CC