Spatial Resolution Characterization for Aerial Digital Imagery

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Spatial Characterization Approach

- NASA and the U.S. Geological Survey (USGS) have jointly developed capability for characterization of aerial digital imagery:
  - USGS defines characterization requirements and interfaces with industry.
  - NASA performs characterizations of image products using the Stennis Space Center (SSC) test range.
- Analysis includes geopositional accuracy and spatial response:
  - Radiometric characterization is to be performed in the future.
- Spatial response is characterized based on measurements of Relative Edge Response (RER):
  - RER is one of the engineering parameters used in the General Image Quality Equation (GIQE) to provide predictions of imaging system performance expressed in terms of the National Imagery Interpretability Rating Scale (NIIRS).
- RER is estimated using the SSC edge targets and the tilted edge technique:
  - RER is a geometric mean of normalized edge response differences measured in two directions of image pixels (X and Y) at points distanced from the edge by -0.5 and 0.5 ground sample distance (GSD).

SSC Edge Targets

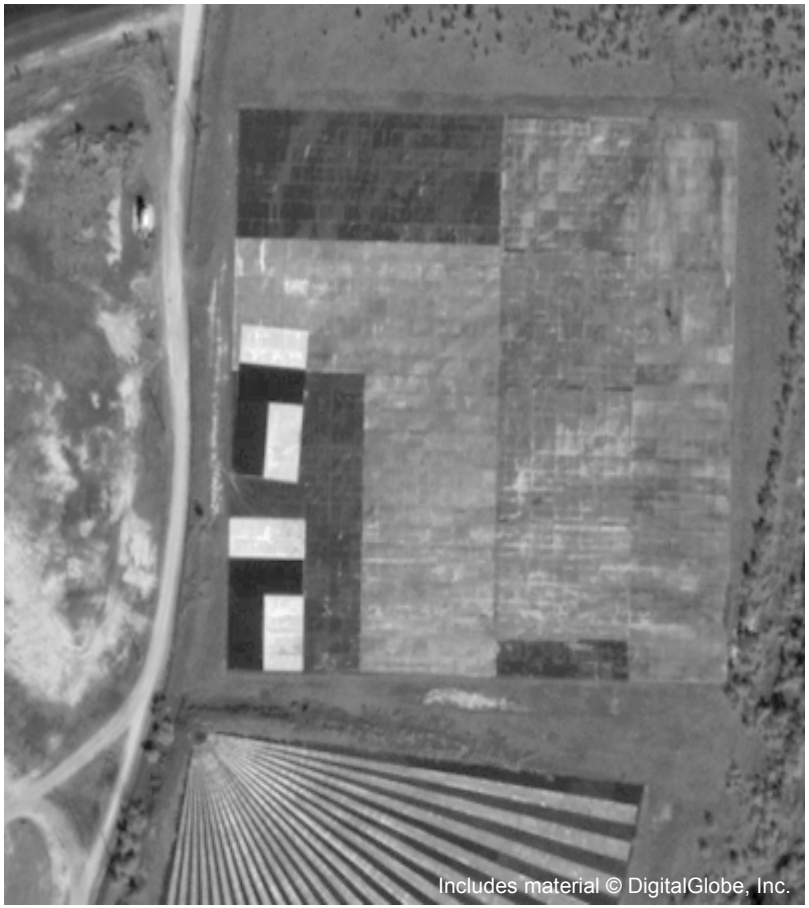
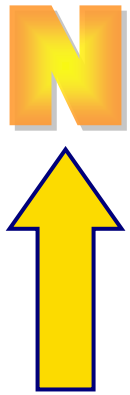
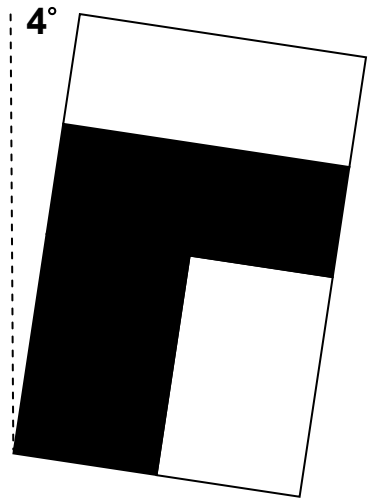
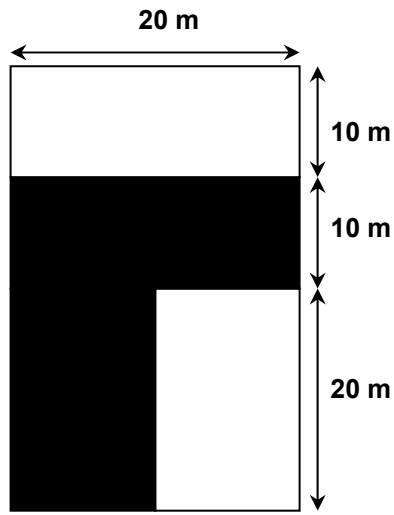


Image of the SSC edge targets acquired by the QuickBird satellite (60 cm GSD)

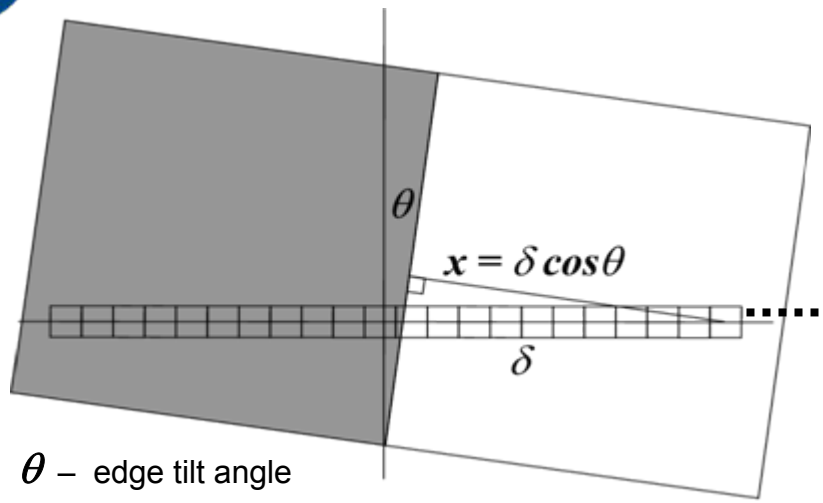




- Two pairs of edge targets painted on a concrete surface
- Orientation differs by 4 degrees to accommodate images with various pixel directions (Universal Transverse Mercator-projected and others)



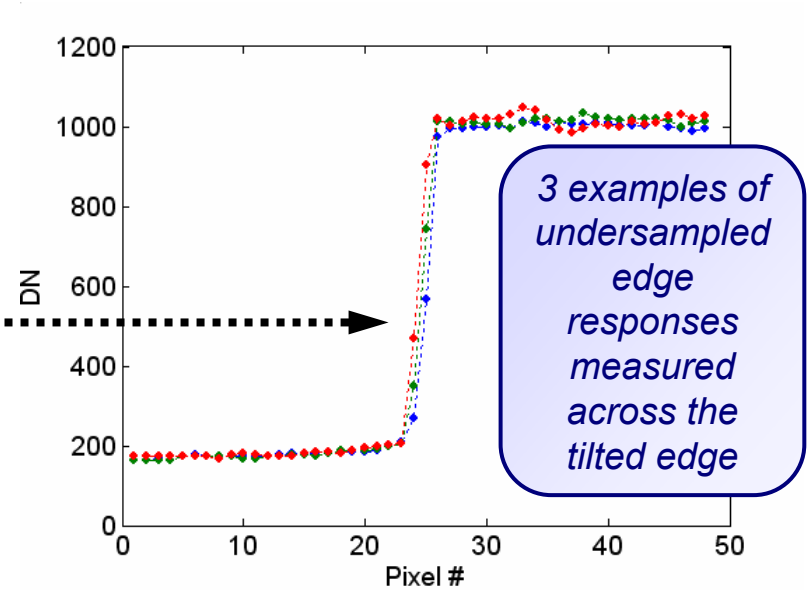
Tilted Edge Technique



θ – edge tilt angle

δ – pixel index

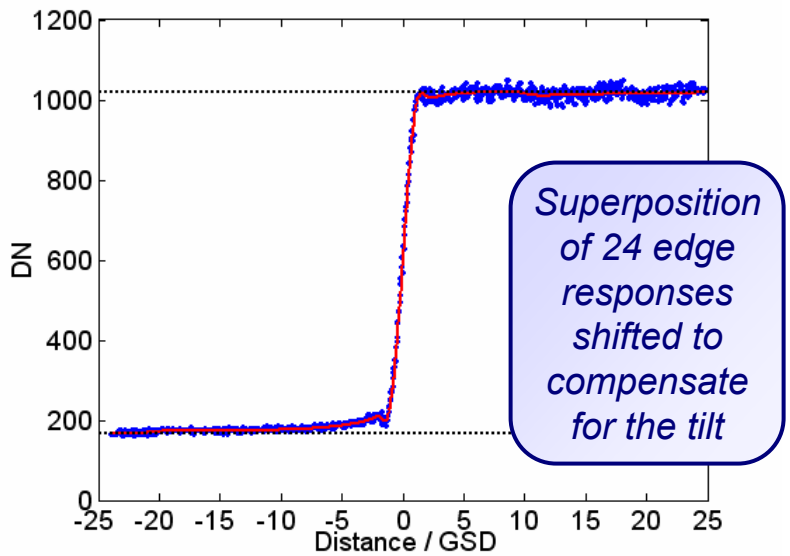
x – pixel's distance from edge (in GSD)



3 examples of undersampled edge responses measured across the tilted edge

***Problem**: Digital cameras undersample edge target*

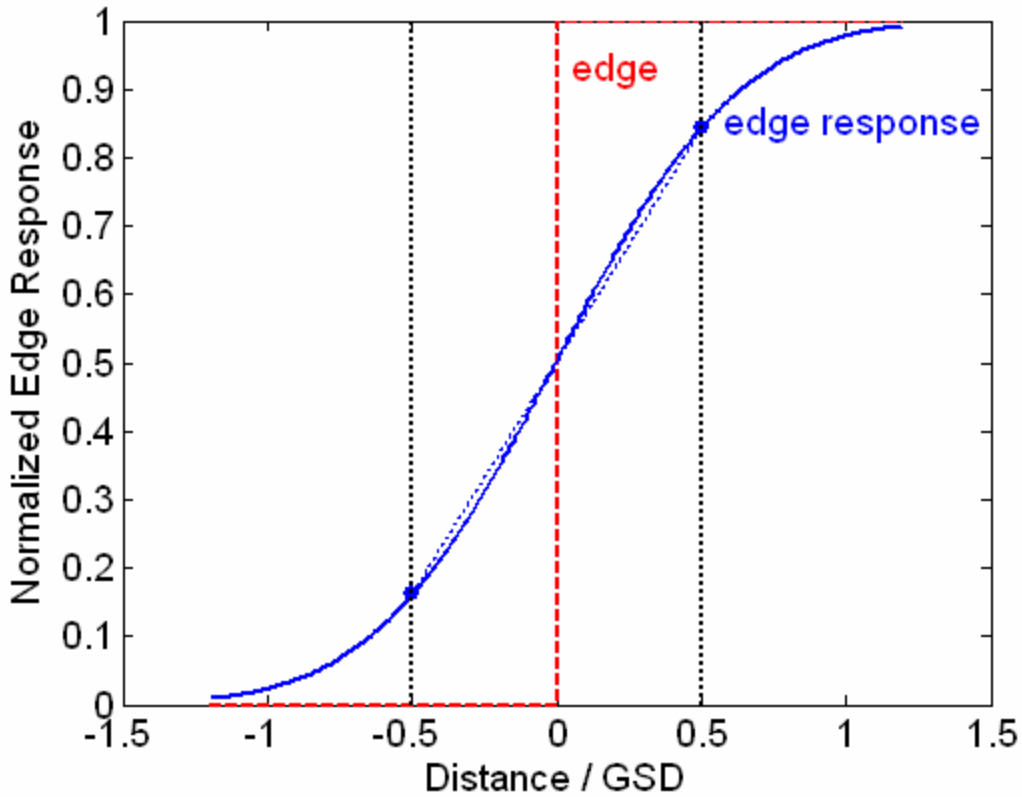
***Solution**: Image tilted edge to improve sampling*



Superposition of 24 edge responses shifted to compensate for the tilt

Relative Edge Response

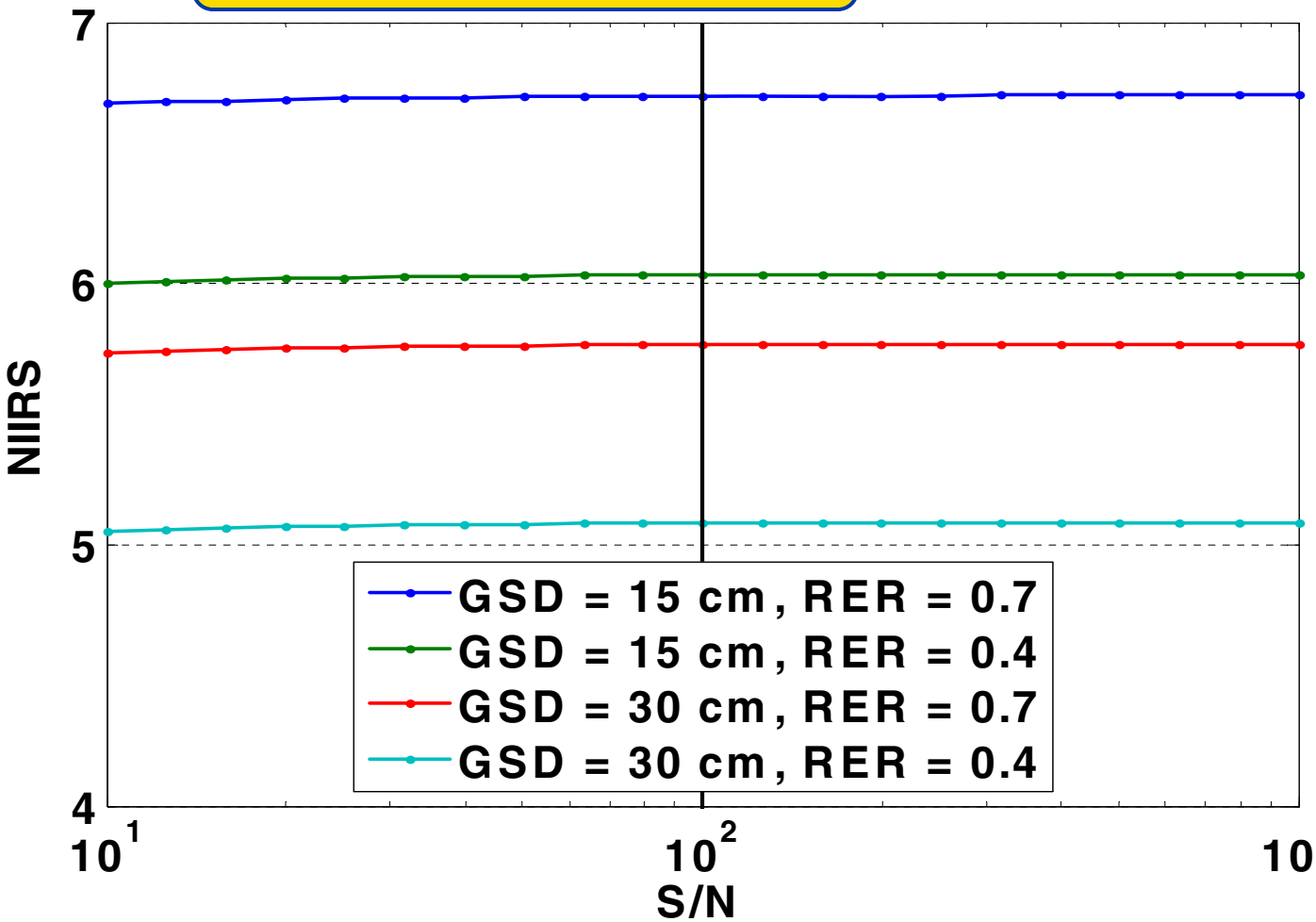
$$RER = \sqrt{[ER_X(0.5) - ER_X(-0.5)][ER_Y(0.5) - ER_Y(-0.5)]}$$



RER estimates effective slope of the imaging system's edge response, because the distance between the points for which the differences are calculated is always equal to the GSD

Effects of RER on Civil NIIRS

NIIRS estimates based on GIQE (assuming no MTF compensation)



Identify large farm animals by type (e.g., horses, cows) (NIIRS 6.7)

Smaller RER can degrade interpretability, despite finer GSD

Detect individual large domesticated animals (e.g., horses, cattle) in grazing pastures (NIIRS 5.3)

Meaning of RER in Remote Sensing

Radiance measured for each pixel is assumed to come from the Earth's surface area represented by that pixel. However, because of many factors, actual measurements integrate radiance L from the entire surface with a weighting function provided by a system's point spread function (PSF):

$$L_T = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} PSF(x,y)L(x,y)dxdy$$

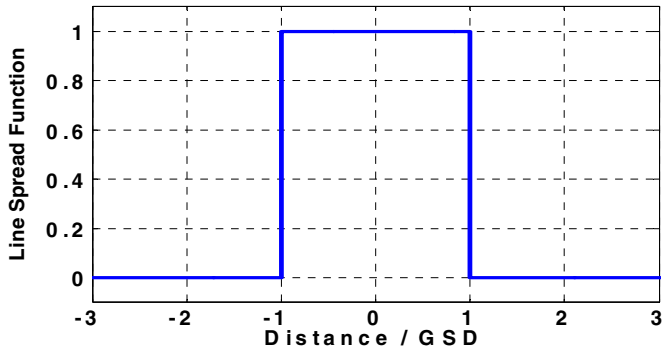
Part of radiance that originates in the pixel area is given by:

$$L_P = \int_{-0.5}^{0.5}\int_{-0.5}^{0.5} PSF(x,y)L(x,y)dxdy$$

One can show that the Relative Edge Response squared (RER^2) can be used to assess the percentage of the measured pixel radiance that actually originates from the Earth's surface area represented by the pixel:

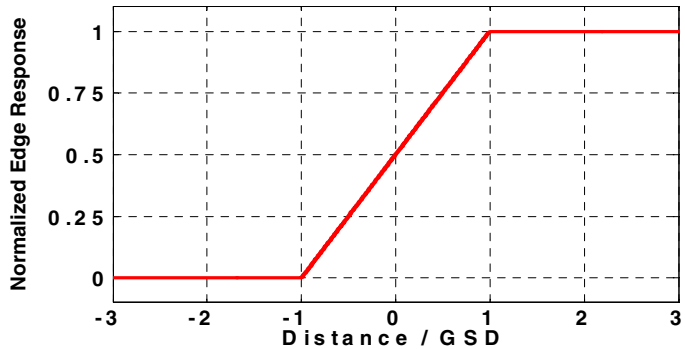
$$L_P / L_T \approx RER^2$$

A simple example:
Box PSF
Width = 2 GSD

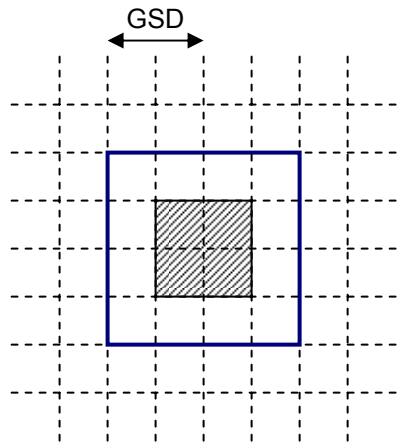


ER(0.5) - ER(-0.5) =
0.75 - 0.25 = 0.50

RER = 0.50

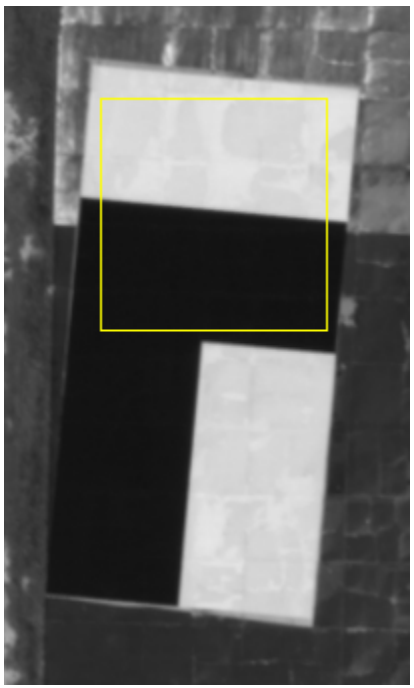


RER^2 = 0.25 means that 25% of information collected with the pixel PSF (blue square) comes from the actual pixel area (shadowed square)

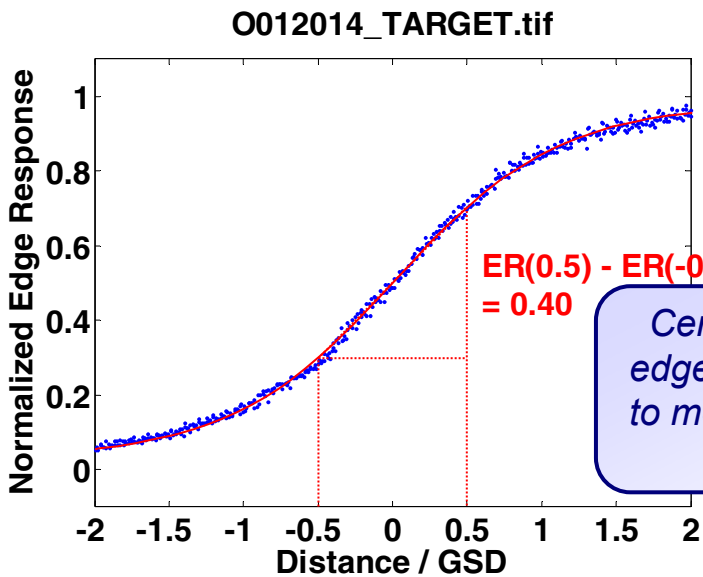


Example: 15 cm GSD Panchromatic Image

Image area selected for the spatial resolution measurement in the Northing direction



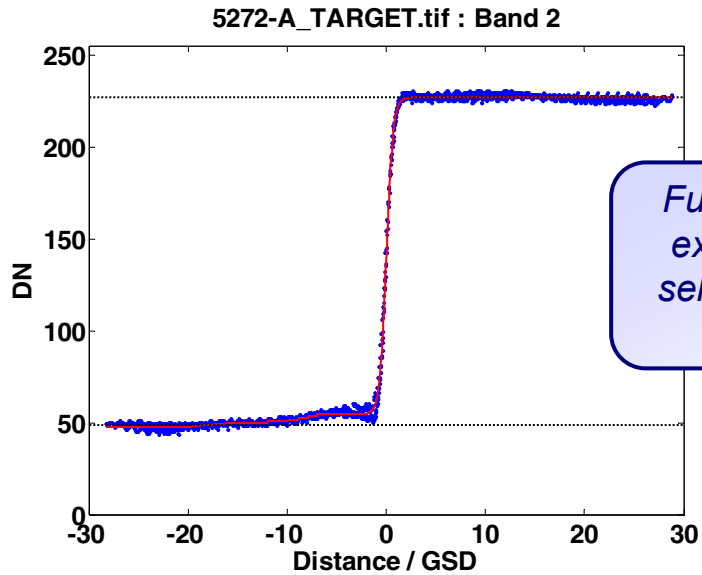
Full edge response extracted from the selected area of the image



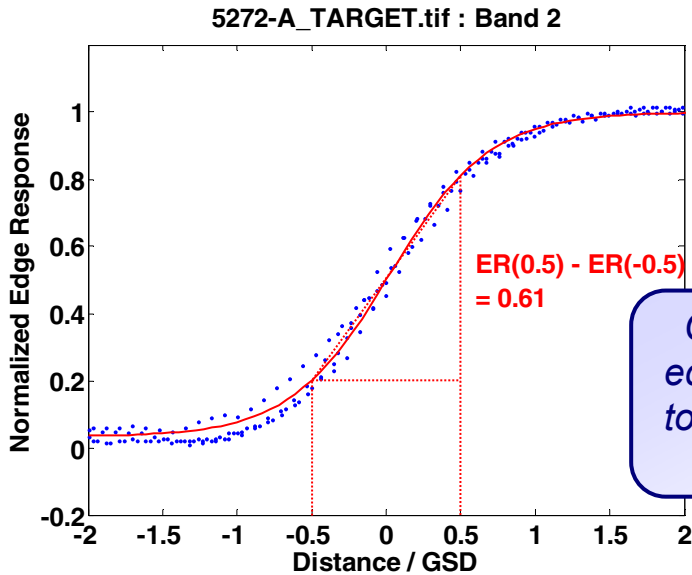
Central part of the edge response used to measure the RER difference

Example: 30 cm GSD Multispectral Image

Section of the characterized image showing the SSC edge targets



Full edge response extracted from the selected area of the image



Central part of the edge response used to measure the RER difference

Spatial Characterization Results

Stennis Space Center

Image Acquisition Date	Sensor	Company	GSD (cm)	RER
22-Nov-2002	Leica ADS40	EarthData International®	25	0.5 (BW) 0.6 (IR) 0.5 (RGB)
24-Nov-2003	DAIS	Space Imaging® (GeoEye™)	50	0.7 (VNIR)
5-Dec-2003	IKONOS*	Space Imaging (GeoEye)	100	0.7 (pan)
18-Feb-2004	Z/I Imaging DMC	AERO-METRIC, INC.®	15	0.4 (pan)
8-Nov-2004	Z/I Imaging DMC	3001, Inc.®	15 30	0.5 (RGB), 0.4 (CIR) 0.6 (RGB), 0.5 (CIR)
23-Feb-2005	Z/I Imaging DMC	Florida Department of Transportation	30	0.6 (RGB)

**satellite*

Reports with the characterization results have been delivered by NASA to USGS

GSD – *Ground Sample Distance*
RER – *Relative Edge Response*
BW – *Black, White*
IR – *Infrared*
RGB – *Red, Green, Blue*
VNIR – *Visible/Near Infrared*
CIR – *Color Infrared*

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14. ABSTRACT
The U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration have jointly conducted characterizations of aerial digital imagery from commercial data providers. In a typical scenario, a vendor acquired imagery over the Stennis Space Center (SSC) test range and provided a common data package to SSC. SSC personnel analyzed the geopositional accuracy and spatial resolution of the images, then documented the characterization results in a report and delivered the report to the USGS.
Spatial resolution characterization was based on edge response measurements using one of the SSC edge targets and the tilted-edge technique. Relative Edge Response (RER) has been estimated for aerial digital imagery from several commercial data providers. RER is one of the engineering parameters used in the General Image Quality Equation to provide predictions of imaging system performance expressed in terms of the National Imagery Interpretability Rating Scale. RER also characterizes applicability of digital image products in quantitative remote sensing, such as thematic mapping based on image classification, because RER squared may be used to assess the percentage of the pixel signal that actually originates from the Earth's surface area represented by the pixel.

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