ITT

On-Orbit MTF Measurement and Product Quality Monitoring for Commercial Remote Sensing Systems

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Outline

- Problem Definition
- Technique Overview
- Validation
- Current Software Implementation
- Product Quality Monitoring Architecture

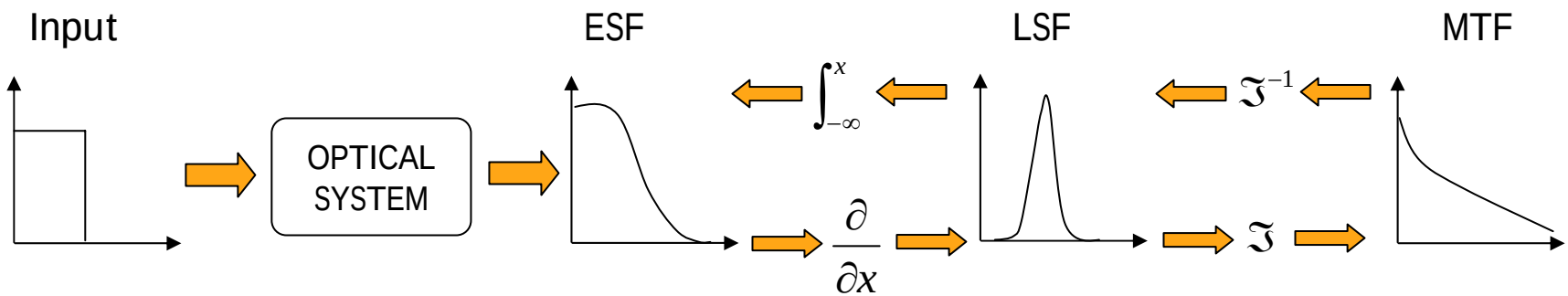
Problem Definition

- Determine the MTF of an on-orbit satellite using in-scene targets:
  - Slant Edge
  - Line Source
  - Point Source
  - Radial Target
- Attempt to facilitate the MTF calculation by automatically locating targets of opportunity.
- Incorporate MTF results into a product quality monitoring architecture.

Relation Between MTF Components

- Initialization and opportunistic targets are chosen that represent the MTF in the spatial domain.

- Ideal targets have simple mathematical relationships.



Review of Potential Targets for MTF Calculation

Method	Approach	Advantage	Disadvantage
Edge Gradient	▪ Computes LSF from edge profile ▪ Basic approaches are similar but different in ways edge profile is determined	▪ ISO has a standard approach ▪ Less sensitive to alignment issues ▪ Targets easier to implement ▪ Good energy at all frequencies	▪ Typically uses curve fits for edge profiles ▪ Computes LSF indirectly from ESF and uses differentiation ▪ Can introduce noise
Pulse Input	▪ Computes LSF directly from target	▪ Less numerical error from MTF	▪ Requires knowledge of target width and resolution for reliable results
Point Source	▪ Computes point spread in x & y directions as a function of intensity and distance across imaged point	▪ Provides 2-D MTF	▪ Requires confidence about location of point source center ▪ Multiple aligned points necessary ▪ Various signal-to-noise issues (atmos. effects, neighboring points, single point SNR, etc.)
Radial Target	▪ Analyzes a series of “pulses” lying on concentric paths about a circle	▪ Can provide visual quality assessment ▪ Provides contiguous frequencies	▪ Difficult to implement ▪ High potential for aliasing

Two Stage Algorithm

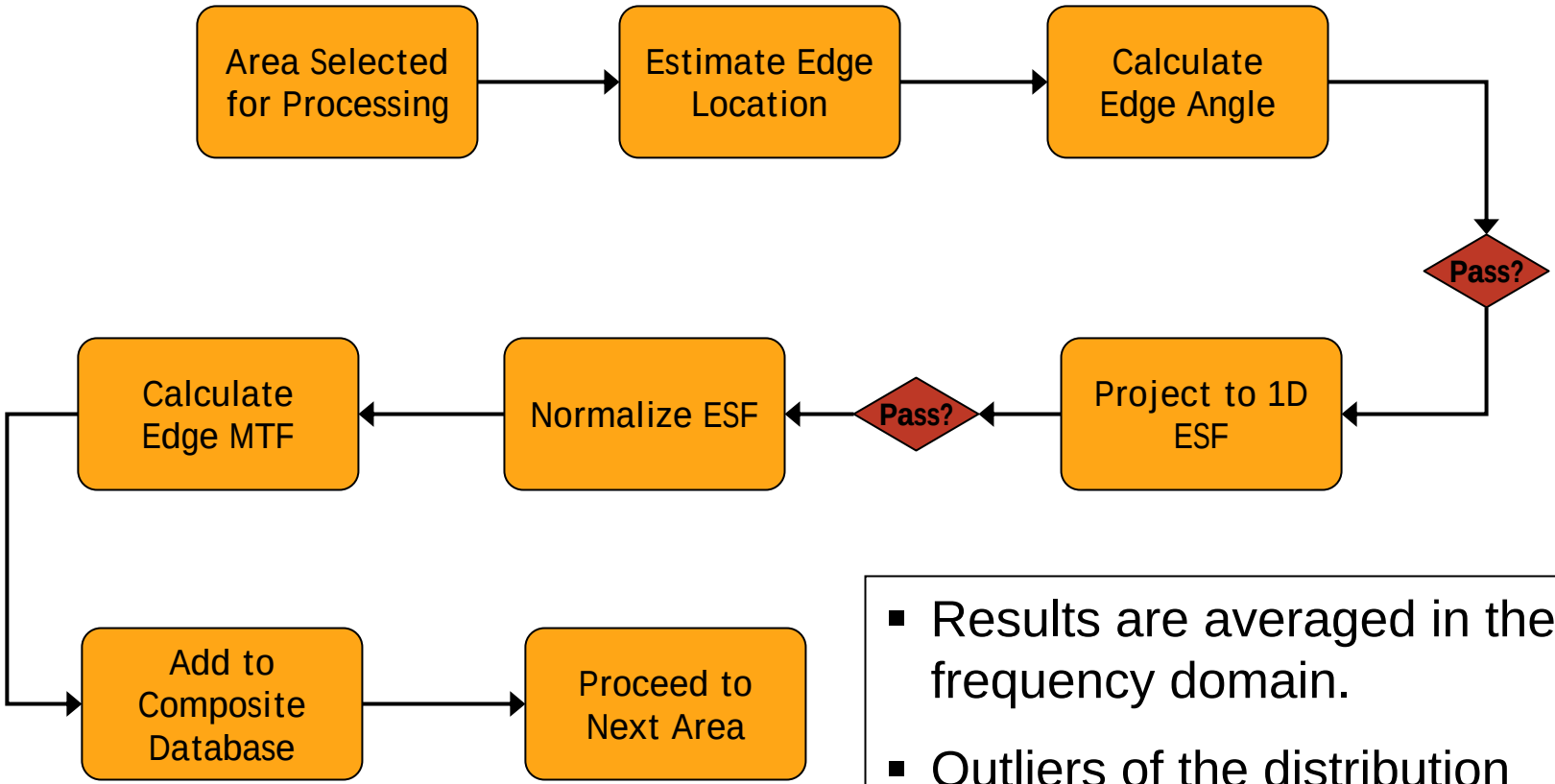
Edge Finding

- Input image area is sequentially searched for areas of edge content.
- A set of user modified parameters are defined to constrain located edges:
  - Edge Size
  - Edge Angle
  - Contrast
  - Uniformity of light and dark areas
- Edges that satisfy all criteria are projected to 1D and passed to the MTF algorithm.

MTF Calculation

- MTF is calculated using a method developed by B. Tatian JOSA, Vol. 55, pp. 1014-1019.
- Avoids taking a discrete derivative of the ESF by approximating the MTF as a set of trigonometric series.
- Errors in the algorithm are dominated by:
  - Edge Size
  - Angle
  - SNR

MTF Algorithm Flow



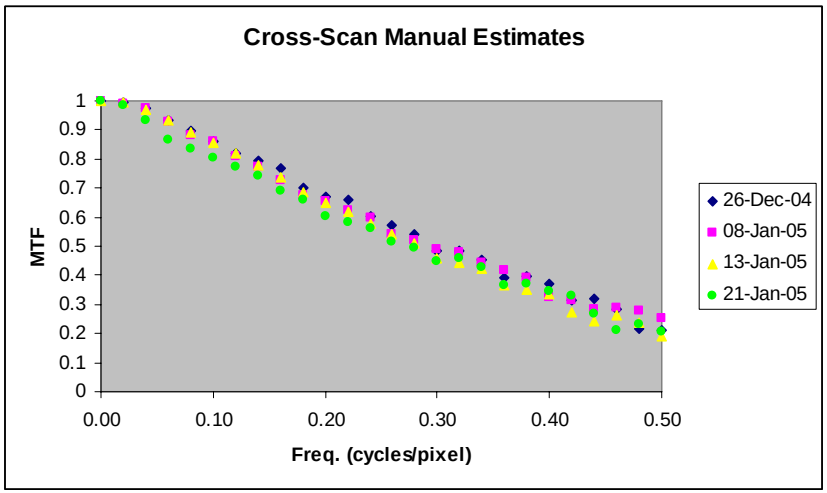
- Results are averaged in the frequency domain.
- Outliers of the distribution rejected from the final average.

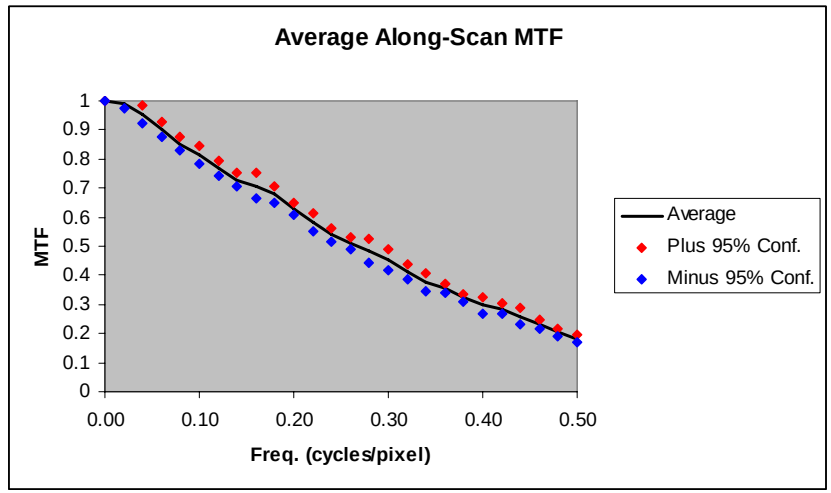
Validation of Current method

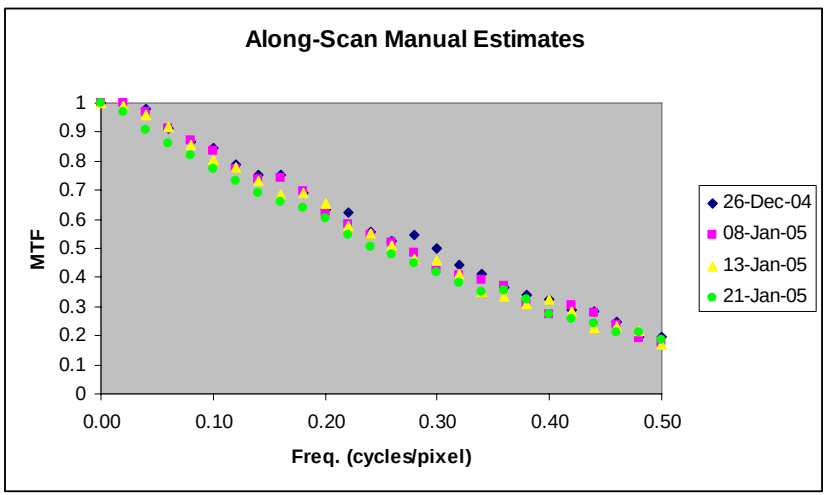
- Four images of the Big Spring, TX test target were provided to ITT by DigitalGlobe.
- MTF algorithm was verified by manually selecting one along-scan and one cross-scan edge from each image for processing.
- Full algorithm was used to process a 400x400 pixel area.

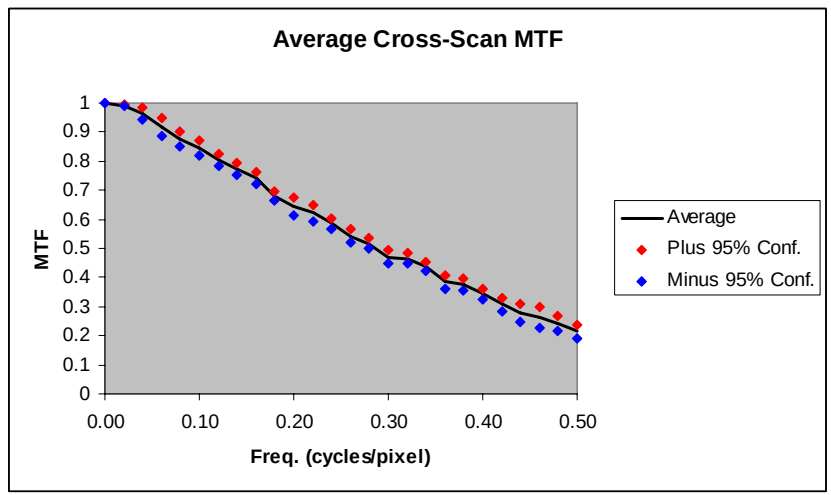
Imagery courtesy of DigitalGlobe/Reprinted with Permission

Results of Manual MTF Estimate from Edge Target









Example Run on Test Target Crop

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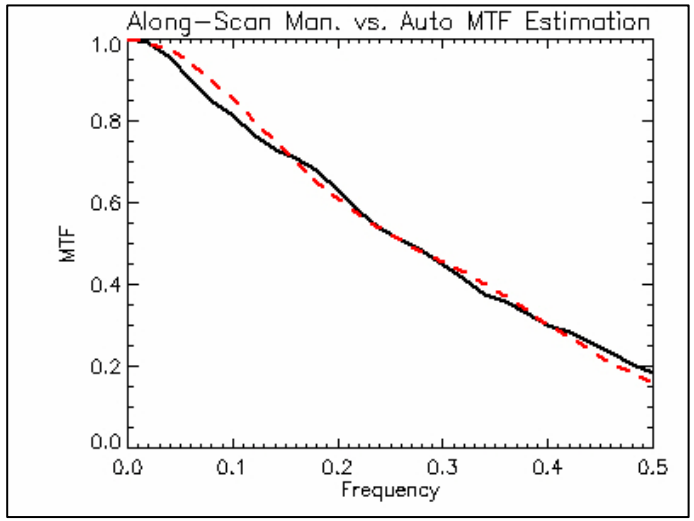
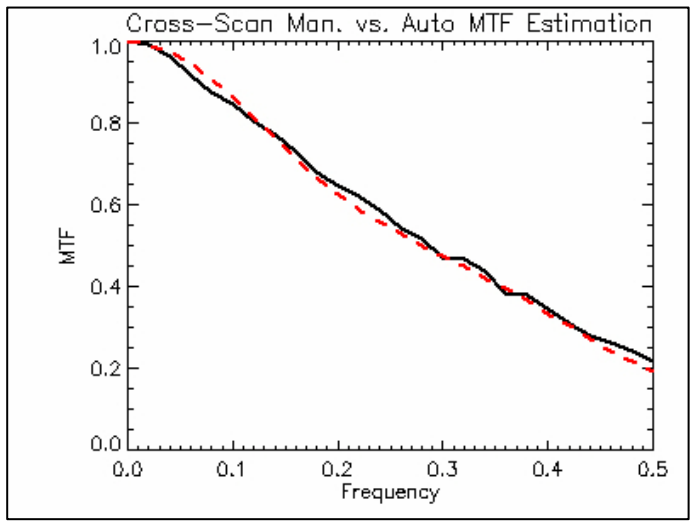
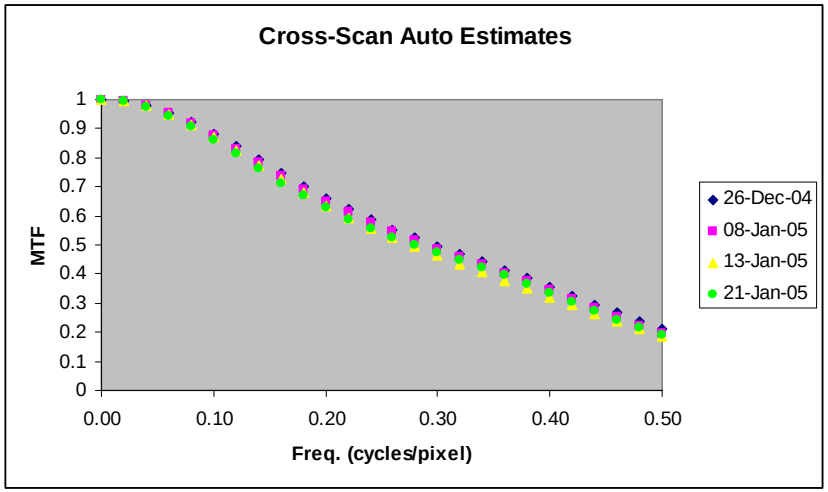
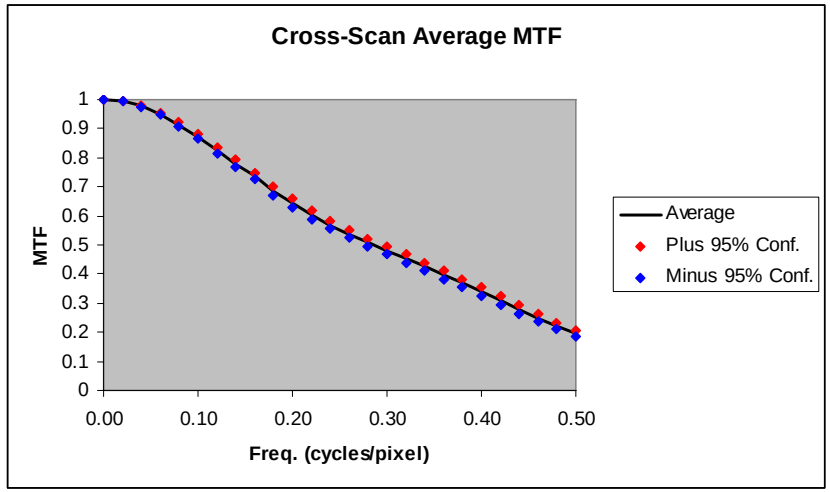
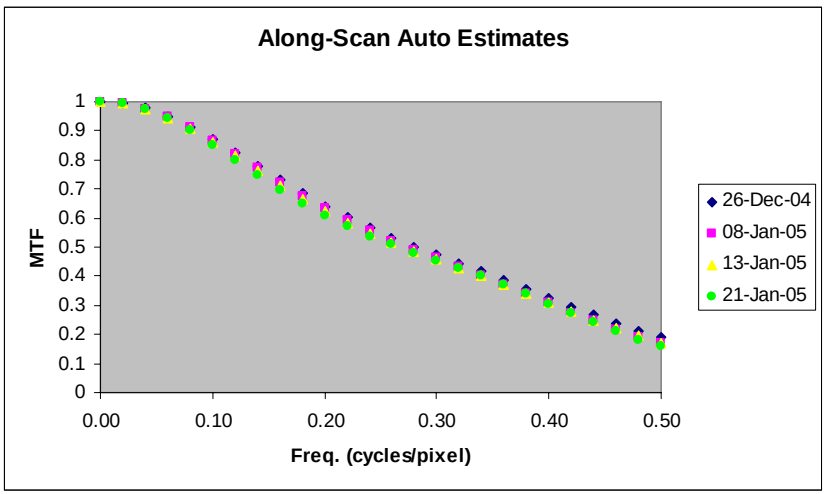


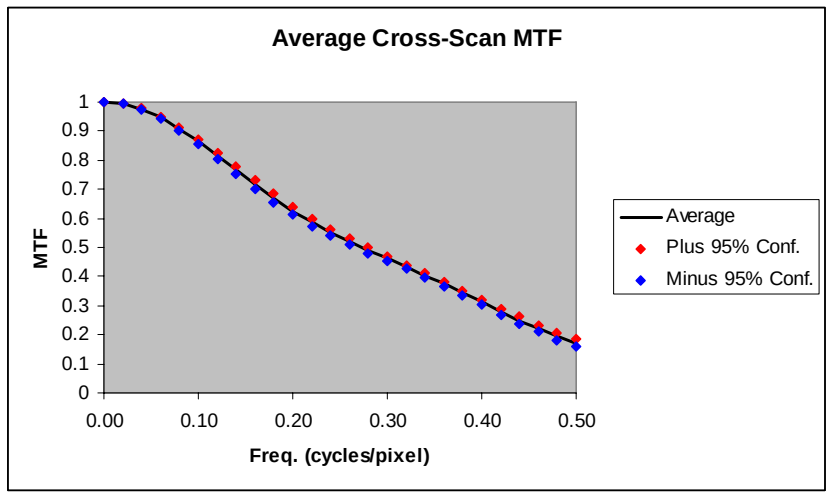


Automatic MTF Estimate from Edge Target

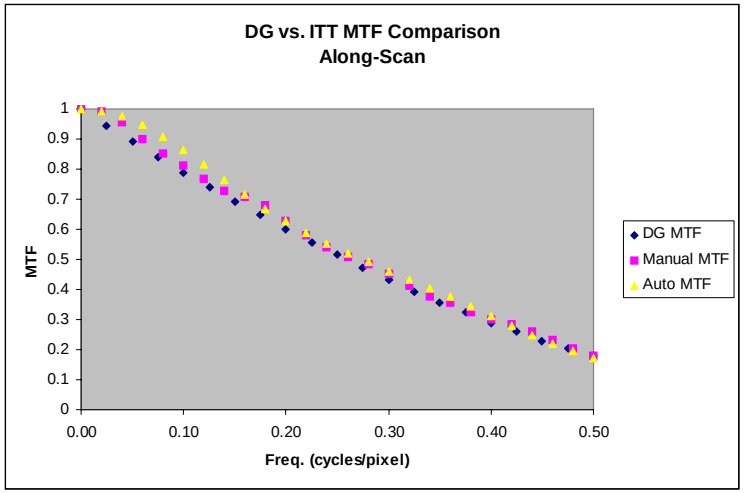


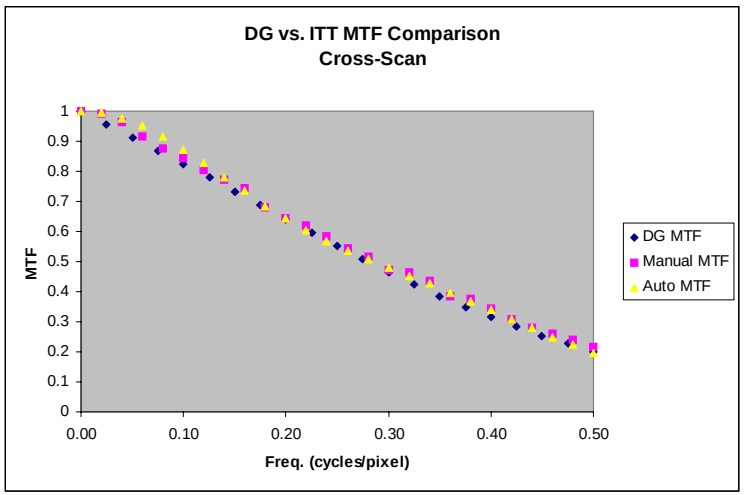






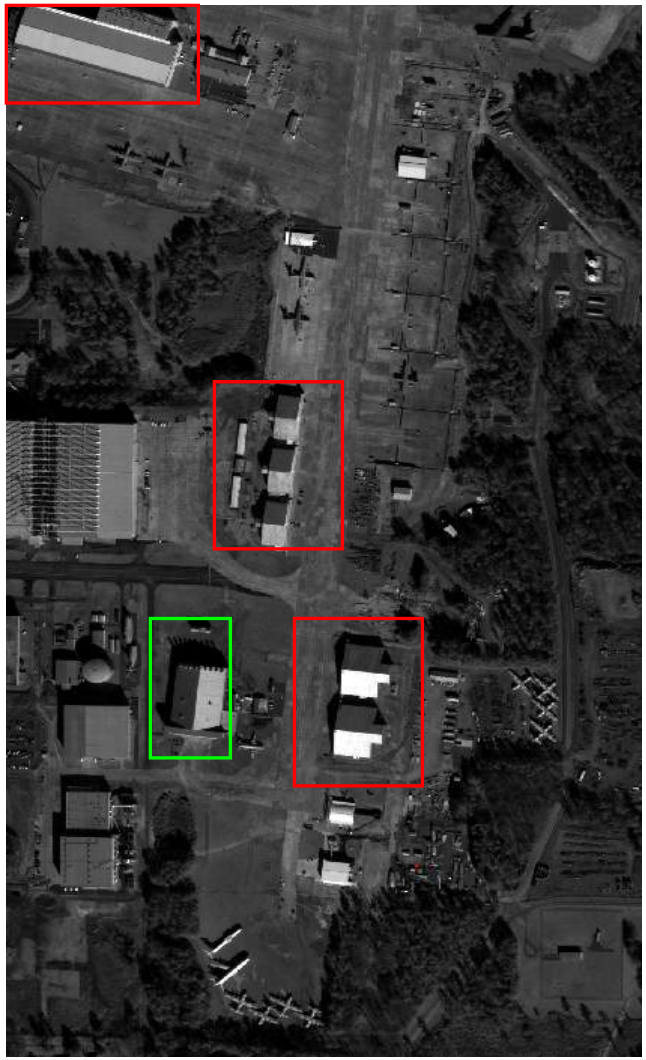
Comparison to DigitalGlobe Results





- Good agreement between the manual estimation and automatic estimation when compared to independent DG results.
- Positive bias in the low frequencies due to small edge size used in computation.

Example Operational Image



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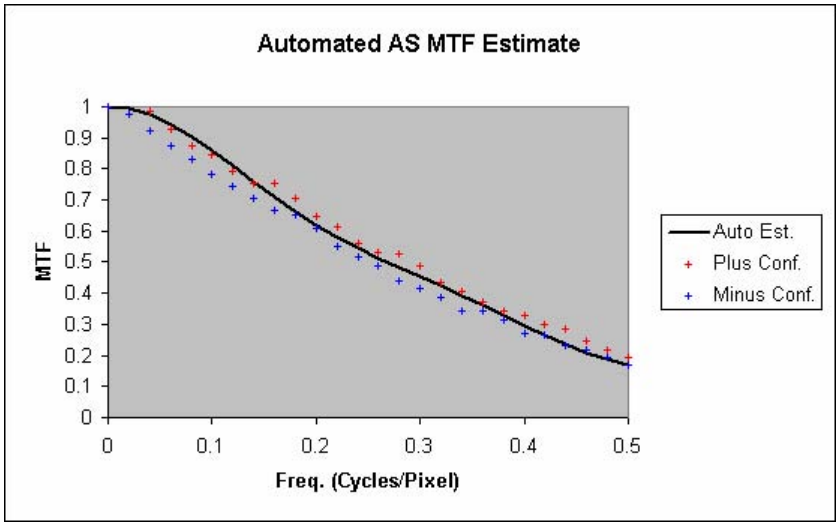
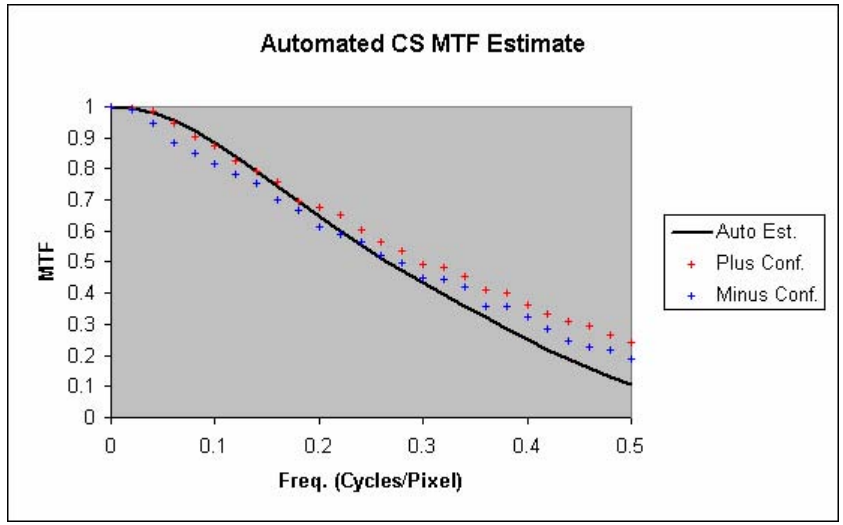
- Algorithm executed with a nominal parameter set on image with potential edge content.
- Red squares indicate targets used to estimate along-scan MTF.
- Green squares indicate targets used to estimate cross-scan MTF.

Results from Extracted Test Image

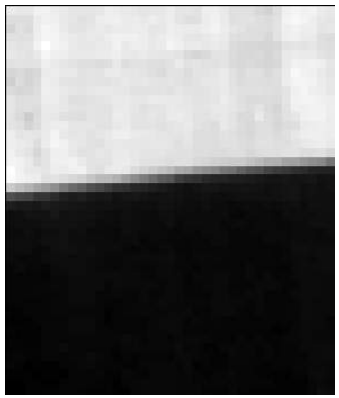




- Cross-scan bias observed in individual edges used to estimate MTF.
  - Possibly due to unobserved roof structure.

Roof Edge Example

Manual Edge Crop



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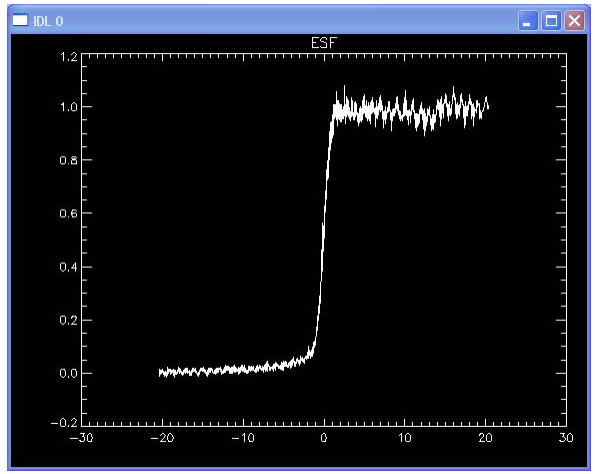
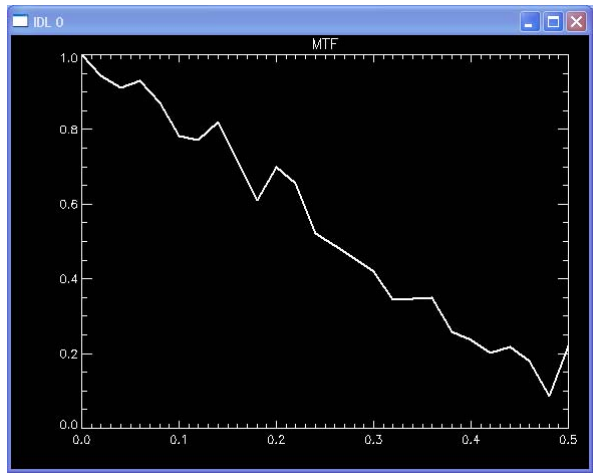




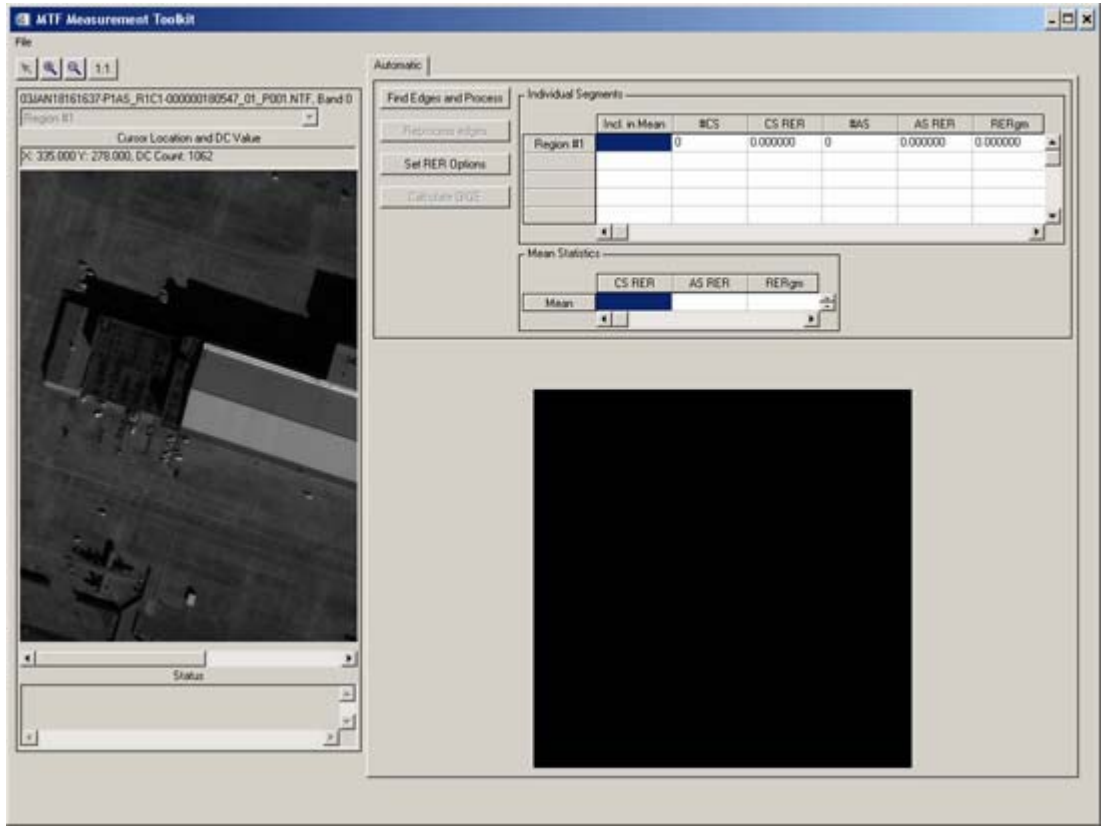
- Further investigation shows nothing unusual about edge.
- Presents a difficult problem for automatic edge detection routine.

Prototype Software Implementation

- The current software implementation attempts to address the edge selection issues.
- Coded in IDL as a plug-in to ENVI.
- Allows user to manipulate imagery with built-in ENVI functionality and select Regions of Interest within an image where edge content appears.
- ROIs are imported into a separate GUI for processing and result display.

Screen Shot of MTF Measurement Toolkit

- Facilitates quick processing of data for time critical results or repetitive monitoring.
- Using a system with a known MTF the Toolkit can identify regions around the globe that approximate “ideal edges”.



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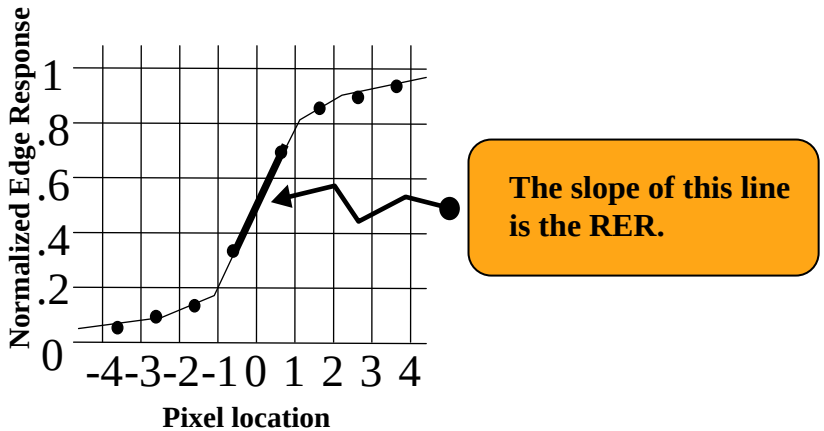
Areas for Future Improvement and Investigation

- Investigate alternate edge finding techniques.
  - Methods which include the least false positives.
  - Region growing techniques to increase number of samples along an edge.
- Investigate benefit of aggregation in the spatial domain vs. the frequency domain.
- Incorporate a database function that allows for tracking and trending of results.

Relative Edge Response Relation to Image Quality

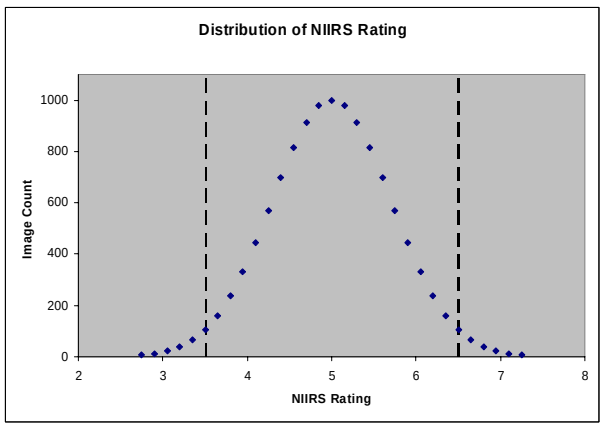
$$NIIRS = A_0 - a\log(GSD) + b\log(RER) - A_1 H - A_2\left(G/SNR\right)$$

- RER is easily calculated along with the MTF using the same algorithm.
- RER is the second largest contributing factor to the General Image Quality Equation (GIQE).



Two possible PQ Monitoring Architectures

- Develop full GIQE model to monitor NIIRS ratings.
- Flag images which fall *N*σ outside the historical distribution of NIIRS ratings.
- Identify shifts in histogram mean.



- Monitor each parameter of the GIQE separately.
- Calculate a baseline mean with confidence bounds.
- Indicate when a parameter falls outside of the baseline behavior.