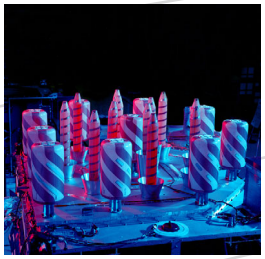
Welcome

On-Orbit System MTF Measurement



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An On-Orbit MTF Measurement Process: *Background*

- Problem of computing an accurate, validated, and repeatable measurement of on-orbit system MTF has been well studied
- From the onset, several requirements existed that have carried through successive versions of our process
  - Ability to work without a priori information of the imaging system
  - Invariance to noise, contrast, blur, and sampling
  - Ability to extract asymmetric (separate A/S and C/S) MTFs
  - Desire unsupervised approach (I.e., many samples, many images)
  - Ability to implement in tandem with other metrics/tasks
- Several related techniques exist and each present pros and cons
  - Edge measurement: Infer MTF from edge response function
  - Point source measurement: Infer MTF from point spread function
- Current ITT/RSI technique is an extension of capabilities developed over 40 years of support to National imaging initialization programs

An On-Orbit MTF Measurement Process: *Study*

ICA recently conducted an assessment study to investigate on-orbit MTF measurement techniques

- Many techniques/approaches were considered
  - Next page summarizes these approaches
- Investigation whittled down to three primary approaches
  - ICA slanted edge assessment
  - ISO slanted edge assessment
  - Point target assessment

The study was completed in early 2004 and briefed to community experts

The recommendations made from the study are being considered for future use on NTM systems

An On-Orbit MTF Measurement Process: *Study*

Method	Approach	Advantage	Disadvantage
Edge Gradient • ICA • ISO	• Computes LSF from edge profile • Basic approaches are similar but different in ways edge profile is determined	• ISO is/has a standard approach • Less sensitive to alignment issues • Targets easier to implement • Good energy at all frequencies • Easy to implement • Robust	• Typically uses curve fits for edge profiles • Computes LSF indirectly from ESF and uses differentiation • Can introduce noise • Requires sufficient ground target contrast
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 location • Single point source used • 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

An On-Orbit MTF Measurement Process: *Study*

Objectives:

- Survey, characterize, and recommend the most accurate, repeatable, practical, and robust technique(s) suitable for on-orbit image-based MTF validation

"Selection" criteria:

- Accuracy and Confidence
- Required sample size(s)
- Robustness
  - Impacts due to contrast ratio, target degradation, and orientation
- Efficiency of use

An On-Orbit MTF Measurement Process: *Study*

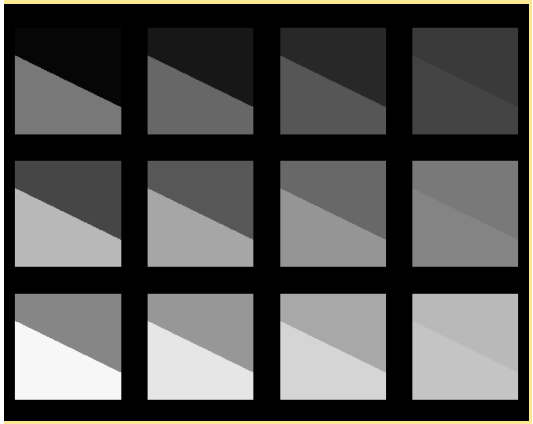
Simulation images used to generate metrics

- Accuracy
- Confidence Bounds

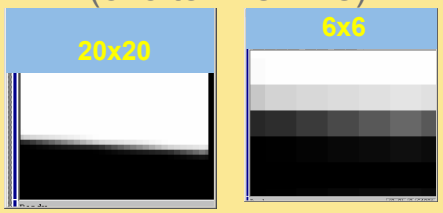
Other variables included:

- Wide range of MTFs
- Jitter (0-0.5p)
- Smear (0-4p)
- # Samples

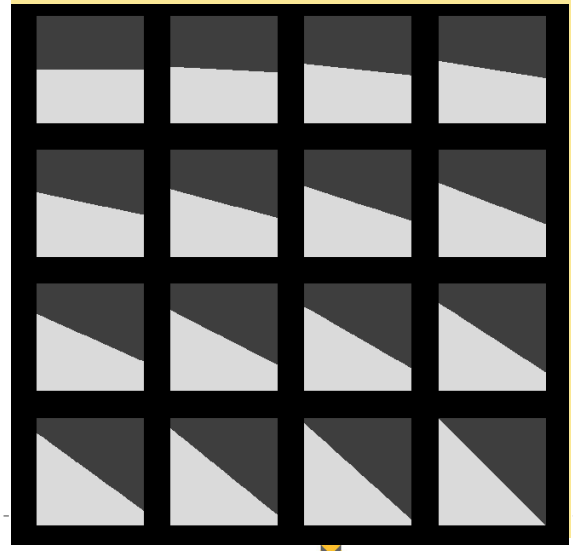
Contrast Ratio
(15 - 80%)



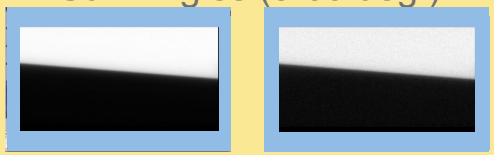
Samples sizes
(6x6 to 128x128)



Rotation Angle
(0 - 90%)



Sun Angles (5-60 deg.)



Sun Angle = 30
SNR = 45

Sun Angle = 5
SNR = 7

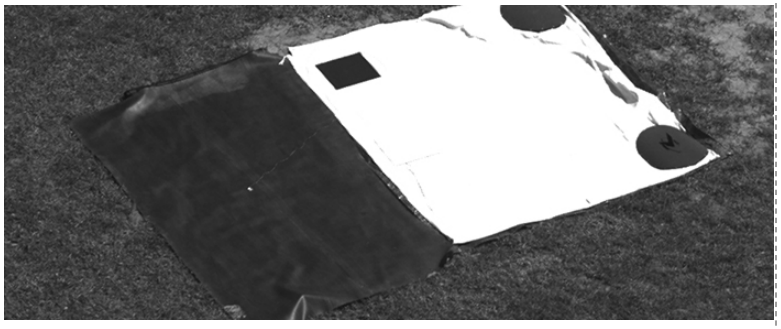
An On-Orbit MTF Measurement Process: *Study Conclusions*

ICA and ISO techniques yield comparable results

- Uncertainty <15-20%
  - Relative standard deviation of mean
- Confidence bounds <15-20%

Target/collection requirements include

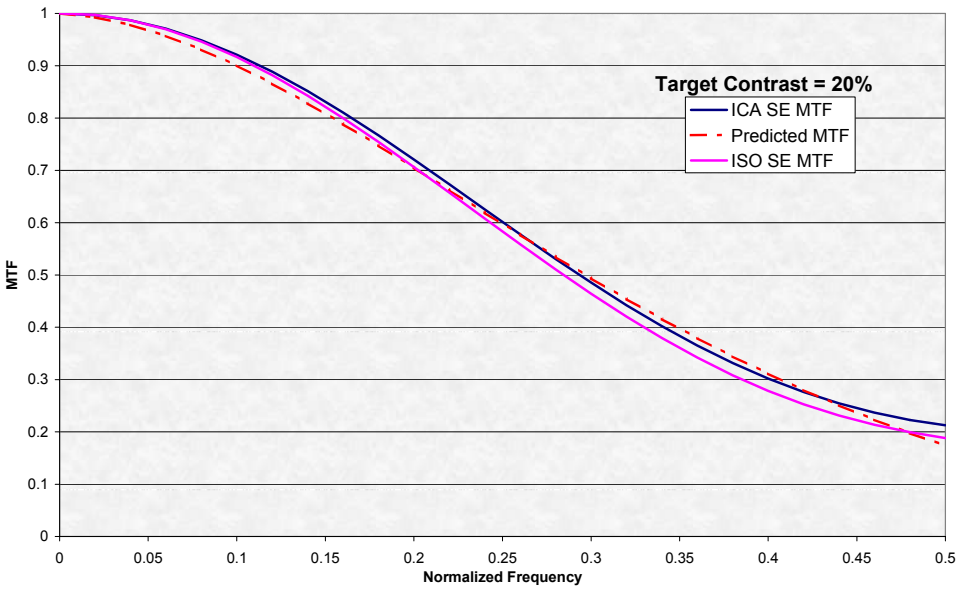
- Contrast ratio > 30%
- Sample size(s) > 20x20 pixels
- SNR > 30 (ie high)
- # Samples > 10 collections



An On-Orbit MTF Measurement Process: *Study Recommendations*

ICA slanted edge technique should be used for on-orbit MTF measurement analysis and characterization

- Comparable results with ISO standard
- Historical precedence with approach
- Historical experience with tools involved

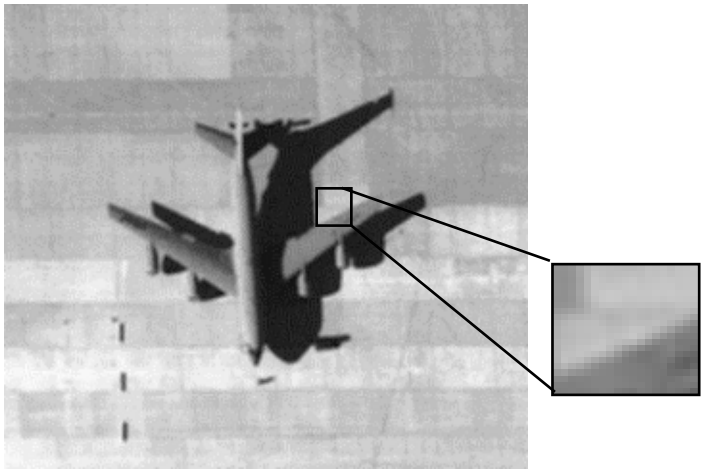


This is the technique built into ICA's genAutoCedge

A Measurement Process: *genAutoCedge*

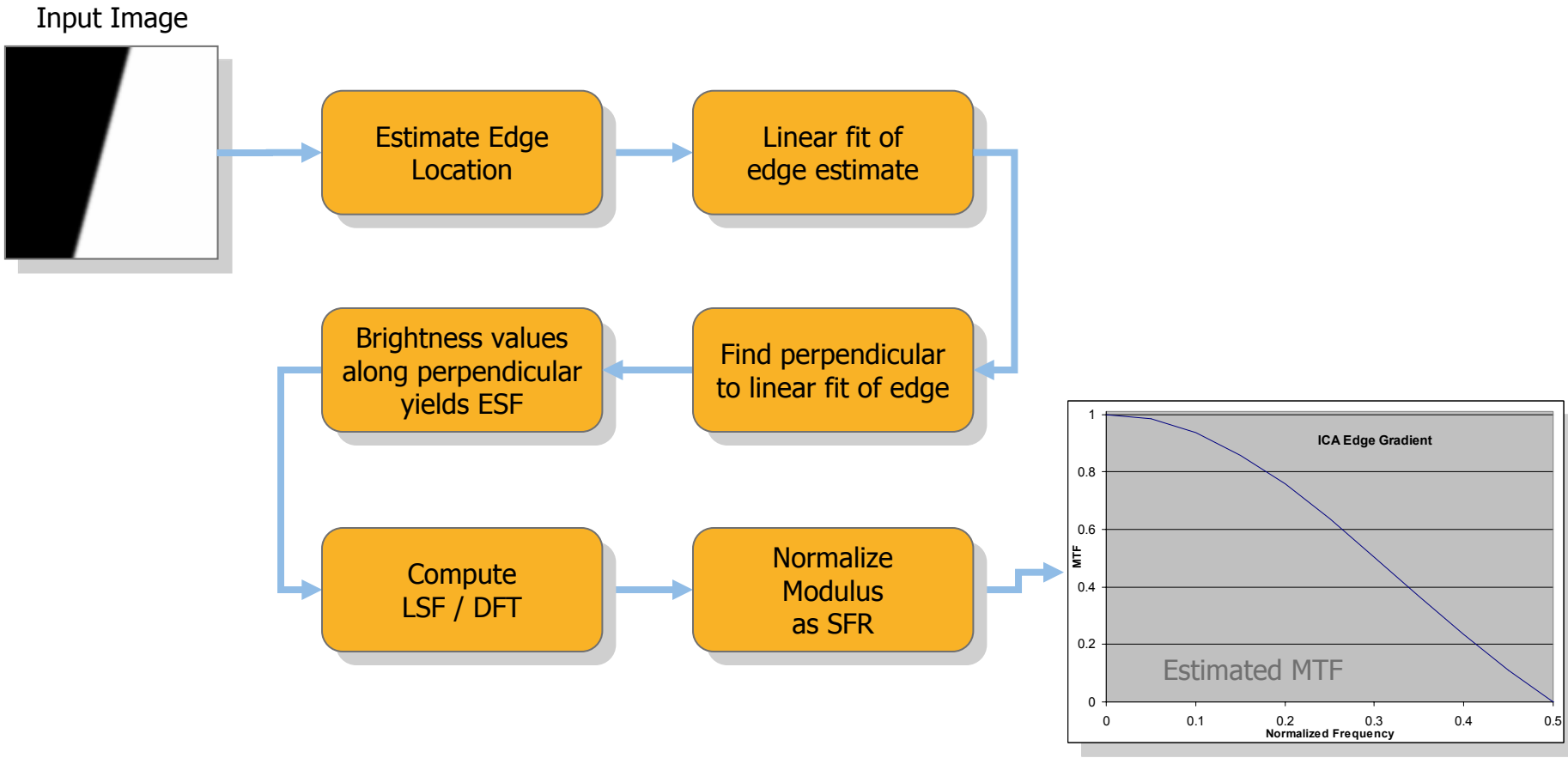
Routine for robust automated MTF measurement

- Exploit naturally occurring intensity changes at edges as opportunistic edge spread functions (ESFs)
- For properly conditioned ESFs, take the derivative to get the Line Spread Function (LSF) which is a 1D slice of the PSF
- Take a Discrete Fourier Transform (DFT) to derive the MTF
- Average over ensemble



A Measurement Process: *genAutoCedge*

genAutoCedge Process (ICA Edge Gradient Method)



A Measurement Process: *genAutoCedge*

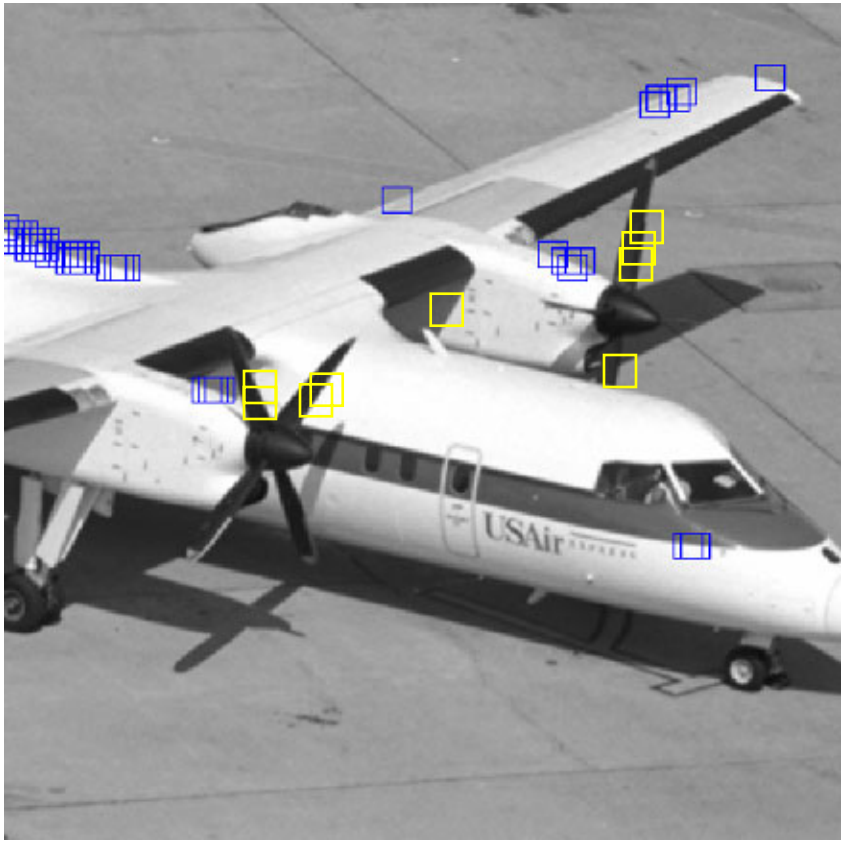
Candidate edges are identified and used to calculate an MTF

Edges are selected based upon

- Comparison to an ideal edge
- Size of edge
- Angle of edge
- Contrast between bright and dark
- Variability within bright and dark regions

Selected edges are depicted

- Blue boxes represent along-scan edges (0 to 45 degrees)
- Yellow boxes represent cross-scan edges (46 to 90 degrees)



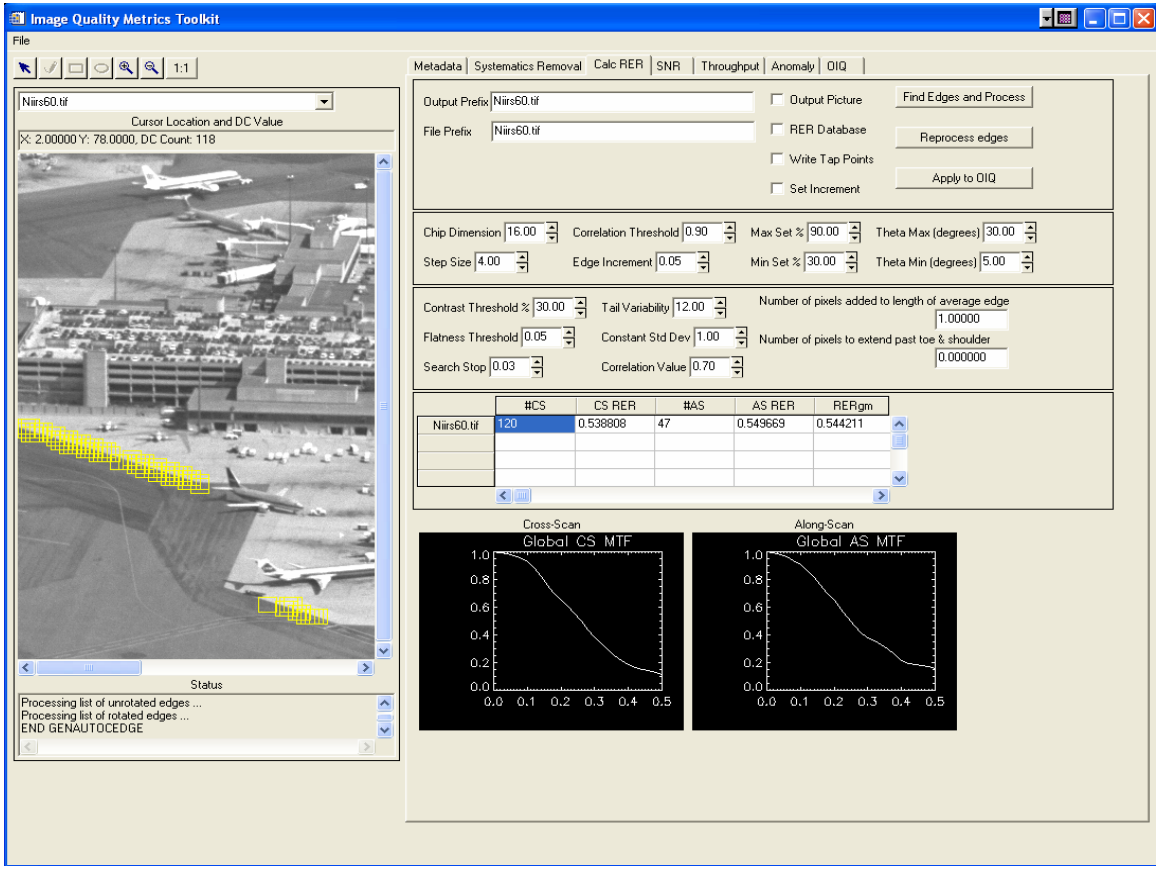
A Measurement Process: *genAutoCedge in IQMT*

ITT and RSI have incorporated *genAutoCedge* into a working tool!

- Incorporated into our Image Quality Metrics Toolkit (IQMT)

IQMT is an excellent resource for operational imaging system characterization

- Real-time algorithm manipulation and results visualization
- Includes several IQ functions
  - SNR Estimation
  - MTF/RER Measurement
  - Artifact/Anomaly tracking
  - Non-uniformity correction
  - GIQE Predictions
- Built using IDL
  - Can be integrated with ENVI
  - Easily extensible



An On-Orbit MTF Measurement Process: *Summary*

On-orbit MTF measurement is not a new problem

- Every system used requires some level of validation

ICA has considerable experience in performing these measurements

- Accurately and precisely

The ICA approach has been included in a more general Image Quality Metric Toolkit (IQMT)

- Many of the most sought after image analysis procedures packaged together into a single, easy to use tool