Edge target for Spatial Quality

November 16, 2015

DongHan Lee, Dennis Helder

Agenda

1. **Spatial Quality for Satellite image data**
2. Database of Standard Artificial (Man-made) Edge targets
3. Standard Processing Step (algorithm) for Edge target [RD5]

References for Spatial Quality

1. [RD1] Mary Pagnutti, Slawomir Blonski, Michael Cramer, Dennis Helder, Kara Holekamp, Eija Honkavaara, and Robert Ryan, 2010, 'Targets, methods, and sites for assessing the in-flight spatial resolution of electro-optical', *Can. J. Remote Sensing*, Vol. 36, No. 5, pp. 583–601
2. [RD2] Philippe Blanc, 2010, 'Calibration Test Sites Selection and Characterisation – WP210', TN-WP210-001-ARMINES, Issue 0.2, ESA/ESRIN
3. [RD3] Philippe Blanc and Lucien Wald, 2008, 'Image Quality – WP224 (ARMINES)', TN-WP224-001-ARMINES, Issue 1.0, ESA/ESRIN
4. [RD4] Dennis Helder and Francoise Viallefont, 2012, 'A Frame for Geo/Spatial Quality', CEOS WGCV IVOS 24
5. [RD5] DongHan Lee, Dennis Helder, Jon Christopherson, Jim Storey, DooChun Seo, Greg Stensaas, 2014, 'RER, FWHM, MTF Processing Step for Edge target (Draft) & Standard Edge targets by KOMPSAT-3', CEOS WGCV IVOS 26

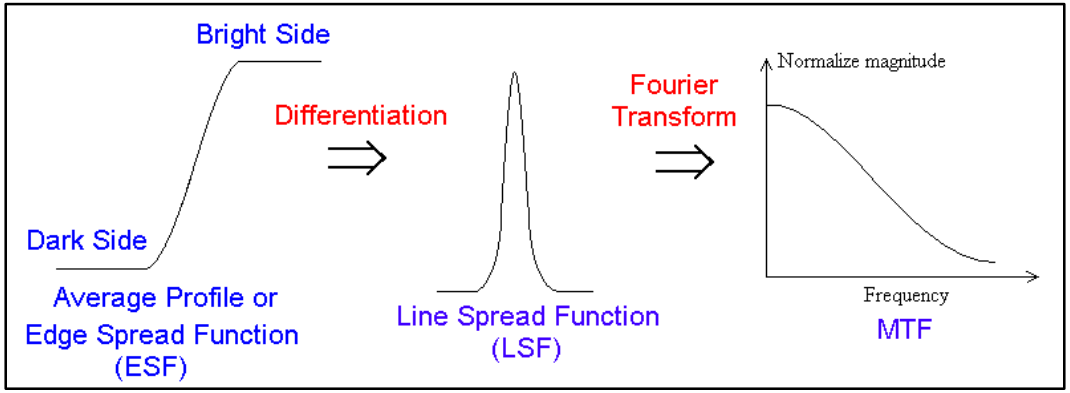


Fig. 1. Processing Steps for Edge target to get ESF, LSF, MTF [RD4]

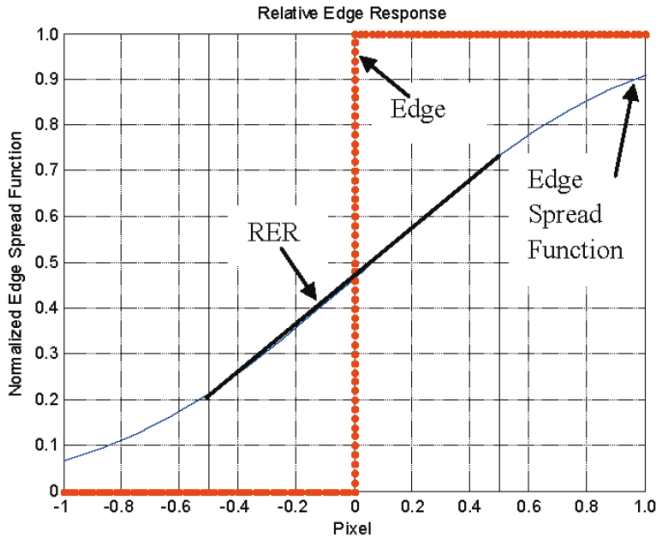
Purpose and Works for Spatial Quality in CEOS WGCV IVOS (led by Dr. Helder, SDSU)

1. (One of Purpose) Get the reasonable quantity of Spatial quality for remote sensing satellite in ***Real conditions***.
2. Develop the Definition of the general Spatial quality Estimators; [RD4, p15]
   a. RER (Relative Edge Response) & Edge Response Slope
   b. FWHM (Full Width at Half Maximum)
   c. MTF curve, and MTF value at Nyquist frequency
3. Develop the Standard process to get RER, FWHM & MTF
   a. Standard target from Artificial (Man-made) & Natural target [RD4, p32]
      ① Edge, Line (Bar), Point, Periodic target
      ② Database for Artificial & Natural target [RD1, RD2]
   b. Conditions (limitations) for Target & Image data [RD4, p33?]
   c. Reference MTF test data
   d. Standard Processing Step (algorithm) for Edge target [RD4, p35], [RD5, p4]
      ① Several options according to the Conditions (limitations)
      ② For target; Edge, Line, Point, Periodic
      ③ For Standard target & For Artificial & Natural target

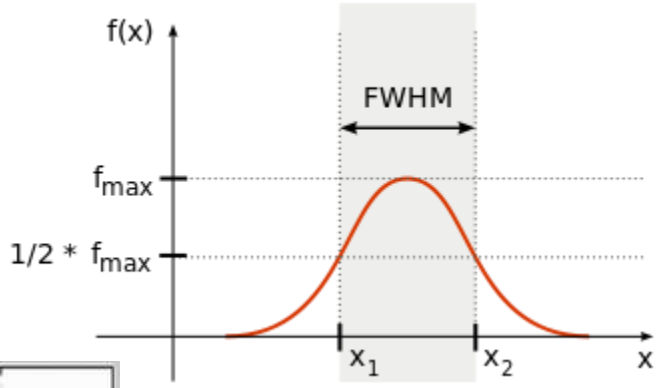
Develop the Definition of the general Spatial quality Estimators

1. RER (Relative Edge Response)
2. Edge response Slope
3. FWHM (Full Width at Half Maximum)
4. MTF (Modulation Transfer Function)
   a. MTF value at Nyquist frequency
   b. MTF curve

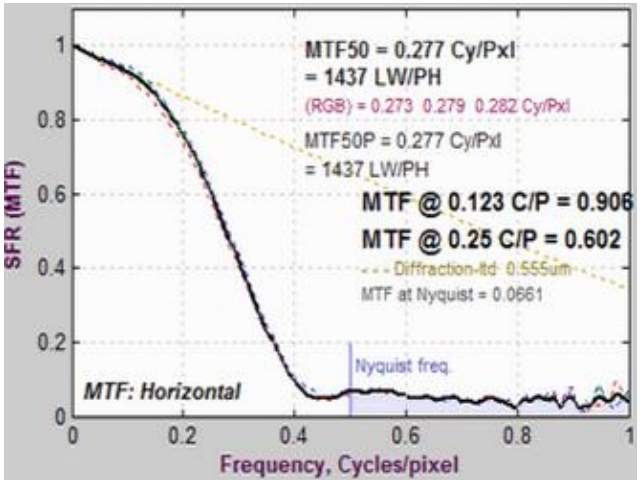
RER



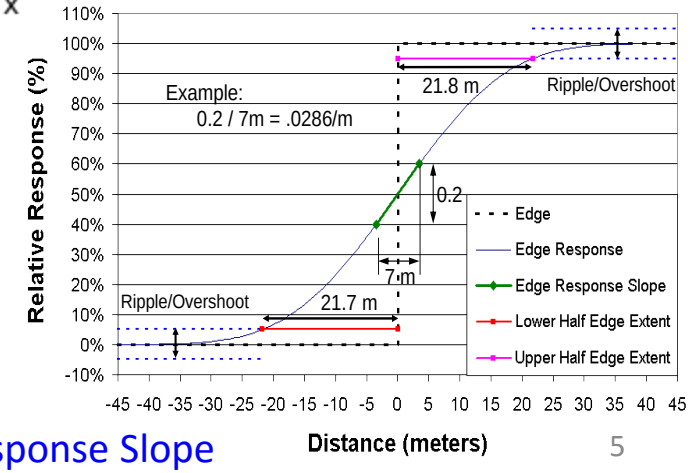
FWHM



MTF



Edge Response Slope



Edge response Slope

Comparison of each Estimator (Draft)

- We need to & will fill in this table in CEOS WGCV IVOS.

Estimator	Good	Weak	Applicable Targets	Re-commend	Comments
RER	High reliable	Only Edge	Edge	OK	Method for RER is needed to be reconsidered. (H1)
Edge slope	High reliable	Need GSD each imaging Only Edge	Edge		Difficulty in measuring
FWHM	High reliable		Edge, Point	Best	FWHM for user; surface, 25% & 80% for Cal/Val?
MTF	MTF Curve	Low reliable MTF @ Ny.	Edge, Point, Periodic	NOK	MTF@Ny. for users; MTF curve for Cal/Val

Agenda

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2. **Database of Standard Artificial (Man-made) Edge targets**
3. Standard Processing Step (algorithm) for Edge target [RD5]

USGS Cal/Val Portal

http://calval.cr.usgs.gov/rst-resources/sites_catalog/

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You are here: Home » RST Resources » Test Sites Catalog » Spatial Sites » Stennis, Mississippi, USA

Test Site Catalog

Site Location: Stennis, Mississippi, USA

Spatial

Stennis Spatial Targets, February 2004

30.386151° -89.628116°

Stennis Spatial Targets, March 2014

Test Site Home

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Select Site

- CEOS Reference Sites
- Radiometry Test Site Gallery
- Download Google Earth KMZ

GEOMETRIC SITES

Select Site

SPATIAL SITES

Select Site

ADDITIONAL INFORMATION

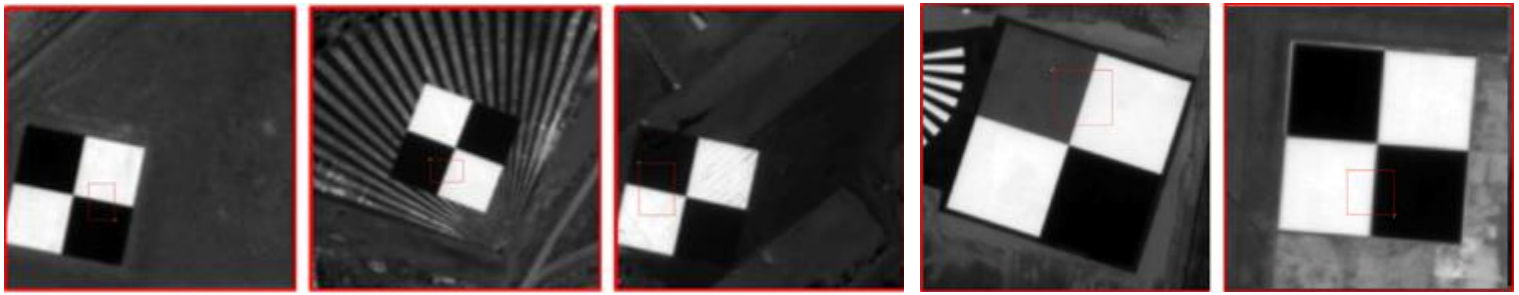
- Acronyms
- References

CEOS QA4EO

Location (City, State, Country):	Stennis, Mississippi, USA
Altitude above sea level Min/Max/Mean (meters):	TBD
Center Latitude,Longitude (Degrees):	30.386151° -89.628116°
UTM Zone:	13 N
Landsat WRS-2 Path / Row:	022039
Owner:	NASA Stennis Space Center
Points of Contact and Affiliation:	Dr. Robert Ryan, Mary Pagnutti
Purpose:	Spatial assessment of high resolution satellites
Range Layout:	Painted concrete targets on the property of NASA Stennis Space Center.
Description:	From ~1998 to ~2009 two targets, one an edge target, the other a quarter Siemens Star, were maintained to some degree. From 2010-2013 targets fell into disrepair and covered. As of 2014 new edge target has been made in location of Siemens Star.
Suitability:	Higher resolution satellites (2m or finer {??} resolution)
Limitations:	Due to proximity to Gulf of Mexico, atmosphere tends to be humid and may often have clouds, particularly in afternoons. Best months for use tend to be: {XXXXX}

List of Standard Edge targets [RD1, RD2]

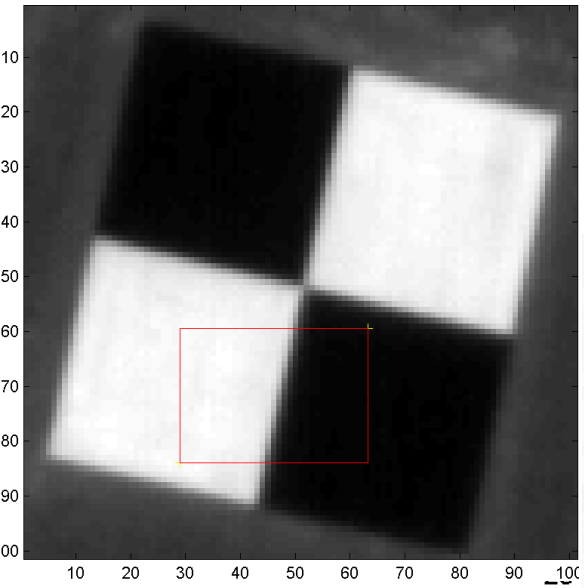
Target	Description and Dimensions	Orientation (to true north)	Lat / Long	Status
Salon de Provence, France	60m x 60m, 2x2 checkerboard, painted tar pad	~-3° / 87°	43.60583N 5.12028E	Good
Stennis Space Center, USA	45m x 45m (?), 2x2 checkerboard		23.51972N 119.58333W	Good
Penghu, Taiwan	60m x 60m, 2x2 checkerboard, painted surface	0° / 90°	30.38667N 89.62861E	Need Repainting
Big Spring, USA	40m x 40m, 2x2 checkerboard, painted concreted			Need Repainting
Baotou city, China	48m x 48m for a single panel, contrast (W/B) > 5:1	5°	40.85167N 109.62889E	Good
Mongol with Korea	70m x 70m, 2x2 checkerboard, painted surface	-11.19°	47.71049N 106.98953E	New

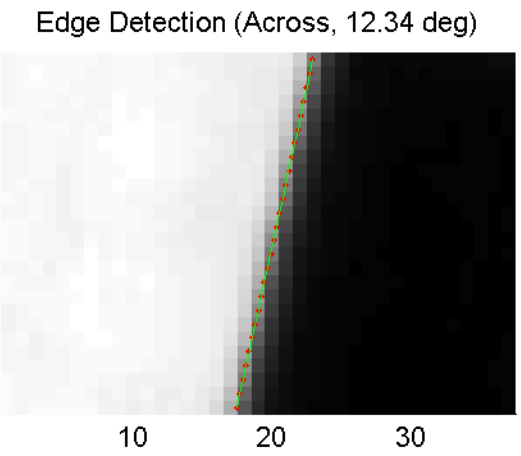


Salon Stennis Penghu Baotou Mongol

Imaged by KOMPSAT-3 GSD (0.7m)

Salon de Provence, France





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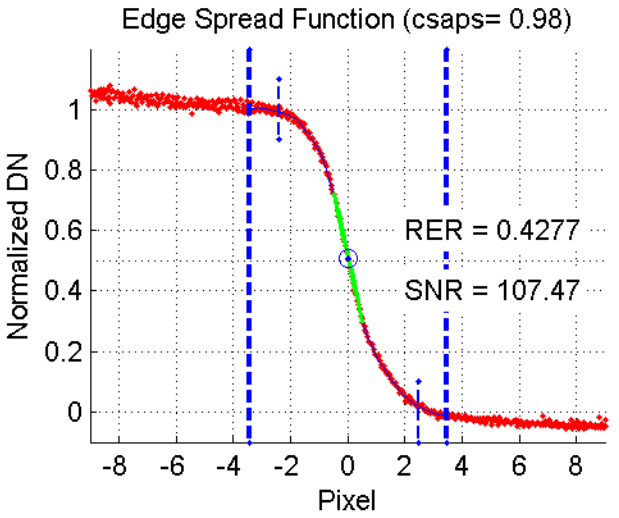

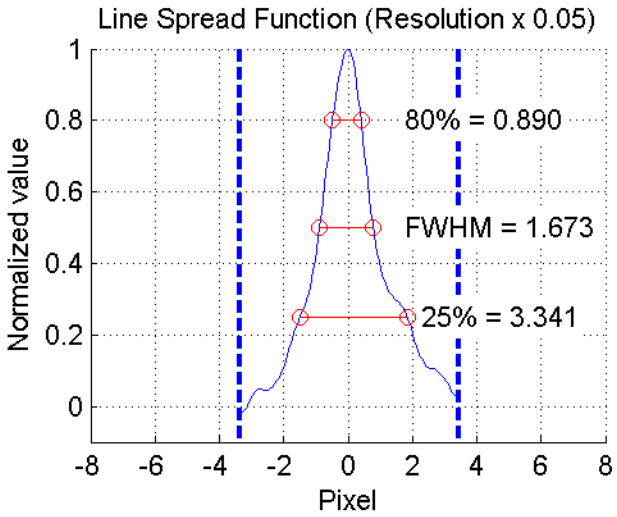

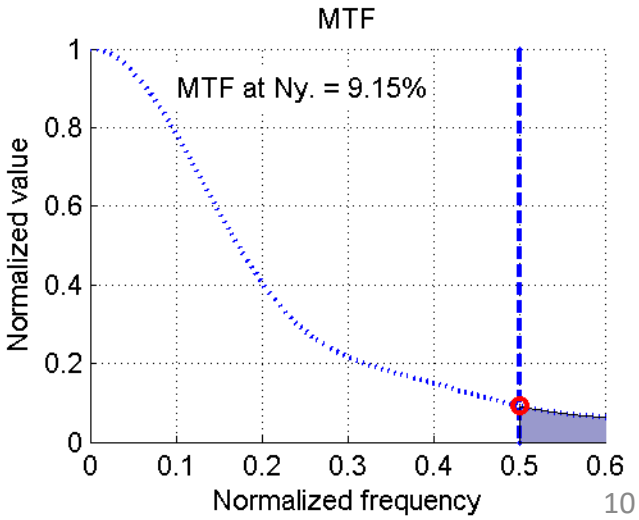

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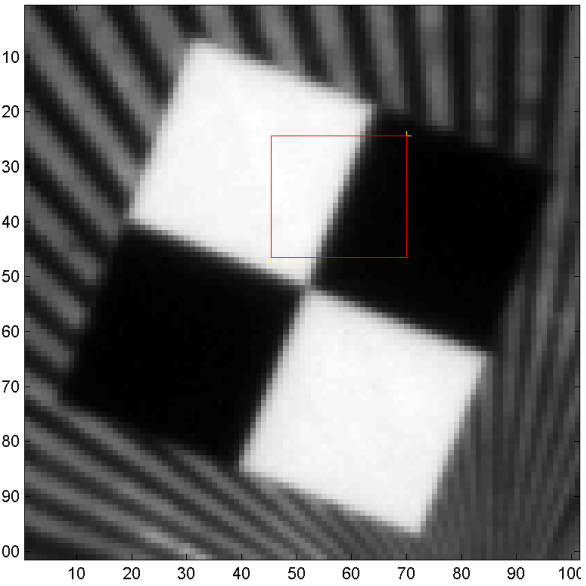
(GSD: 0.7m)

Stennis Space Center, USA



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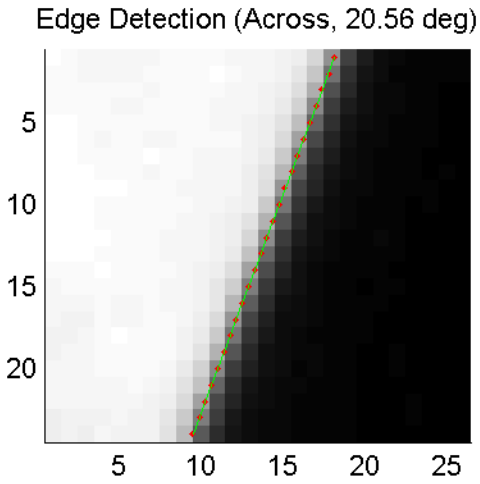
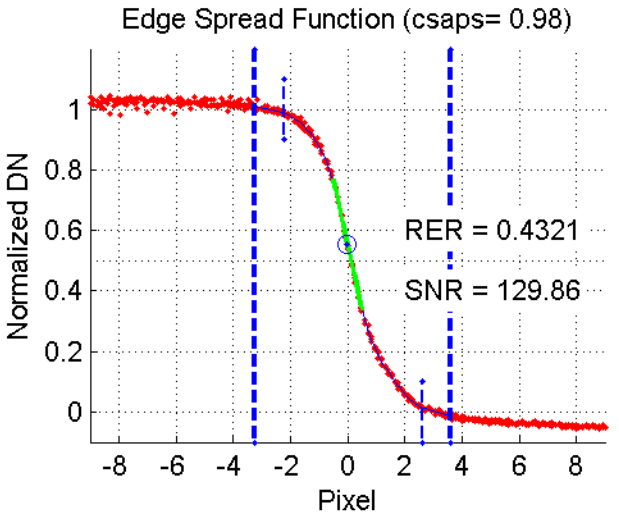
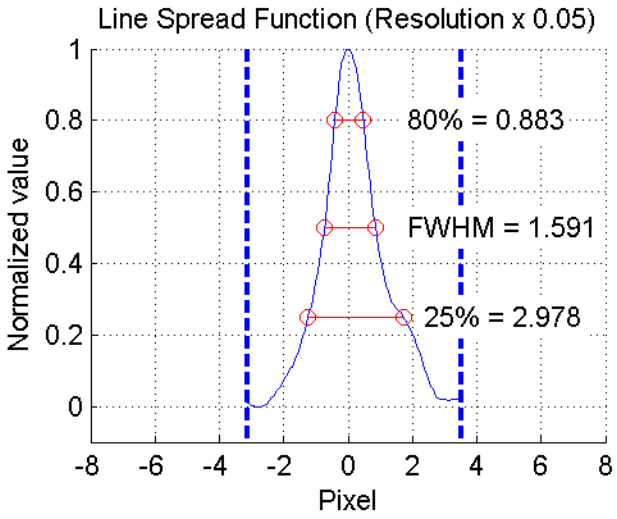
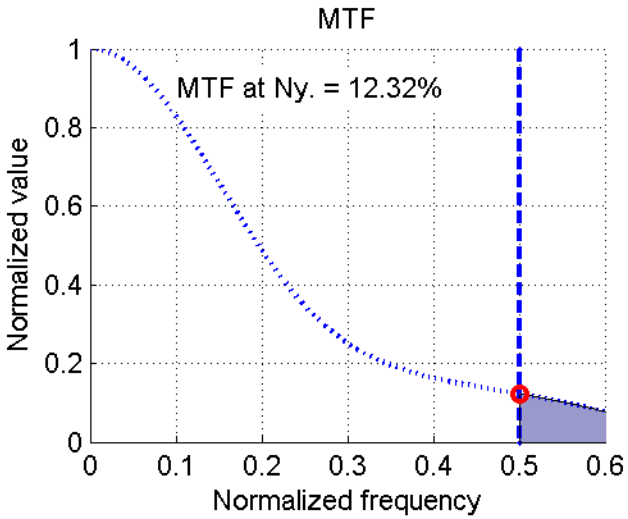


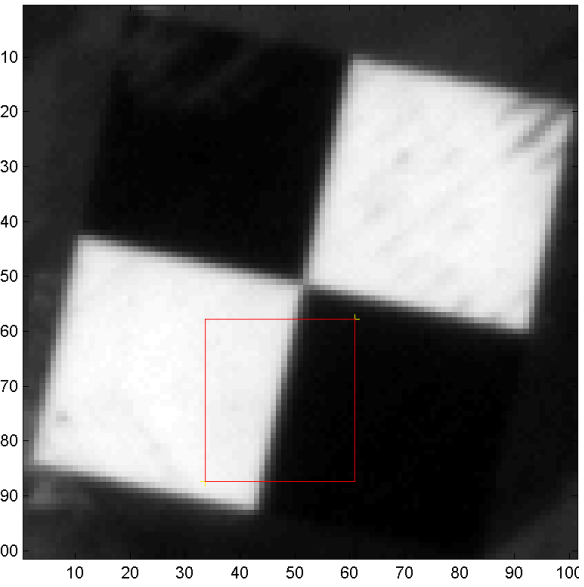






Imaged by KOMPSAT-3
(GSD: 0.7m)

Penghu, Taiwan



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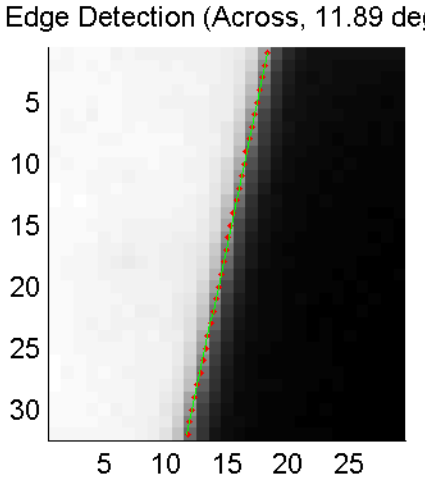
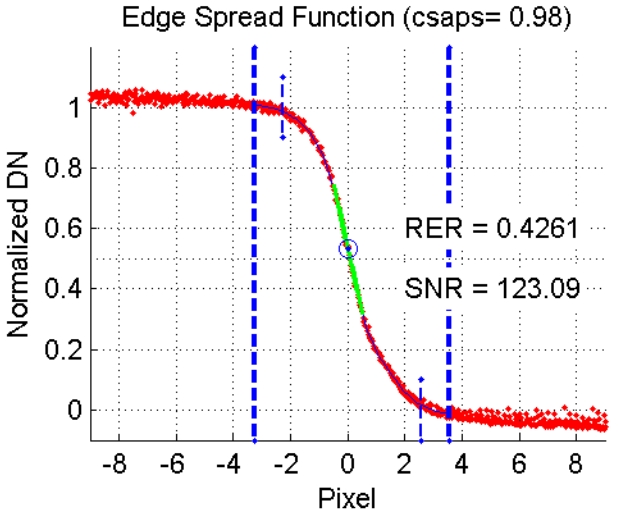
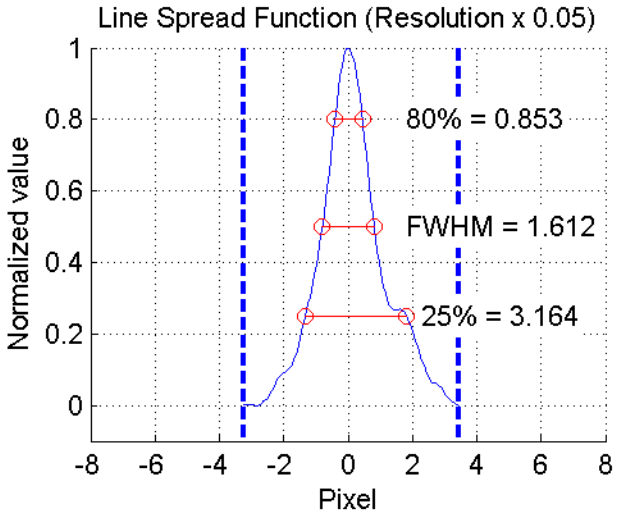
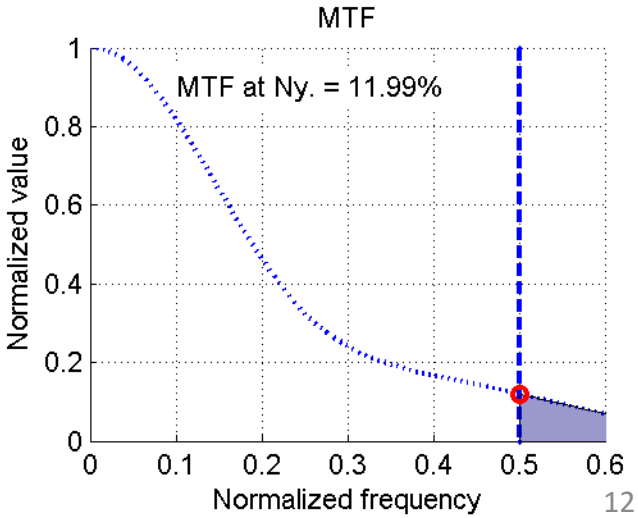


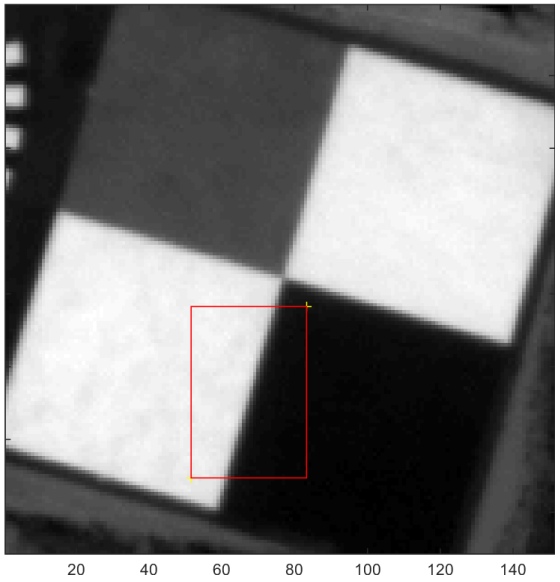






Imaged by KOMPSAT-3
(GSD: 0.7m)

Baotou, China



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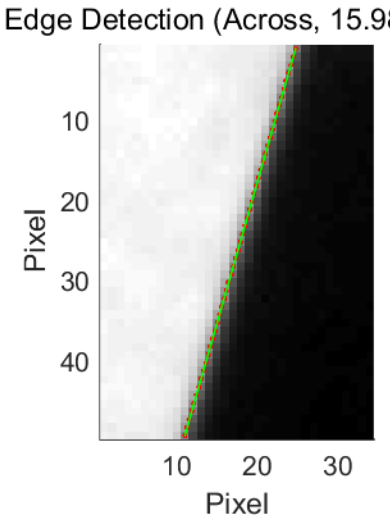
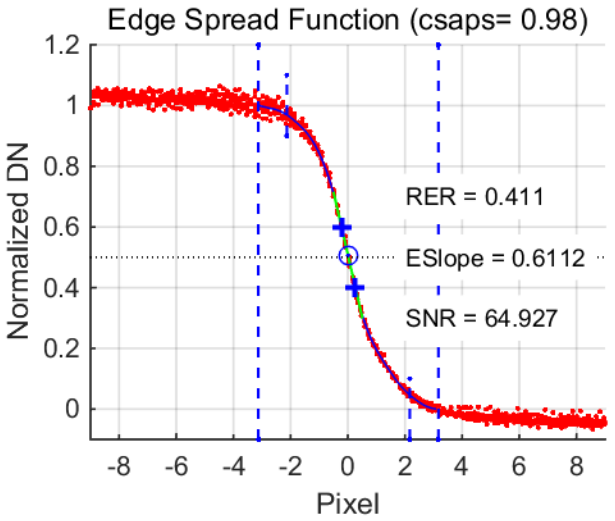
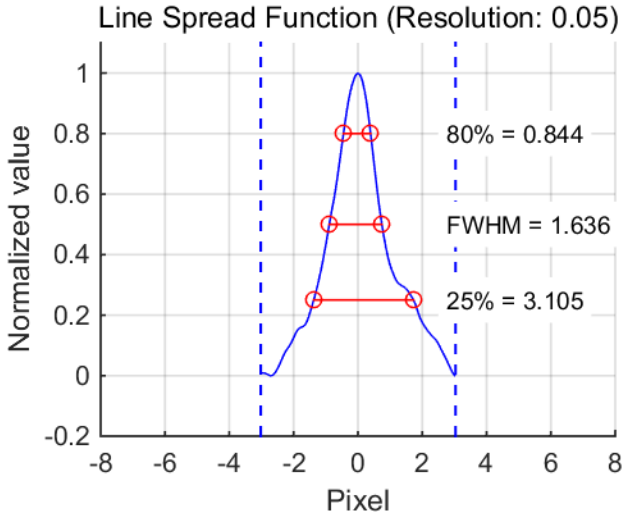
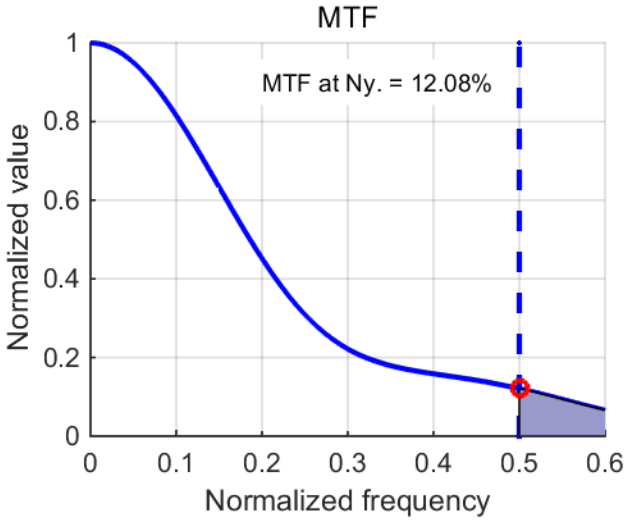


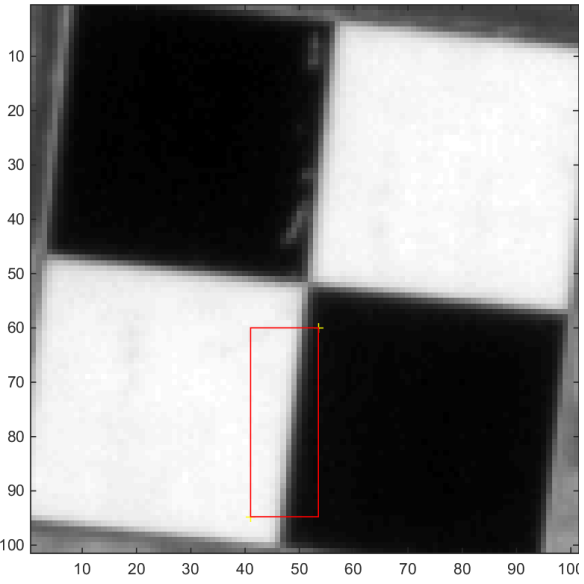






Imaged by KOMPSAT-3
(GSD: 0.7m)

Mongolia



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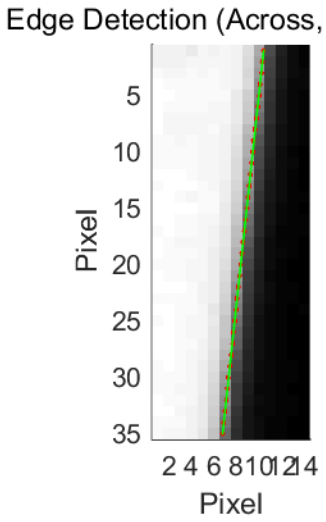
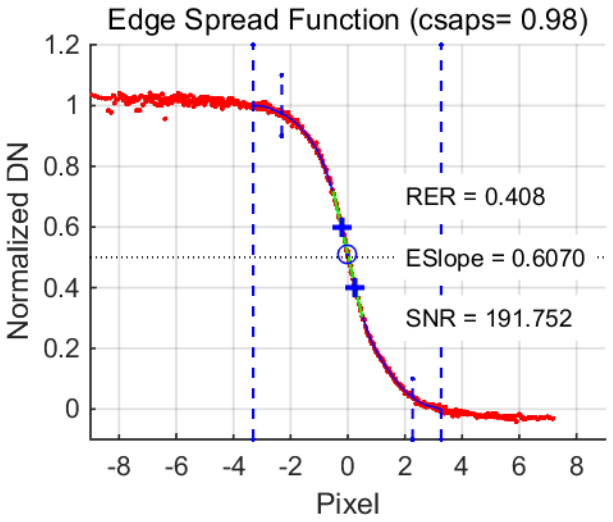
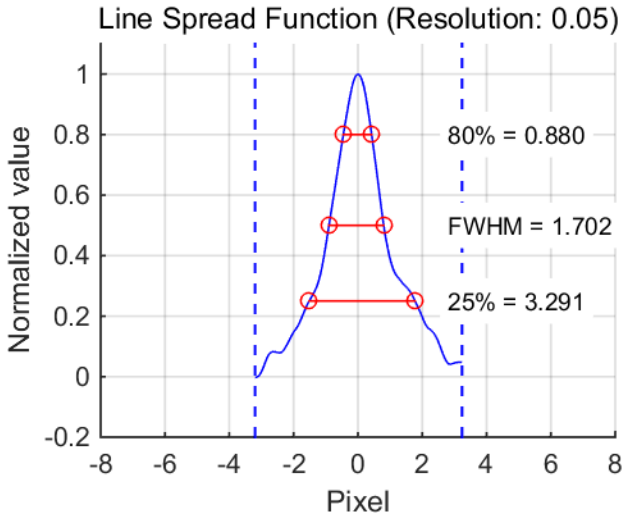
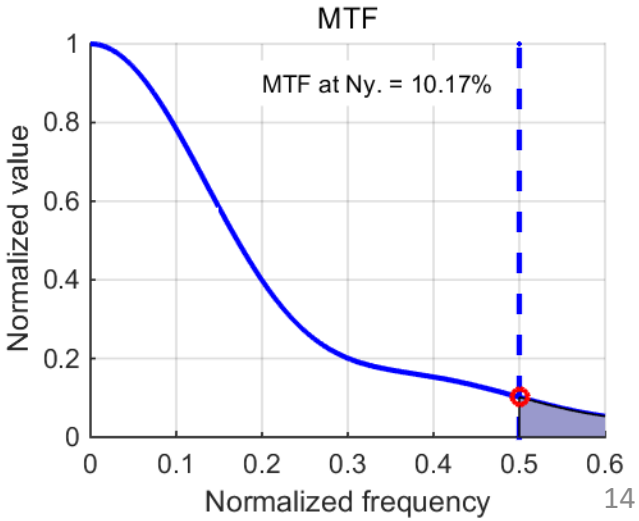








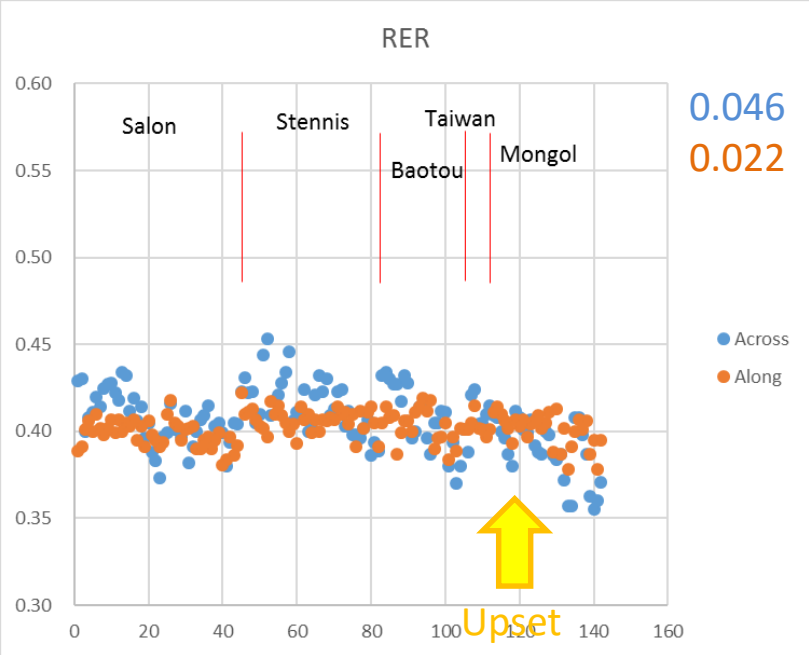
Imaged by KOMPSAT-3
(GSD: 0.7m)

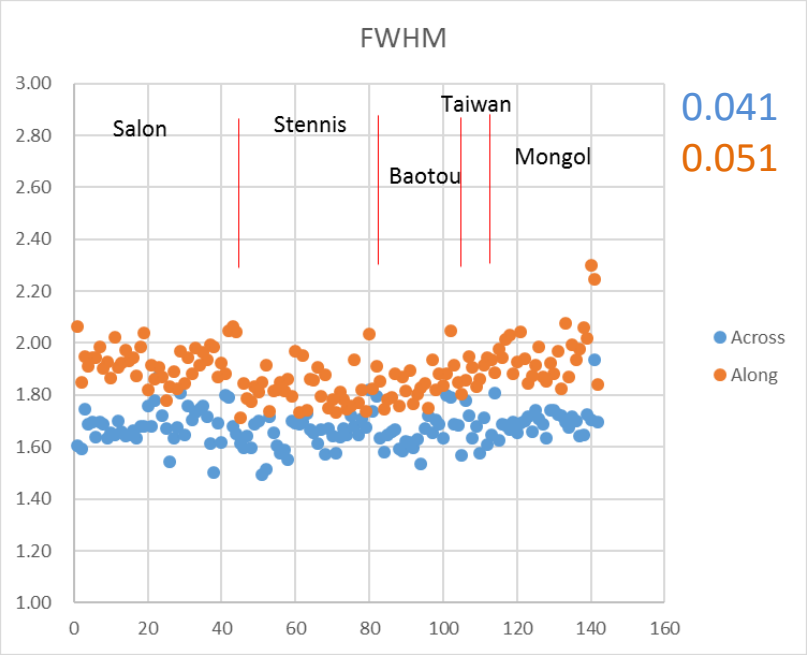
Results from Edge targets with KOMPSAT-3

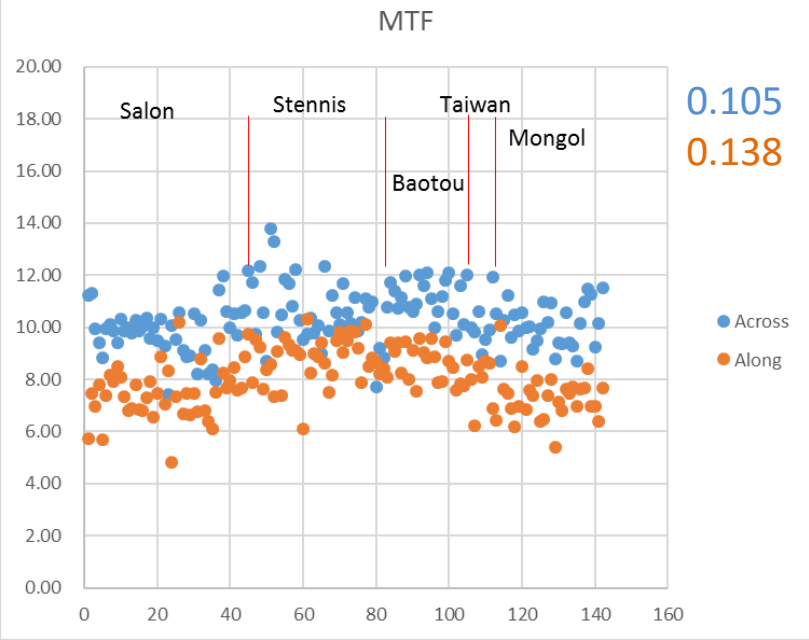
		No.	RER	FWHM			MTF	SNR
				50%	80%	25%		
Across	Salon	22	0.407	1.685	0.894	3.249	9.81	94.28
	Stennis	19	0.415	1.654	0.872	3.086	10.64	111.81
	Baotou	12	0.408	1.656	0.890	3.243	11.10	77.64
	Taiwan	4	0.412	1.673	0.902	3.192	10.00	101.13
	Mongol	14	0.387	1.701	0.914	3.340	10.11	158.88
	SD/Mean		0.046	0.041	0.076	0.068	0.105	0.436
	StdDev		0.018	0.069	0.068	0.218	1.09	47.40
	Mean		0.406	1.674	0.892	3.219	10.32	108.81
Along	Salon	22	0.398	1.929	0.982	3.018	7.47	95.75
	Stennis	19	0.407	1.824	0.934	3.020	8.80	109.07
	Baotou	12	0.403	1.842	0.948	2.981	8.61	103.67
	Taiwan	4	0.406	1.904	0.948	3.006	7.94	56.16
	Mongol	14	0.400	1.965	1.020	2.945	7.23	131.86
	SD/Mean		0.022	0.051	0.094	0.045	0.138	0.353
	StdDev		0.009	0.096	0.091	0.135	1.10	37.37
	Mean		0.402	1.892	0.969	2.997	8.00	105.93

(Imaging duration) Jan.16.2014 ~ Oct.21.2015

RER, FWHM, MTF



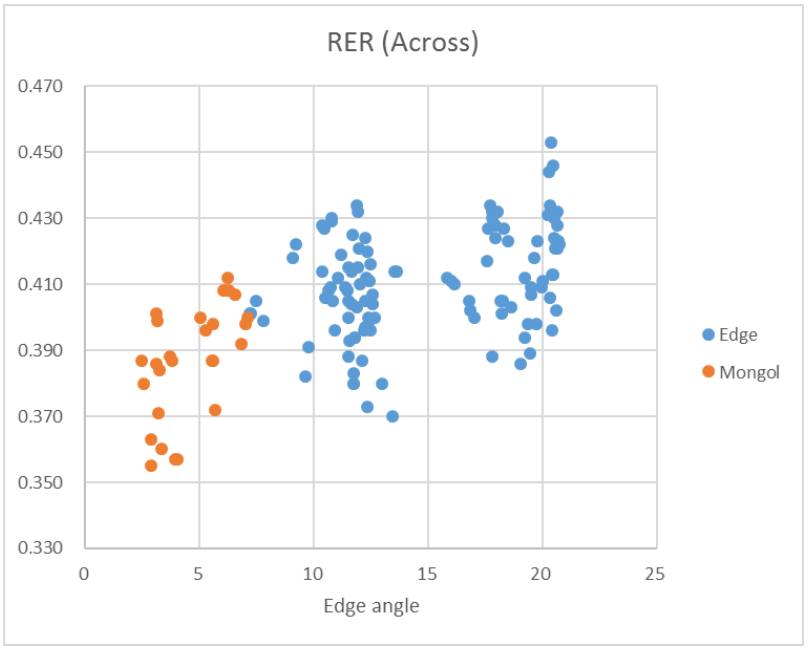


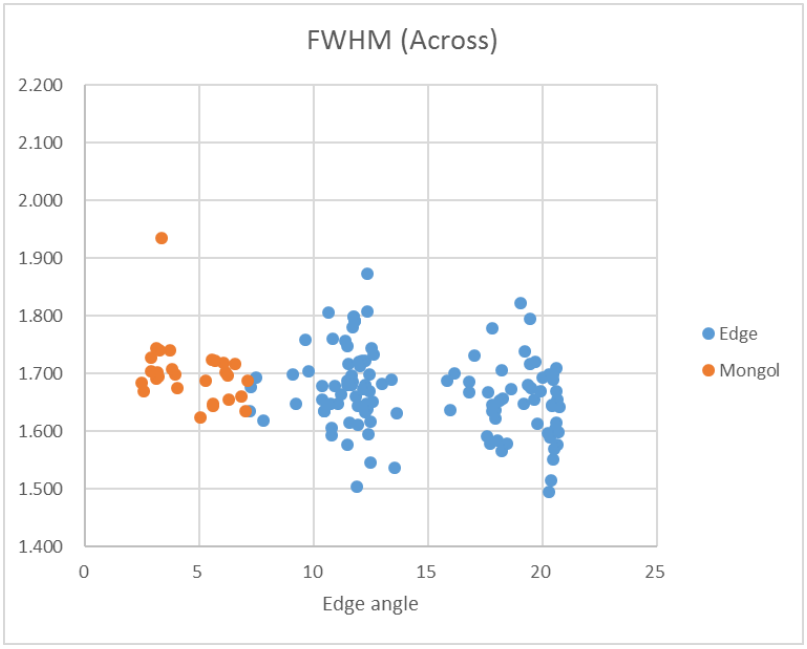


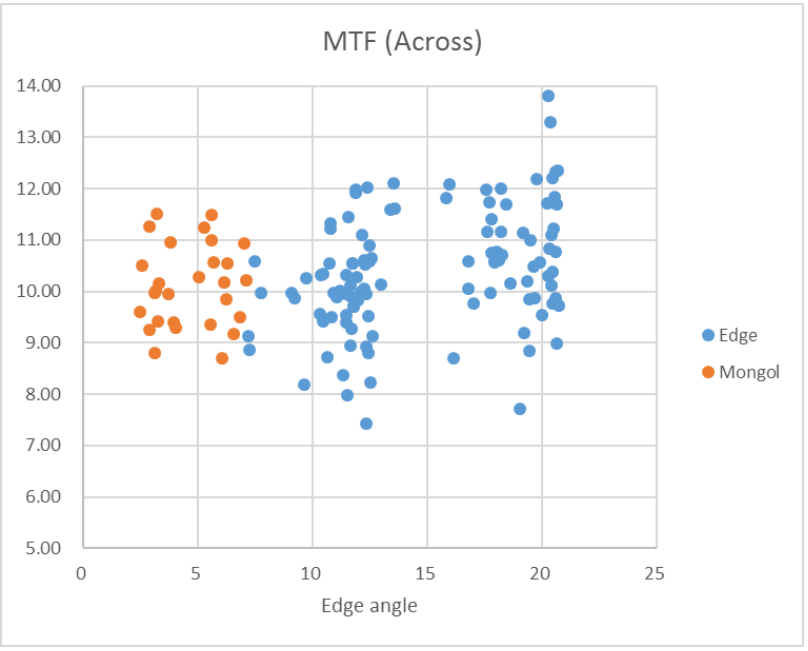
1. MTF @ Ny as estimator is worst.
2. RER & FWHM is stable.
3. RER at Mongol is upset with Across & Along
   - ✓ Edge angle may be small; 2~7deg (?)
4. FWHM (Across) is best stable.
   - ✓ RER (Along) has a unreliable factor; TDI Line rate by Orbit propagator

(Across) Std.Dev / Average
(Along) Std.Dev / Average

RER, FWHM, MTF (Edge angle; Across)



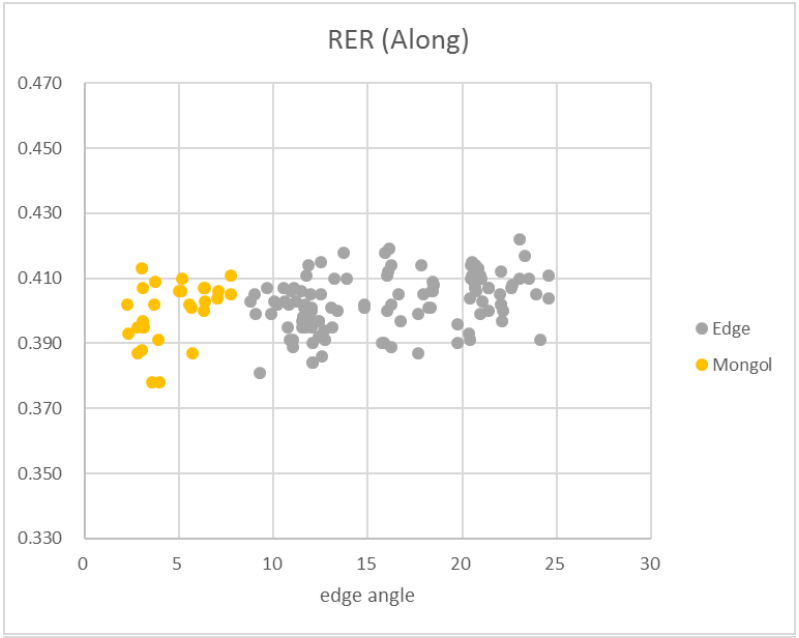


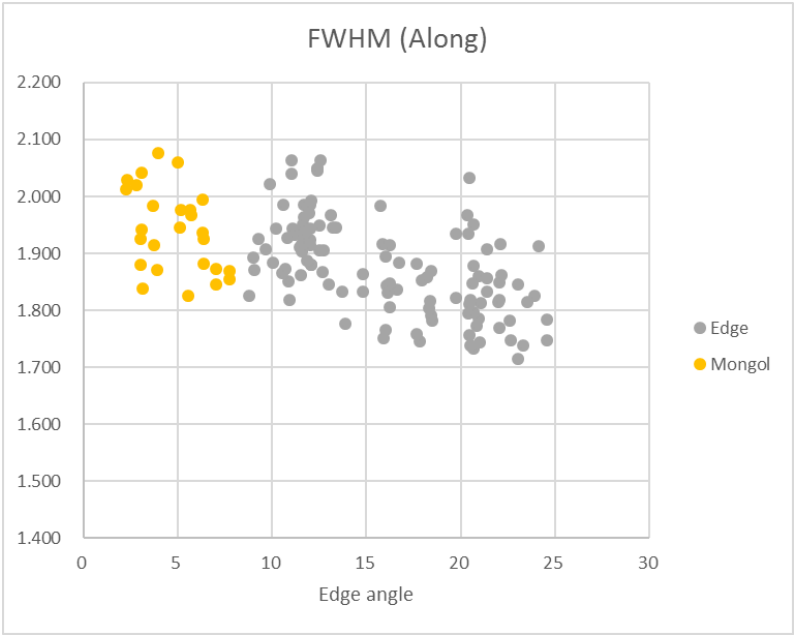


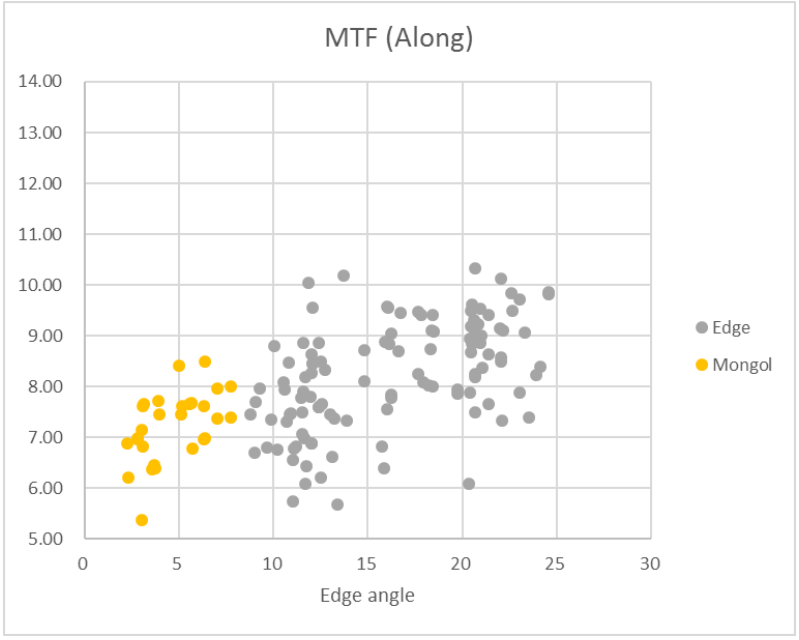
1. RER at Only Mongol has Low value.
2. FWHM don't depend on Edge angle.
3. MTF has a little slope (?)
4. FWHM & MTF have a similar pattern.
5. Edge angle at Mongol is Small; 2~7deg (?)

❖ The method for RER is needed to be reconsidered. (H1) [RD5, p11]

RER, FWHM, MTF (Edge angle; Along)



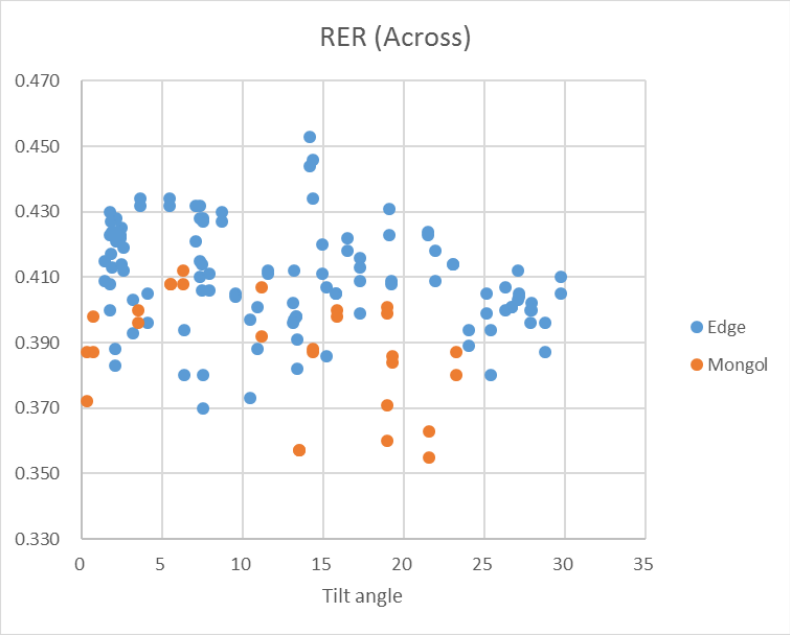


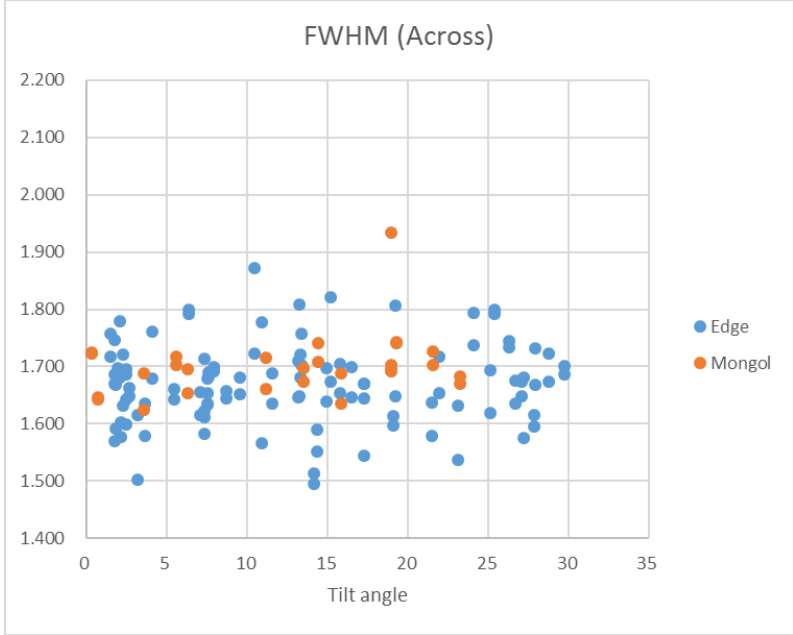


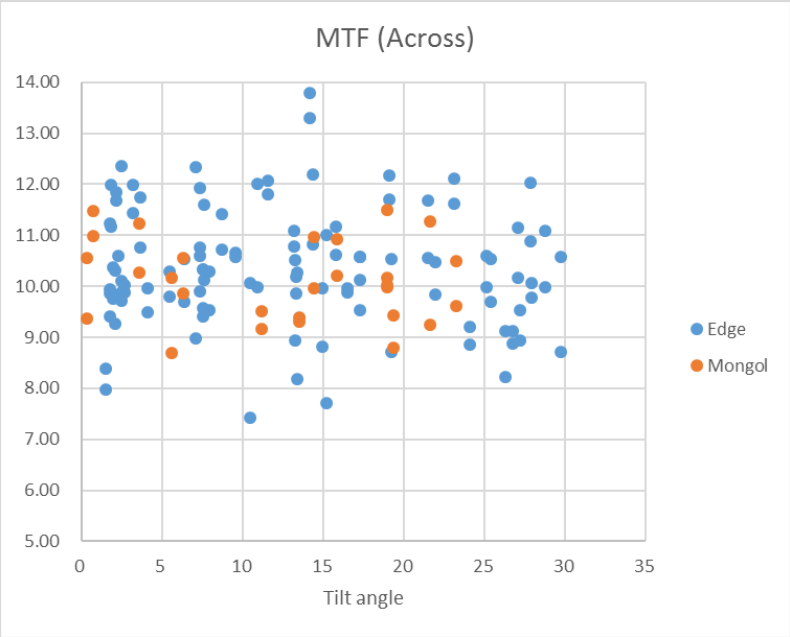
1. There are slopes on FWHM & MTF
2. Only RER don't depend on Edge angle.
3. Why are there slopes on FWHM & MTF?
4. But, RER (Along) has a unreliable factor.
   a. TDI Line rate by Orbit propagator

❖ The method for RER is needed to be reconsidered. (H1) [RD5, p11]

RER, FWHM, MTF (Roll tilt angle; Across)



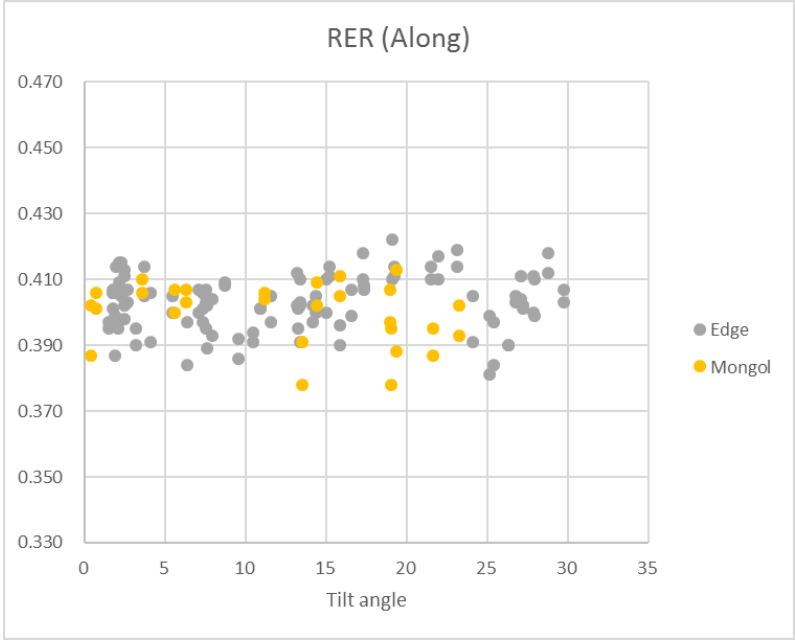


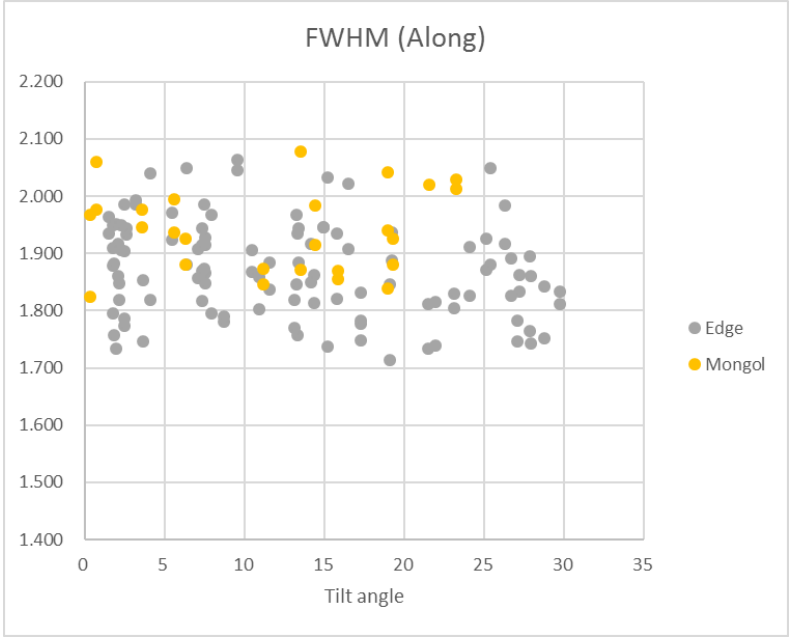


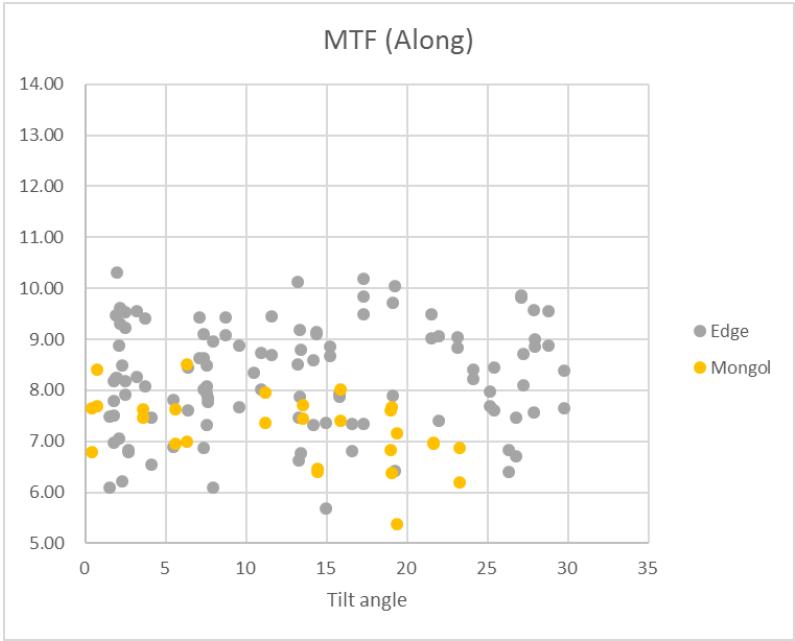
1. RER at Only Mongol has Low value.
2. RER has a little slope (?)
3. FWHM & MTF don't depend on Roll tilt angle.
4. FWHM & MTF have a similar pattern.

❖ The method for RER is needed to be reconsidered. (H1) [RD5, p11]

RER, FWHM, MTF (Roll tilt angle; Along)







1. FWHM & MTF at Only Mongol have Low value.
2. RER, FWHM & MTF don't depend on Roll tilt angle.
3. FWHM & MTF have a similar pattern.
4. But, RER (Along) has a unreliable factor.
    a. Line rate by Orbit propagator

❖ The method for RER is needed to be reconsidered. (H1) [RD5, p11]

Issues and Future works (1/2)

1. As Estimator
   a. MTF @ Ny as estimator is worst.
   b. RER & FWHM is stable.
   c. FWHM (Across) is best stable.
   d. (StdDev / Mean) in Across
      - ✓ RER: 0.046
      - ✓ FWHM: 0.041
      - ✓ MTF: 0.105

2. Dependence on Edge angle
   a. FWHM don't depend on Edge angle.
   b. FWHM & MTF have a similar pattern.

3. Dependence on Roll tilt angle
   a. FWHM & MTF don't depend on Roll tilt angle.
   b. FWHM & MTF have a similar pattern.

4. Mongol Edge target
   a. RER at Mongol is upset with Across & Along
      - ✓ Edge angle may be small; 2~7deg (?)
   b. RER at Only Mongol has Low value.

5. The method for RER is needed to be reconsidered. (H1) [RD5, p11]

6. RER (Along) has a unreliable factor.
   a. TDI Line rate by Orbit propagator

Issues and Future works (2/2)

1. Database for the Standard Edge target in Worldwide [RD1, RD2]
   a. Need to keep and share the Information of Every Edge target [RD4]
   b. On USGS Cal/Val portal (http://calval.cr.usgs.gov/rst-resources/sites_catalog/)

2. USGS EROS Cal/Val Portal (http://calval.cr.usgs.gov/rst-resources/sites_catalog/)
   a. Database for the Standard Edge targets
   b. Status of Every edge target (TBD)

3. Maintenance and Monitoring be Needed to;
   a. Keep and Share the status of the Edge target [RD4]
   b. CCTV in Web site (TBD)
   c. Keep and Share the standard MTF measuring code

4. Maintenance and Monitoring of the Status of Targets and Sites
   a. Acquire quarterly to monitor status of test sites
   b. Imaging by the several satellites
   c. KOMPSAT-3 & 3A, Pleiades & SPOT, Worldview, GeoEye, etc.

5. Point, Bar, Periodic (Radial, Siemens) target

6. Natural target (TBD)
   a. Various Situation of the Natural edge target
      i. Clear sky, Dry, Broad building, Dam, Artificial lake, Airstrip, etc.
   b. Database of recommended cities of the Natural edge target
      i. Phoenix, Dallas, Las Vegas, Los Angels, Denver, etc. (Cities in USA)
      ii. Airports in the world

Agenda
1. Spatial Quality for Satellite image data
2. Database of Standard Artificial (Man-made) Edge targets
3. Standard Processing Step (algorithm) for Edge target [RD5]

Processing Steps (Recommended)

1. Imaging by the Satellite
2. Read & Select ROI of the Edge target on the image data
3. Check the status and health of the Edge target image data
4. Select and Determine ROI of Edge on the Edge image data
5. Detect the Edge line on ROI
6. Get & Plot Edge Spread Function (ESF) with Pixel data
7. Decide the Staring point of the Bright & Dark area
8. Calculate and Plot ESF by Fitting from the Trimmed ESF pixel data
9. Calculate Relative Edge Response (RER) (by one pixel)
10. Calculate and Plot Line Spread Function (LSF)
11. Calculate Full Width at Half Maximum (FWHM)
12. Calculate and Plot MTF (Modulation Transfer Function)

Processing Steps in Detail (1/7)

1. Imaging by the Satellite
   a. Edge target on Ground [RD1] [RD2] [RD4]
      I. Standard (Artificial) target (Salon, Stennis, etc. by USGS CalVal Portal)
      II. Natural target (Edge of Building, Airstrip, etc.)
   b. Condition of Imaging & Image data
      I. Cloud, Noise, etc.
      II. Product Processing Level (resampling, with / without MTFC, etc.)
      III. Along (Flight) & Across direction on the image data (if with asymmetric PSF)
      IV. Storage format (TIFF, HDF, raw, etc.)
   c. (Loosely) link to the satellite Resolution

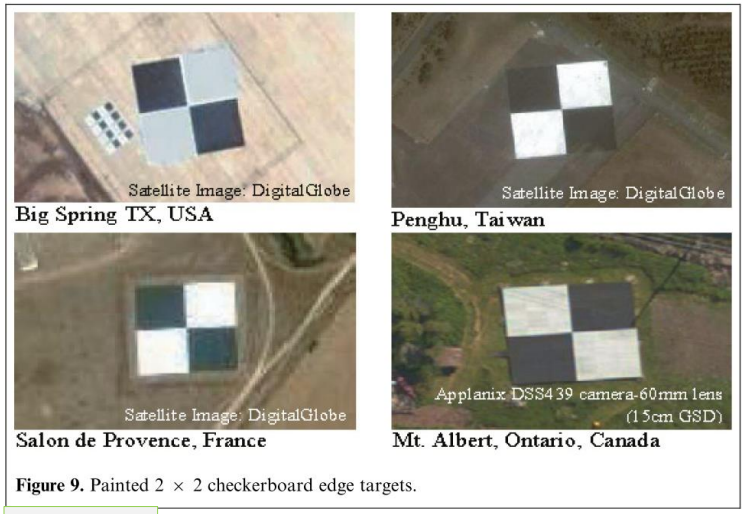
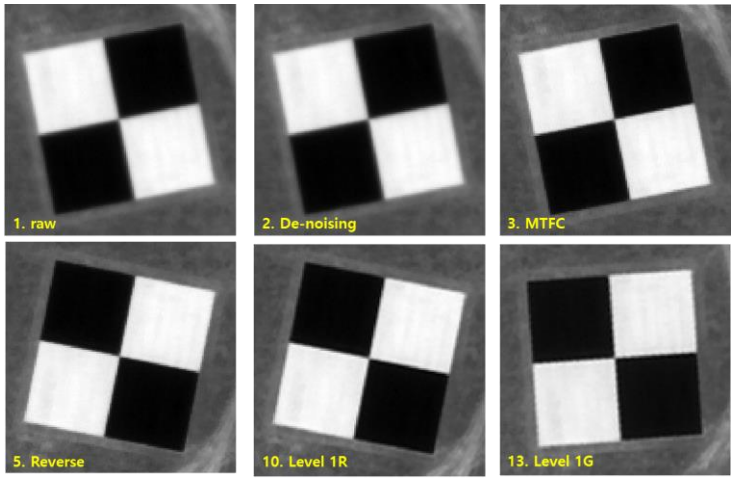
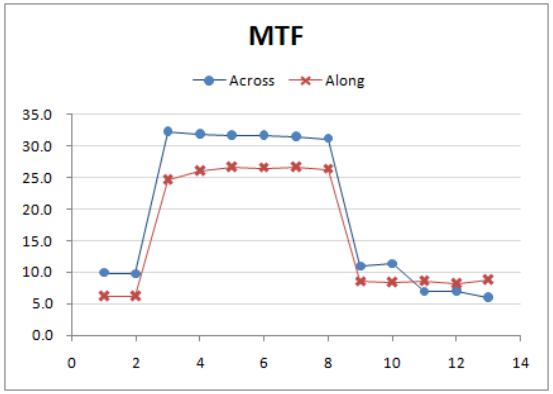


Figure 9. Painted 2 × 2 checkerboard edge targets.

(1:a:i)

[RD1]



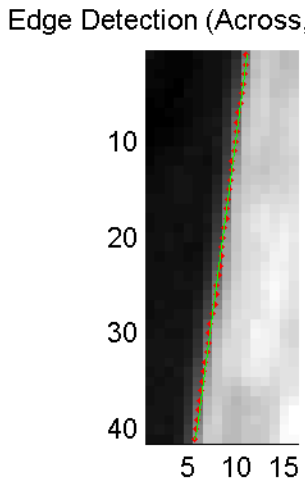


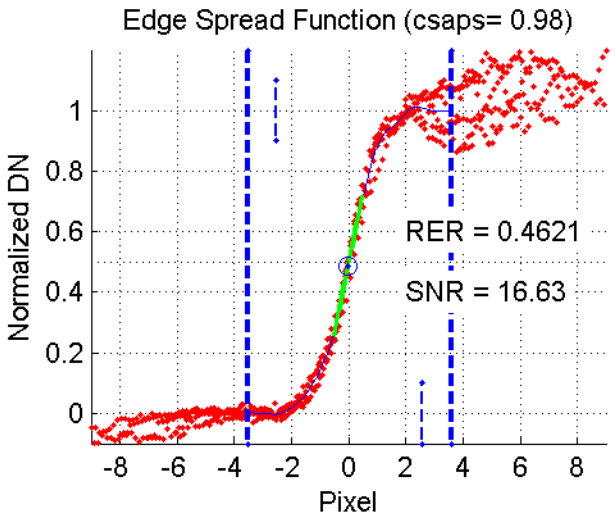
(1:b:ii)

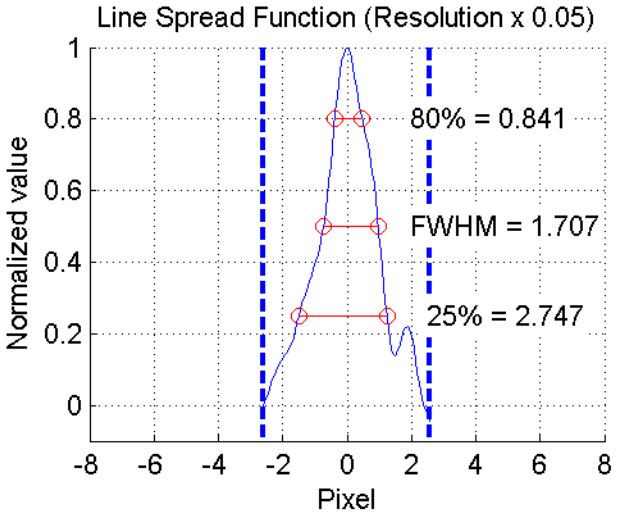
MTF according to KOMPSAT-3 Steps

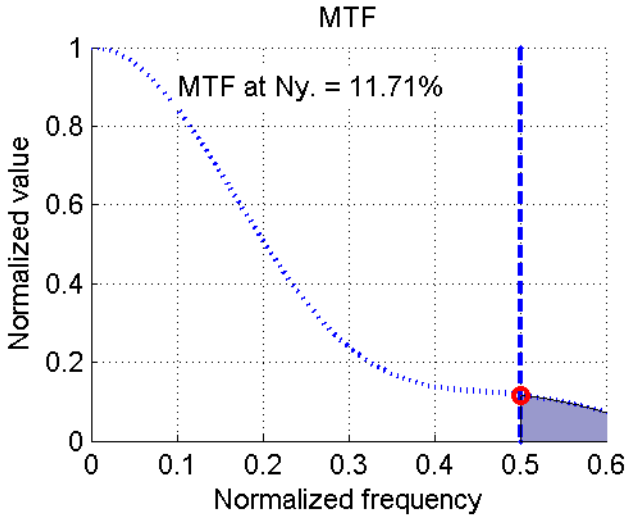
Processing Steps in Detail (2/7)

2. Read & Select ROI of the Edge target on the image data
   a. Reading the image data according to the storage format
   b. Search
      •





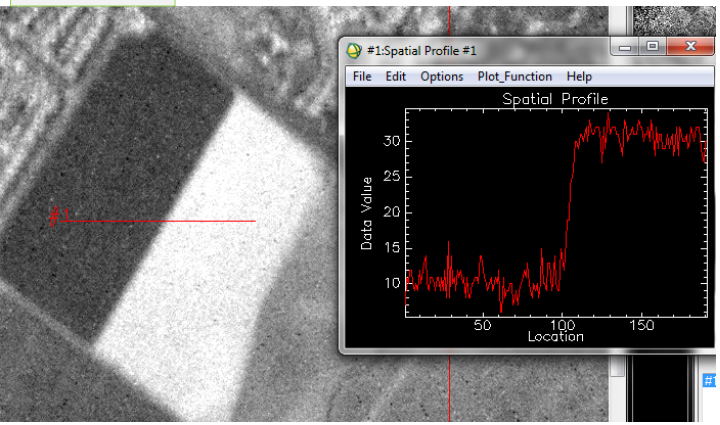




Processing Steps in Detail (3/7)

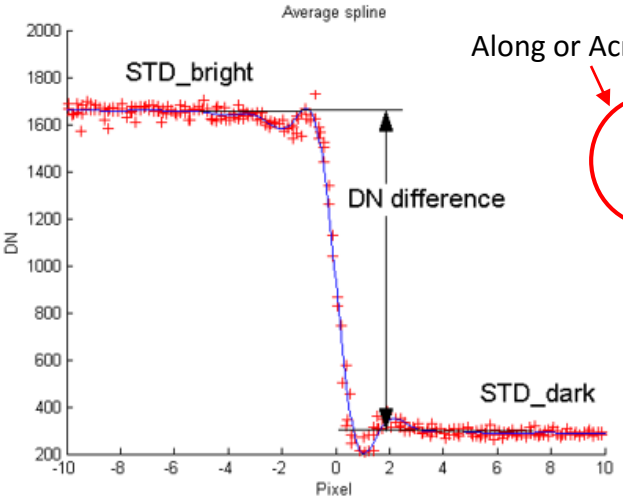
3. Check the status and health of the Edge target image data [RD2, 2.1]
   a. Straight line on Edge
      - ??? (TBD)
   b. Uniformity on Bright and Dark area
      - SNR > 50 (TBR) (Helder, 2002)
   c. DN difference between Bright and Dark
      - ΔDN > 50 (TBR) (Helder, 2002)
   d. Permitted Angle range between Edge and Along / Across direction
      - 0 ~ 30deg (TBR)
   e. Number of Pixel on Edge line
      - > 10~20 pixels (TBR)
   f. Width of Bright and Dark area
      - > 5 pixels (TBR)

(3:b,c)



Because of low SNR, it is impossible to calculate the RER, FWHM, MTF.

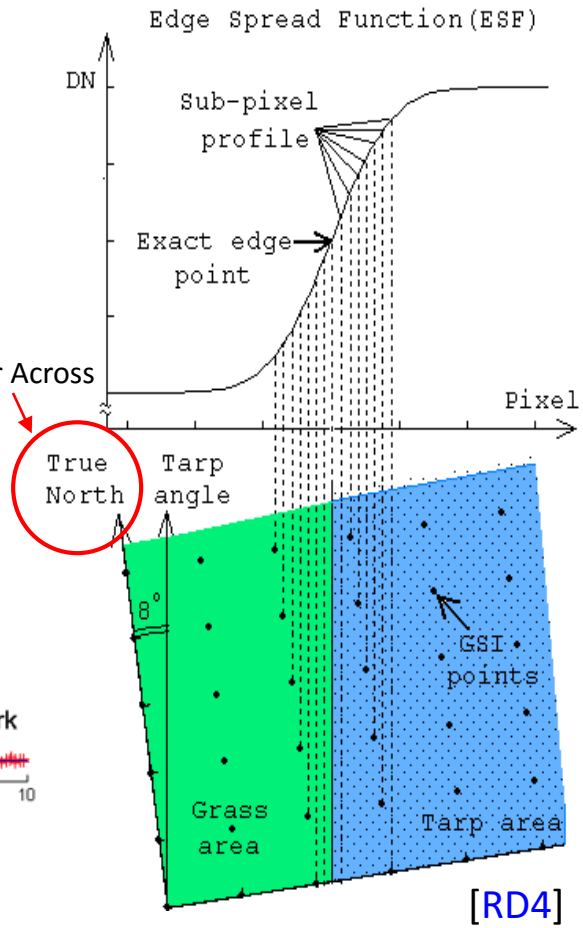
(3:b,c)



$$SNR = \frac{\text{DN difference}}{(\text{STD\_bright} + \text{STD\_dark}) / 2}$$

[RD4]

(3:d)



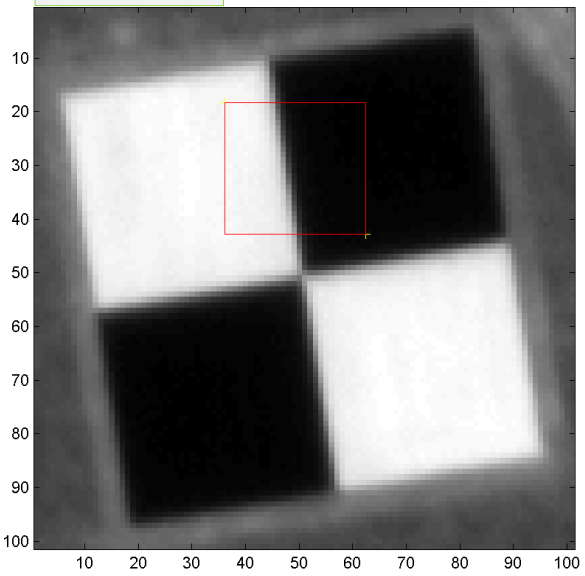
[RD4]

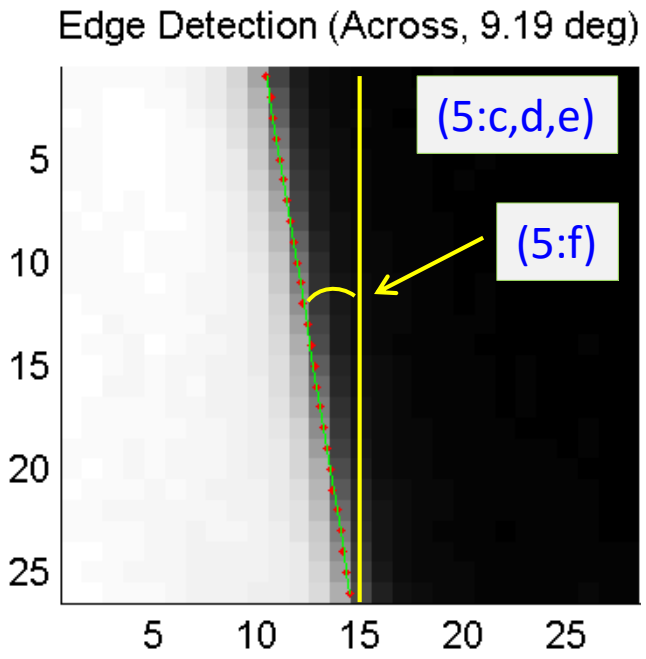
Processing Steps in Detail (4/7)

4. Select and Determine ROI of Edge on the Edge image data [RD2, 2.1]
   a. Determine Along & Across direction
   b. Determine Bright and Dark side

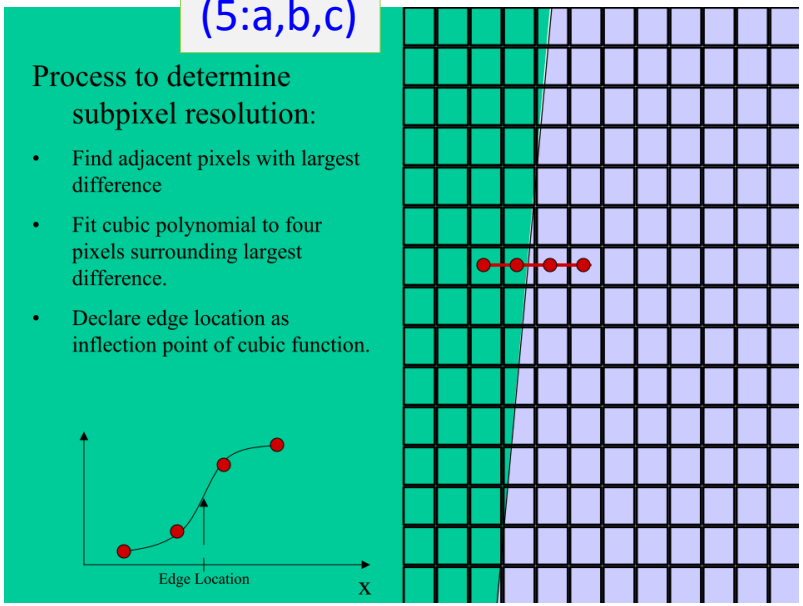
5. Detect the Edge line on ROI
   a. At every line, Find adjacent pixels with largest difference
   b. Fit cubic polynomial (TBC) to (more than) 4 pixels (TBC) surrounding largest difference
   c. Declare edge location as inflection point of cubic function (Red dot) (TBC)
   d. Linear fitting with all edge locations of lines (Green line)
   e. Get the Edge line (Green line)
   f. Calculate the Angle of Edge line (ɵ; Along/Across vs. Edge line)

(2, 3, 4)





(5:a,b,c)

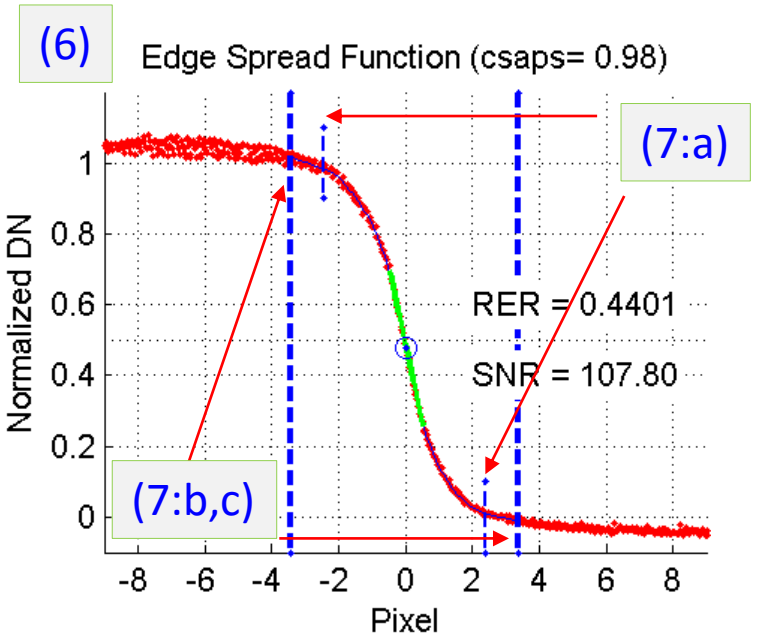


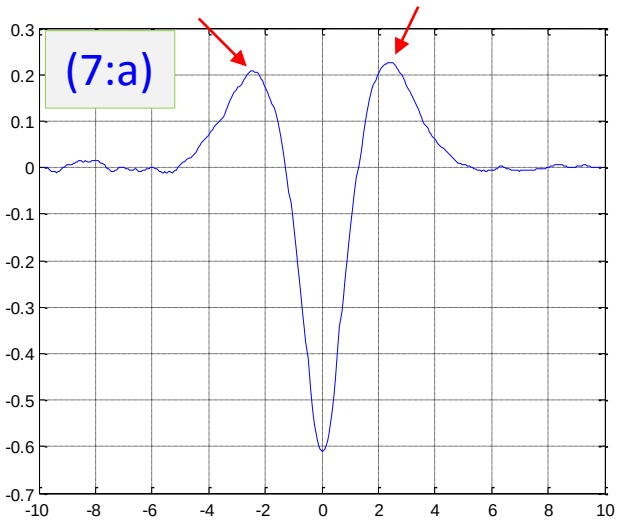
(Helder, 2001)

Processing Steps in Detail (5/7)

6. Get & Plot Edge Spread Function (ESF) with Pixel data
   a. Divide 'the Relative distance of every pixel' by 'cos(ɵ); Along/Across vs. Edge line'
   b. (X-axis) Relative distance of every pixel from the Edge line on the each line by pixel unit
   c. (Y-axis) DN value of each pixel (Red dot)

7. Decide the Staring point of the Bright & Dark area
   a. Inflection point on LSF for the Starting point (TBR)
      I. Fitting (Cubic Smoothing Spline; TBR) with Pixel data
      II. Differential Fitted ESF to LSF
      III. 2 more Differential LSF for the Inflection point
   b. The width of Bright / Dark area; 1 pixel (TBR)
   c. Trim ESF with Pixel data with Bright / Dark area (Blue dot Line)

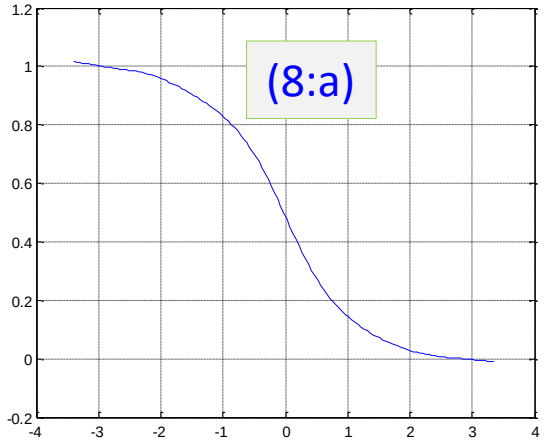


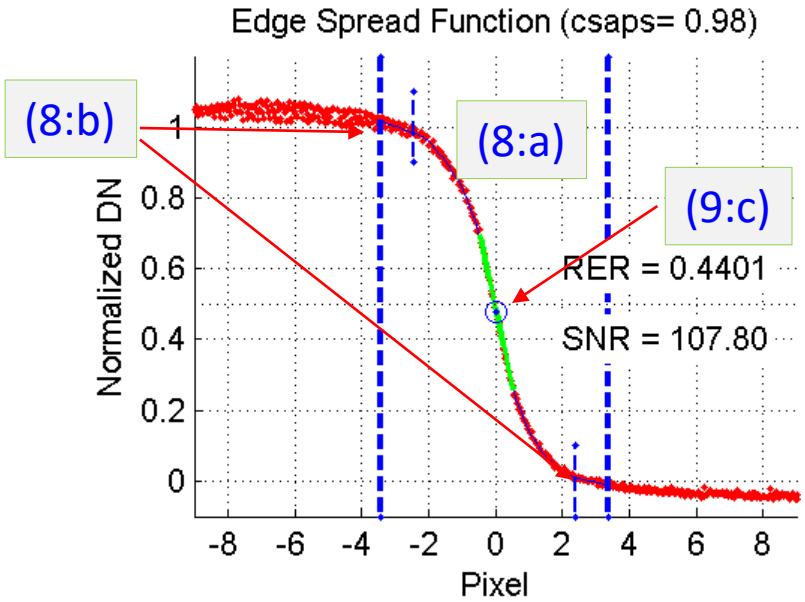


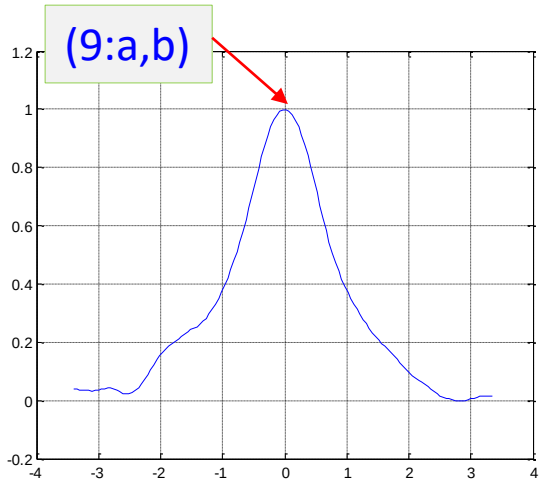
Processing Steps in Detail (6/7)

8. Calculate and Plot ESF by Fitting from the Trimmed ESF pixel data
   a. Fitting by the next (according to the asymmetric LSF) (TBD);
      I. Parametric (Fermi-Dirac)
      II. Non-parametric (Cubic Smoothing Spline, Savitzky-Golay)
   b. Normalization by fitted ESF, and Plot

9. Calculate Relative Edge Response (RER) (by one pixel)
   a. Differential ESF and get LSF ('8')
   b. The Inflection point (Top) is the Center of RER (TBR)
   c. Calculate RER by one pixel (Green line)
   d. If Parametric fitted ESF,
      - The Center of RER is '0.5' on Normalized DN





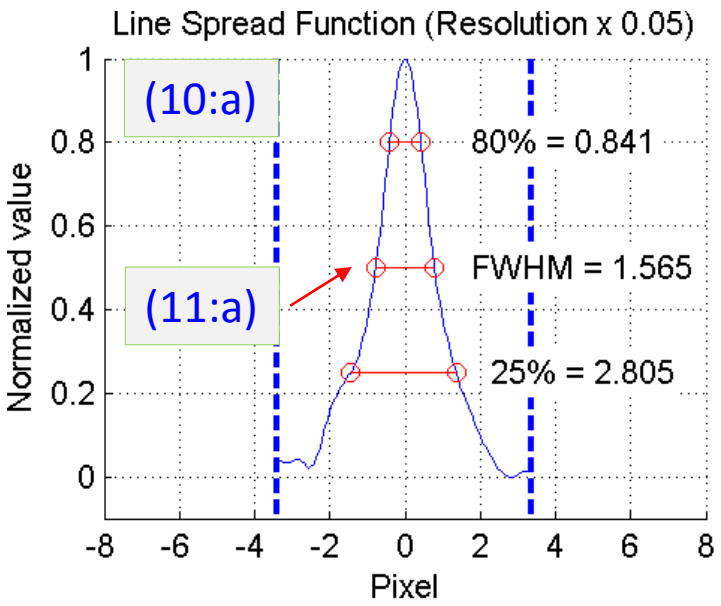


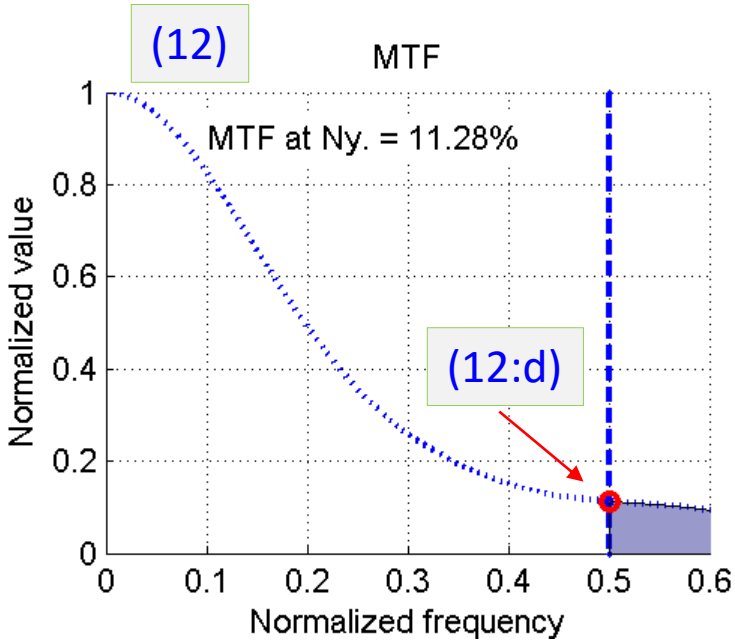
Processing Steps in Detail (7/7)

10. Calculate and Plot Line Spread Function (LSF)
    a. Differential ESF and get LSF (‘8’)

11. Calculate Full Width at Half Maximum (FWHM)
    a. FWHM (50%)
    b. 80%, 25% (if Parametric Fitting, and in Optional)

12. Calculate and Plot MTF (Modulation Transfer Function)
    a. Calculate Nyquist frequency
    b. FFT apply to LSF
    c. Plot MTF
    d. Get MTF value at Nyquist frequency (Red dot)





TBD, TBR & TBC (Draft)

No.		Item	Content	Link	TB.
A	1	**Reference target**	Status of Reference target		TBD
	2	**Natural target**	What is Requirements of Natural target?		TBR
	3	**Satellite Resolution**	(Loosely) Link to Satellite Resolution	D1	TBR
B	1	**Asymmetric PSF & LSF**	How to reflect and handle Asymmetric PSF & LSF	H1	TBD
C	1	**RER, FWHM, MTF**	What is the best Reasonable (Representative) Estimator?	H1	TBD
D	1	**Straight Line on Edge**	Limitation of Straight line by One pixel	A3	TBD
	2	**Uniformity on Bright & Dark area**	Limitation of Uniformity on Bright and Dark area by SNR (> 50)		TBR
	3	**DN Difference between Bright and Dark area**	Limitation of DN Difference between Bright and Dark area by SNR (> 50)		TBR
	4	**Angle between Edge and Along / Across direction**	Permitted Angle range between the Edge and Along / Across direction (0~30deg)		TBR
	5	**Number of Pixel on Edge line**	Limitation of Number of Pixel on Edge line (> 10~20 pixels)		TBR
	6	**Width of Bright & Dark area**	Width (pixel) of Bright and Dark area (> 5 pixels)		TBR
E	1	**Fitting Cubic polynomial**	Fitting Cubic polynomial for Detecting the Edge line on ROI		TBC
	2	**4 pixels for Edge detecting**	4 pixels for Detecting the Edge line on ROI		TBC
	3	**Edge location as Inflection point of Cubic function**	Edge location as Inflection point of Cubic function for Detecting the Edge line on ROI		TBC
F	1	**Inflection point on LSF for Starting point**	What is Starting point of Bright & Dark area		TBR
	2	**Fitting (Cubic Smoothing Spline) for 'F1'**	Fitting method (Cubic Smoothing Spline) for Inflection point on LSF for Starting point, and Weight value of Cubic Smoothing Spline	F1	TBR
	3	**Width of Bright / Dark area**	Width of the Bright & Dark area from the Starting point (1 pixel)		TBR
G	1	**Fitting method on ESF**	What it the optimal fitting method on ESF?		TBD
H	1	**Inflection point of RER Center**	What is Center of RER; Inflection point (Top) on LSF or Half DN	B1,C1	TBR