RER, FWHM, MTF Processing Step
for Edge target (Draft)
&
Standard Edge targets by KOMPSAT-3

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References

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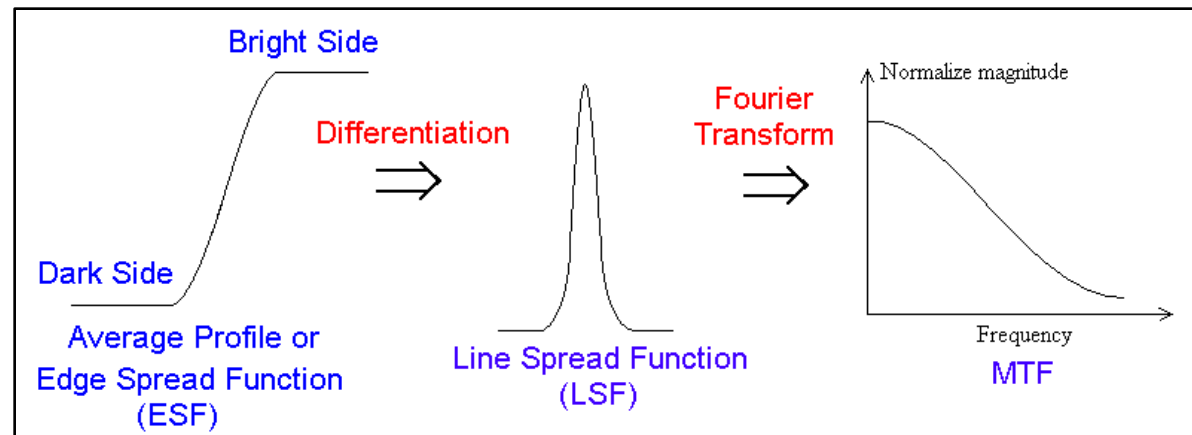
Fig. 1. Processing Steps for Edge target to get ESF, LSF, MTF [RD4]

Purpose

1. (main) Get the reasonable quantity of Spatial quality for the remote sensing satellite in the ***Real conditions***.

2. Set up the general reasonable parameters (item) of the Spatial quality; [RD4, p15]

   a. RER (Relative Edge Response)

   b. FWHM (Full Width at Half Maximum)

   c. MTF curve, and MTF value at Nyquist frequency

3. Propose and Set up 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. **Standard Processing Step (algorithm) for Edge target** [RD4, p35]

   ① Several options according to the Conditions (limitations)

   ② For target; Edge, Line, Point, Periodic

   ③ For Standard target & For Artificial & Natural target

MTF, RER, FWHM Processing Step
for Edge target (Draft)

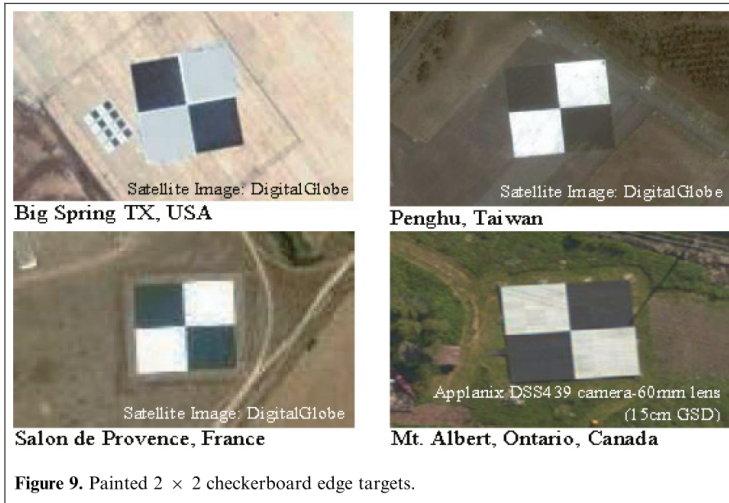## Standard Edge target from Artificial (Man-made)

Processing Steps

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)
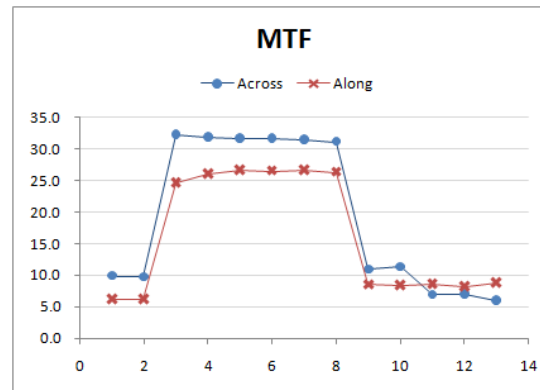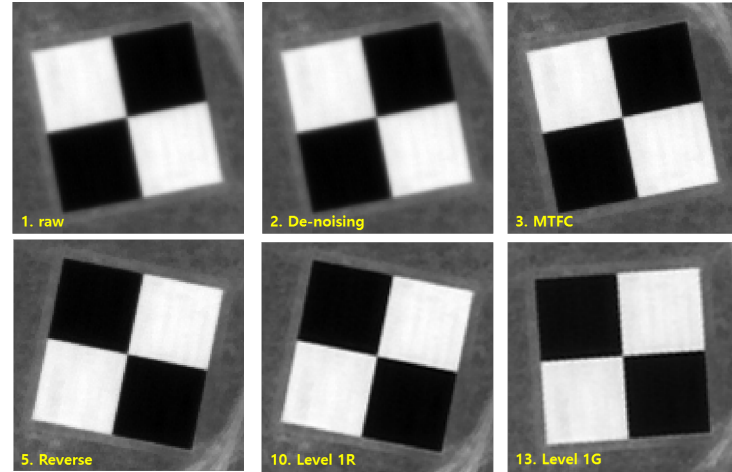
Processing Steps in Detail (1/7)

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

Big Spring TX, USA — Satellite Image: DigitalGlobe
Penghu, Taiwan — Satellite Image: DigitalGlobe
Salon de Provence, France — Satellite Image: DigitalGlobe
Mt. Albert, Ontario, Canada — Applanix DSS439 camera-60mm lens (15cm GSD)

Figure 9. Painted 2 × 2 checkerboard edge targets.

(1:a:I)

[RD1]

1. raw
2. De-noising
3. MTFC
5. Reverse
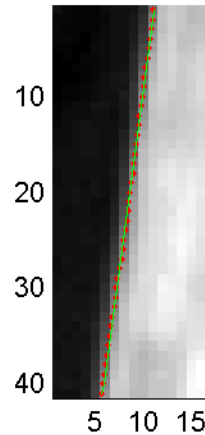10. Level 1R
13. Level 1G

MTF

(1:b:II)

MTF according to KOMPSAT-3 Steps

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Processing Steps in Detail (2/7)
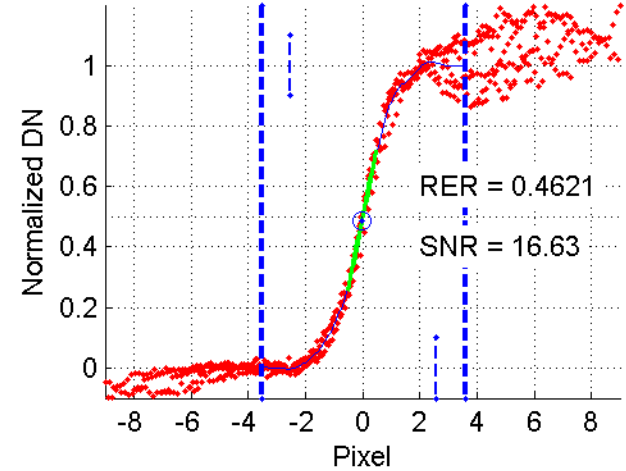
2. Read & Select ROI of the Edge target on the image data
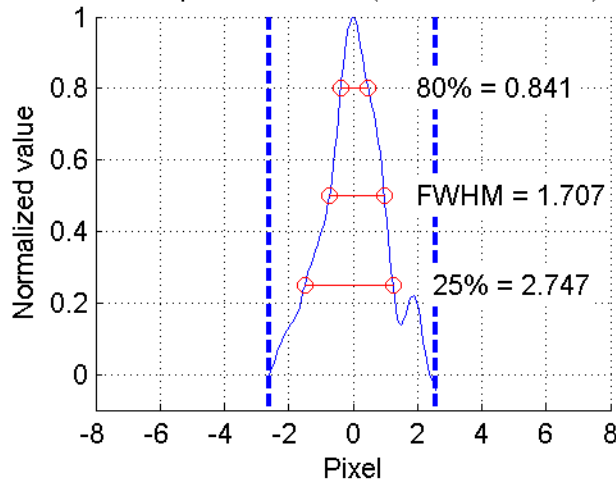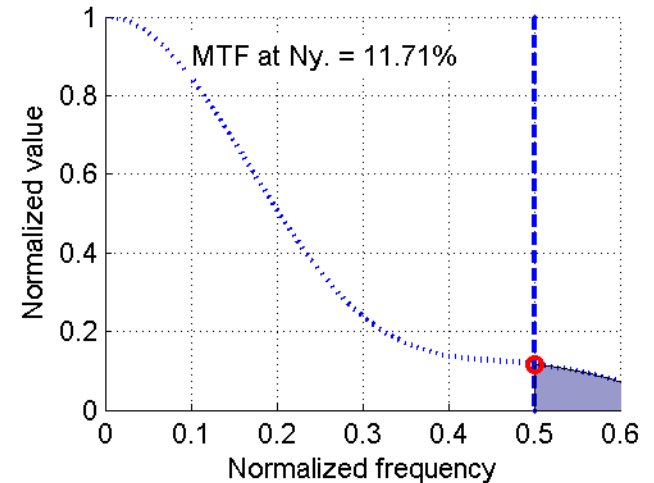   a. Reading the image data according to the storage format
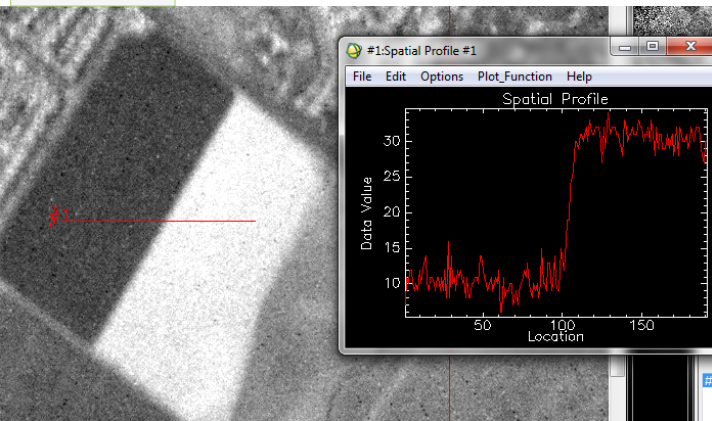   b. Search
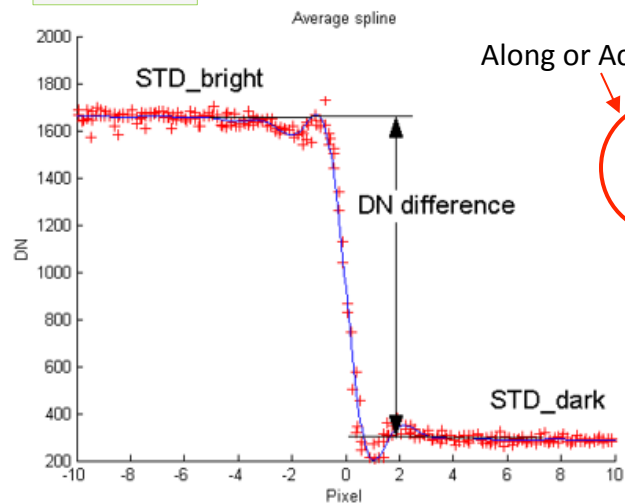
3. Check the status and health of the Edge target image data [RD2, 2.1]
   a. Straight line on Edge
      - ??? (TBD)
   b. Uniformity on the Bright and the Dark area
      - SNR > 50 (TBR) (Helder, 2002)
   c. DN difference between Bright and Dark
      - SNR > 50 (TBR) (Helder, 2002)
   d. Permitted Angle range between Edge and Along / Across direction
      - 0 ~ 30deg (TBR)
   e. Number of Pixel on Edge line
      - > 10~20 pixels (TBR)
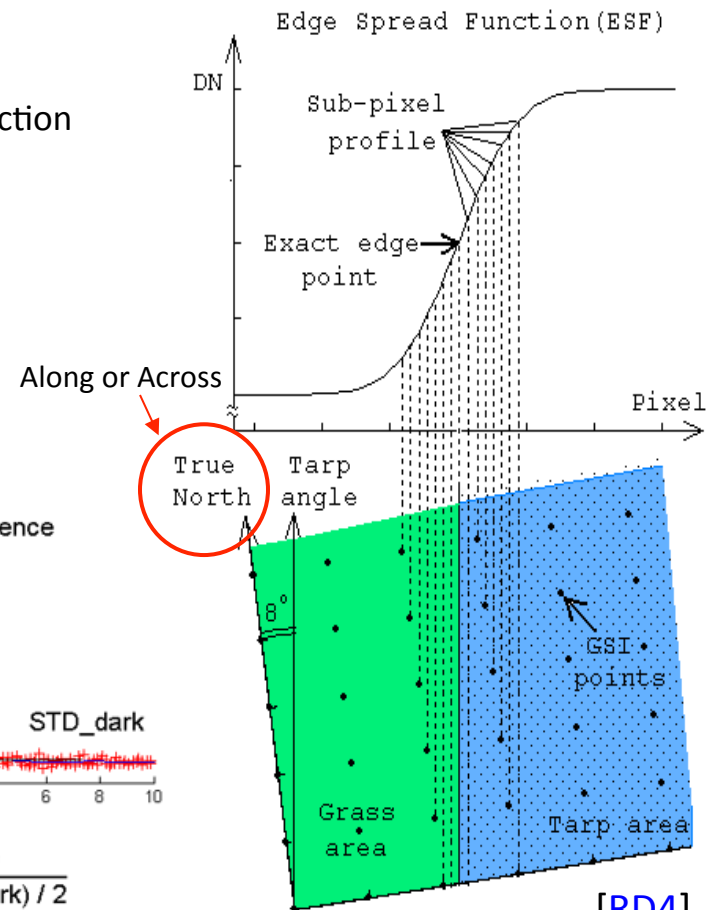
(3:d)

(3:b,c)

(3:b,c)

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

[RD4]

[RD4]

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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)
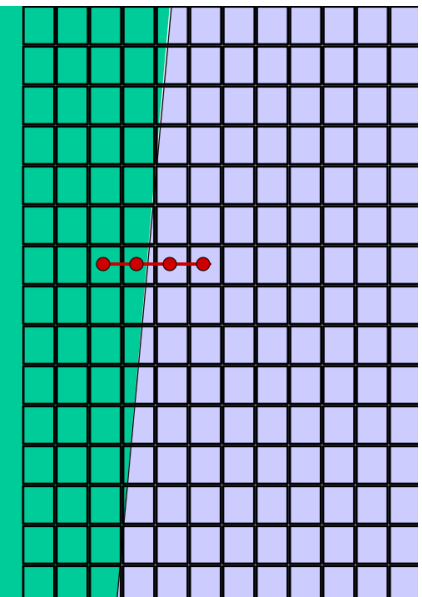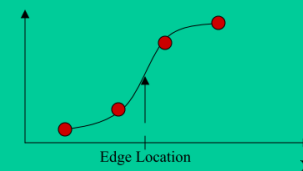   f. Calculate the Angle of Edge line (θ; Along/Across vs. Edge line)
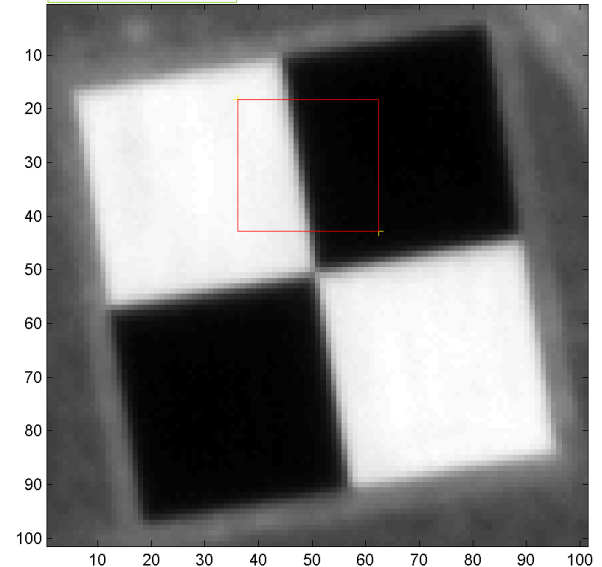
Edge Detection (Across, 9.19 deg)

(5:c,d,e)

(5:f)
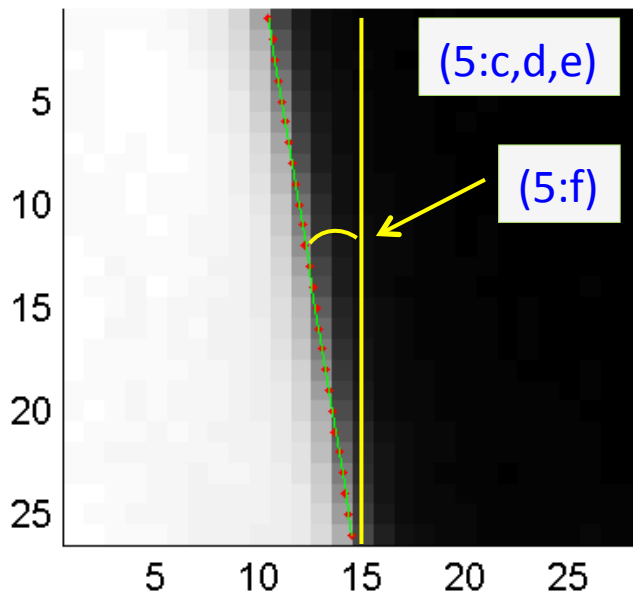
(5:a,b,c)

Process to determine subpixel resolution:

- Find adjacent pixels with largest difference
- Fit cubic polynomial to four pixels surrounding largest difference.
- Declare edge location as inflection point of cubic function.

Edge Location

x

(Helder, 2001)

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6. Get & Plot Edge Spread Function (ESF) with Pixel data
    a. Divide 'the Relative distance of every pixel' by 'cos(θ); 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)
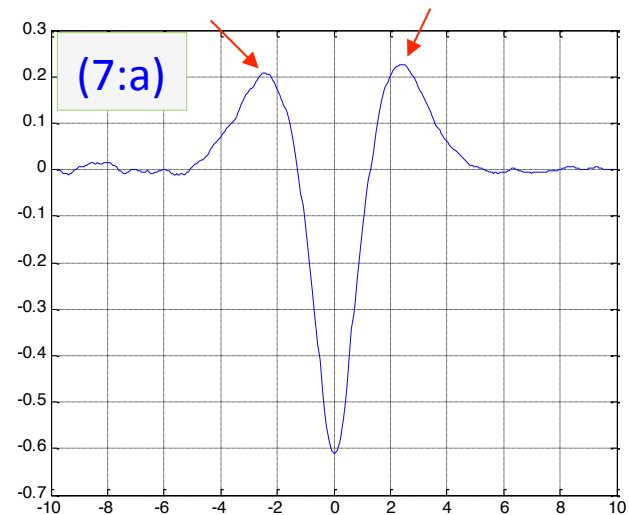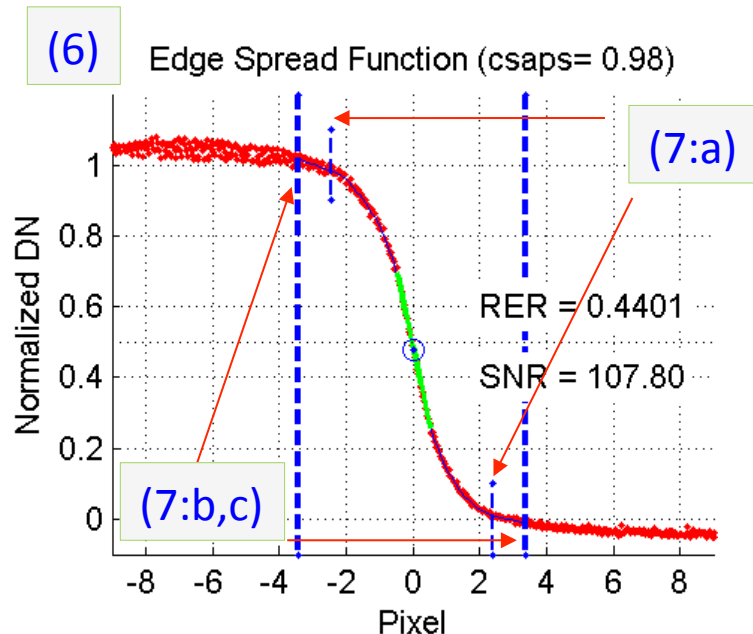
8. Calculate and Plot ESF by Fitting from the Trimmed ESF pixel data
    a. Fitting by the next (according to the asymmetric LSF);
        I. Parametric (Fermi-Dirac)
        II. Non-parametric (Cubic Smoothing Spline, Savitzky-Golay)
    b. Normalization by fitted ESF, and Plot

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

(8:a)

Edge Spread Function (csaps= 0.98)

(8:b)

(8:a)

(9:c)

RER = 0.4401

SNR = 107.80

(9:a,b)
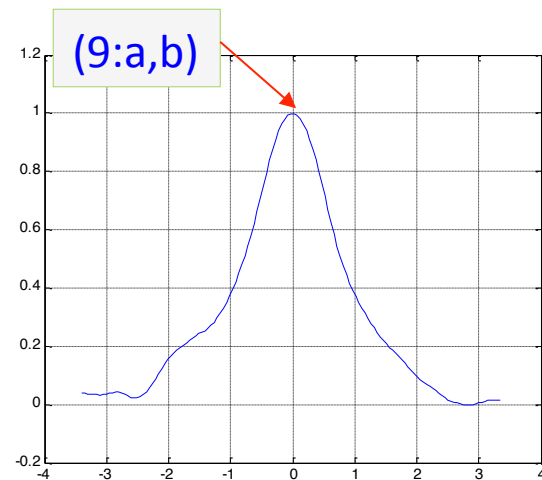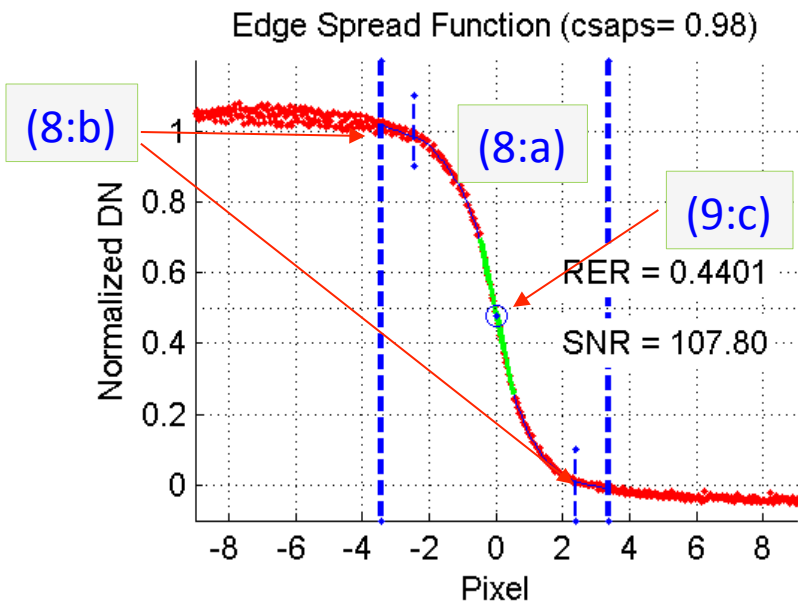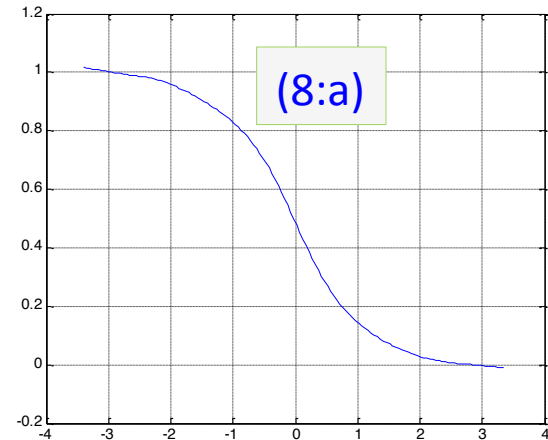
Processing Steps in Detail (7/7)

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)
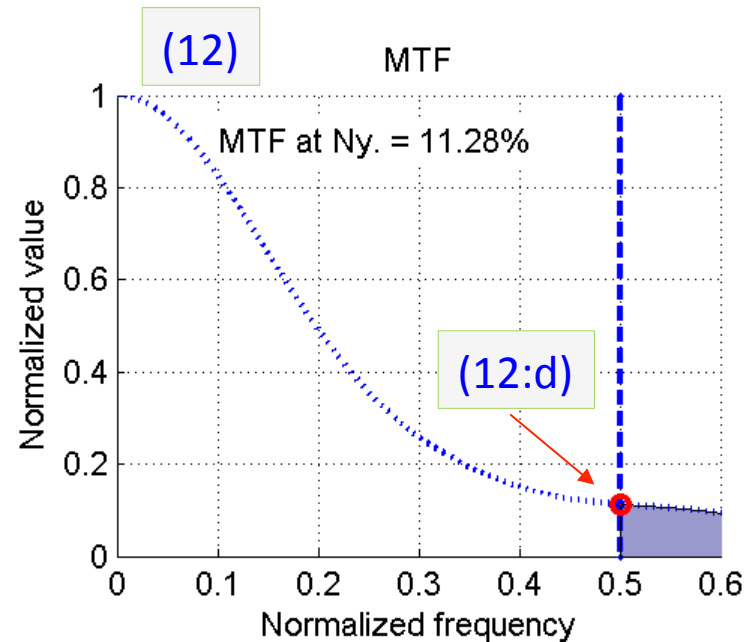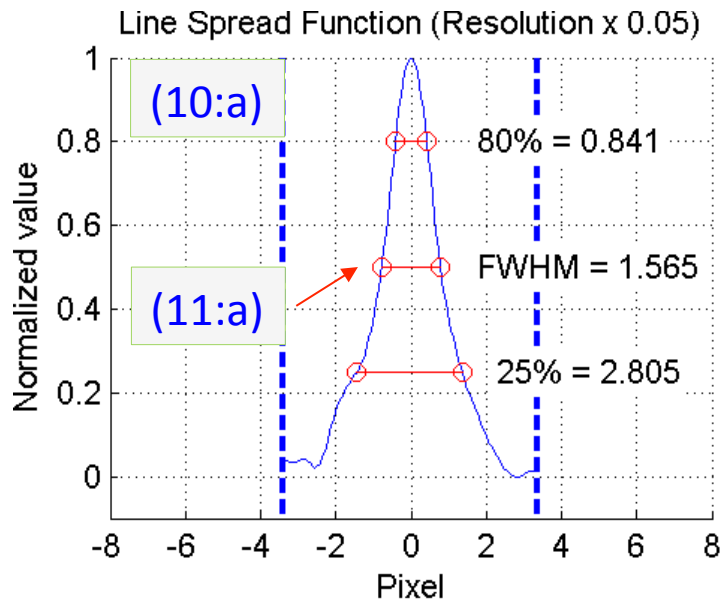
Issues and Future works

1. MTF code is directly link to the next Edge target;
   a. Reference target by USGS CalVal Portal
      I. Status of Reference target
   b. Natural target
      I. What is the requirements of Natural target?
   c. (Loosely) link to the satellite Resolution

2. What is the best Reasonable (Representative) parameter?
   a. RER, FWHM, MTF at Ny., etc.

3. How to reflect and handle Asymmetric PSF & LSF
   a. Asymmetric PSF means different LSF each Along and Across direction.
   b. Asymmetric LSF means different shape on Left and Right side of LSF.

4. What is Starting point of Bright / Dark area?
   a. What is Width of Bright / Dark area?

5. What is Optimal Fitting method for ESF?
   a. Parametric
   b. Non-Parametric

6. What is the Center of RER on Parametric fitting?
   a. Inflection point on LSF
   b. Normalized[(mean(Bright area) + mean(Dark area))] / 2

TBD, TBR & TBC (Draft)

No.		Item	Content	Link	Assign	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	G1		TBD
C	1	**RER, FWHM, MTF**	What is the best Reasonable (Representative) parameter?	G1		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
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	**Inflection point of RER Center**	What is Center of RER; Inflection point (Top) on LSF or Half DN	B1,C1		TBR

MTF, RER, FWHM Processing Step
## for Edge target (Draft)

Standard Edge target from Artificial (Man-made)

Candidate 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°36'21"N / 05°07'13"E	Good
Stennis Space Center, USA	45m x 45m (?), 2x2 checkerboard		23°31'11"N / 119°35'00"W	Good (New)
Penghu, Taiwan	60m x 60m, 2x2 checkerboard, painted surface	0° / 90°	30°23'12"N / 89°37'43"E	Good
Big Spring, USA	40m x 40m, 2x2 checkerboard, painted concreted			
Baotou city, China	48m x 48m for a single panel, contrast (W/B) > 5:1	5°	40°51'06"N / 109°37'44"E	New
GoHeung & Mongol, Korea				in Construction
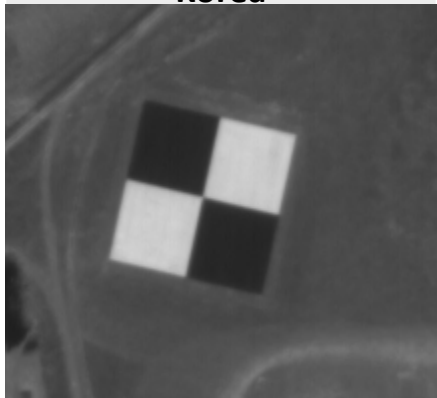
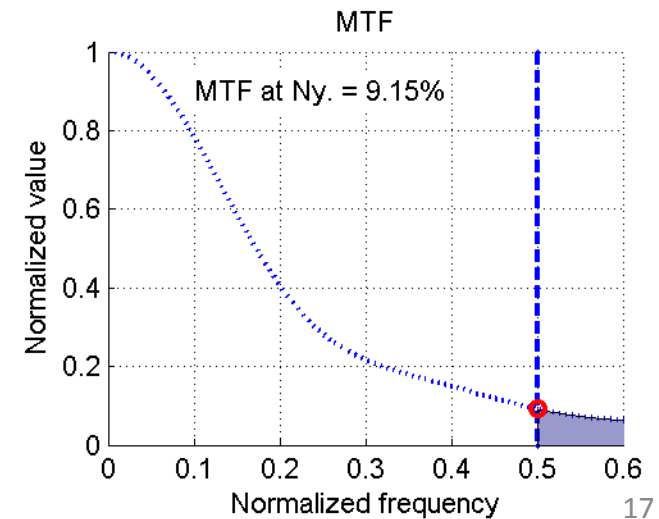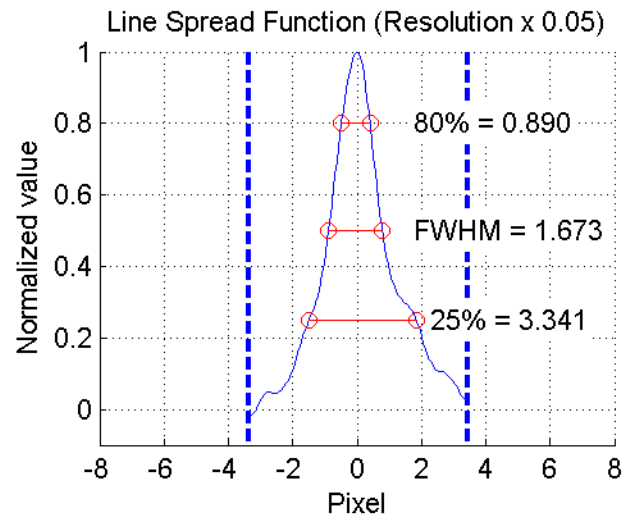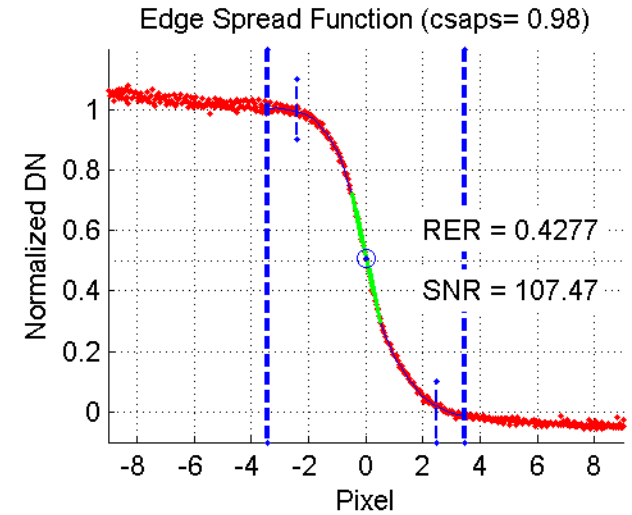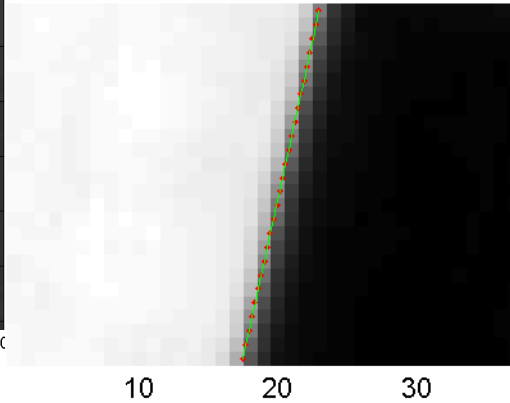Salon de Provence
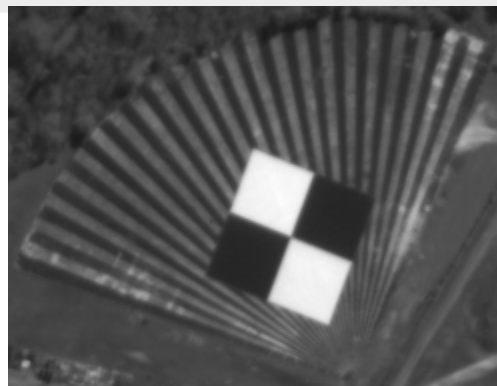
Stennis Space Center
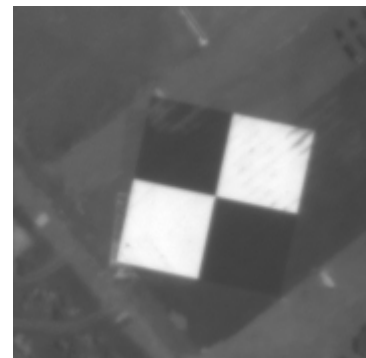
Penghu

Imaged by KOMPSAT-3 GSD (0.7m)

Salon de Provence, France

- Imaging date: 03.05.2014
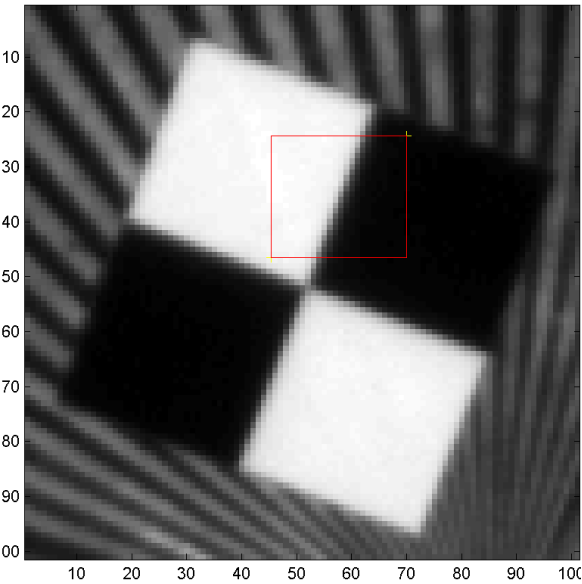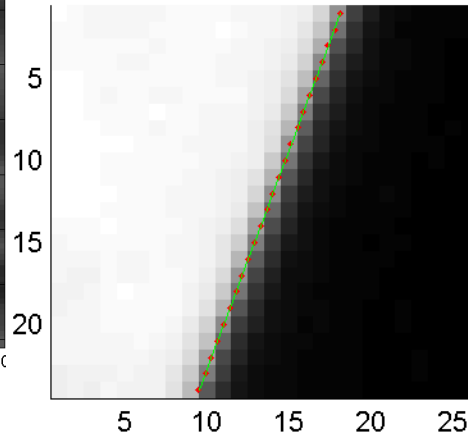- Tilt angle: -14.94deg
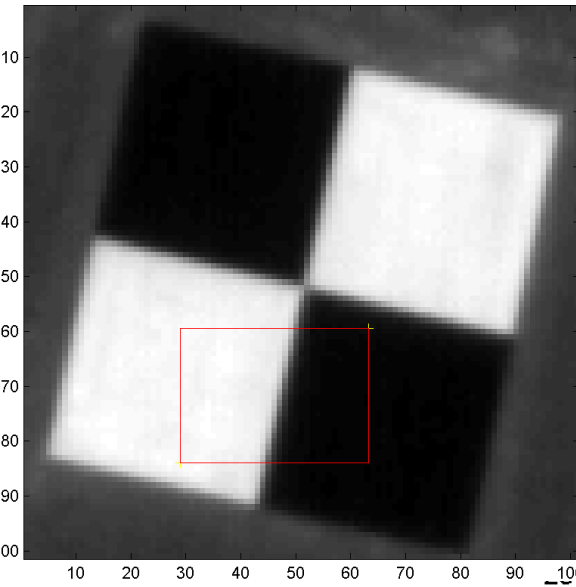
Imaged by KOMPSAT-3
(GSD: 0.7m)

Stennis Space Center, USA

- Imaging date: 04.30.2014
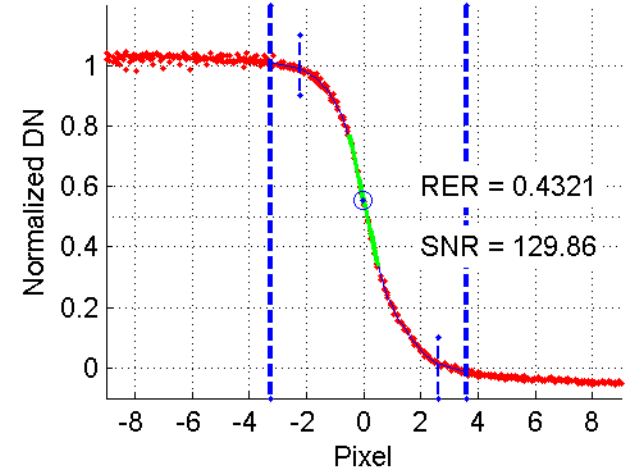- Tilt angle: 2.11deg

Imaged by KOMPSAT-3
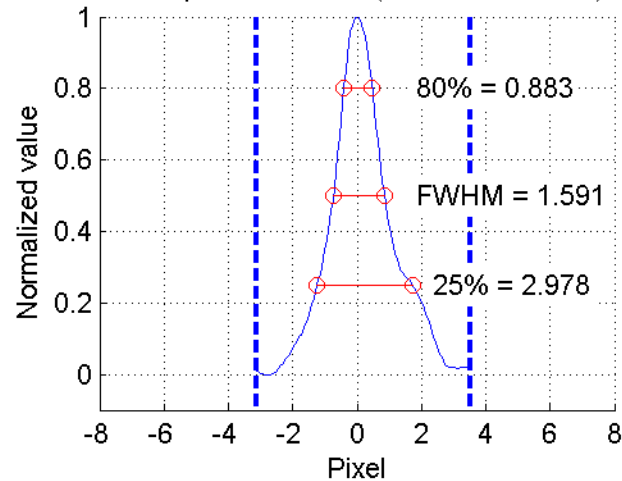(GSD: 0.7m)

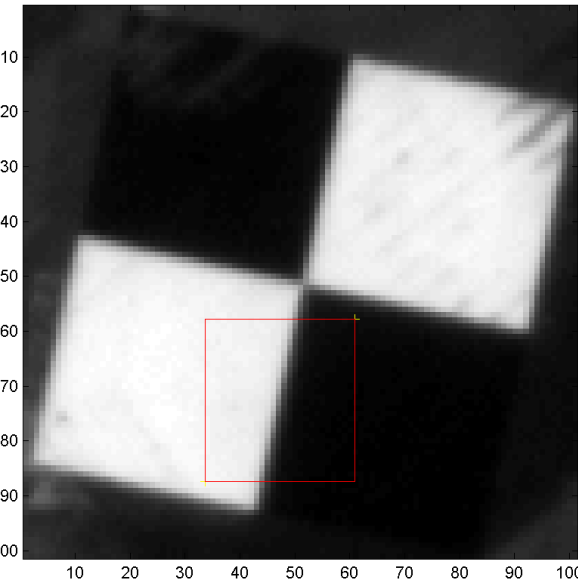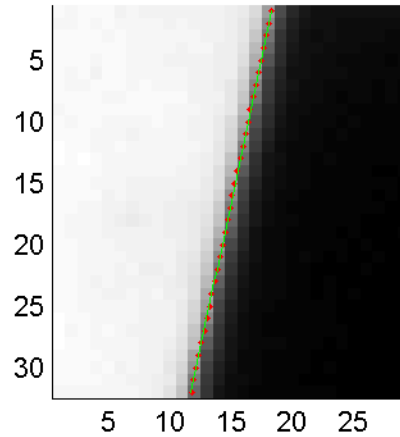# Penghu, Taiwan

- Imaging date: 04.29.2014
- Tilt angle: 7.29deg

Imaged by KOMPSAT-3
(GSD: 0.7m)

Edge Detection (Across, 11.89 deg)

Edge Spread Function (csaps= 0.98)

RER = 0.4261

SNR = 123.09
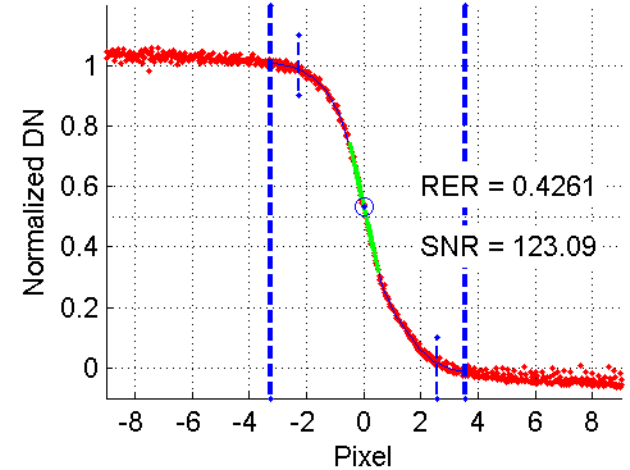
Line Spread Function (Resolution x 0.05)

80% = 0.853

FWHM = 1.612

25% = 3.164

MTF

MTF at Ny. = 11.99%
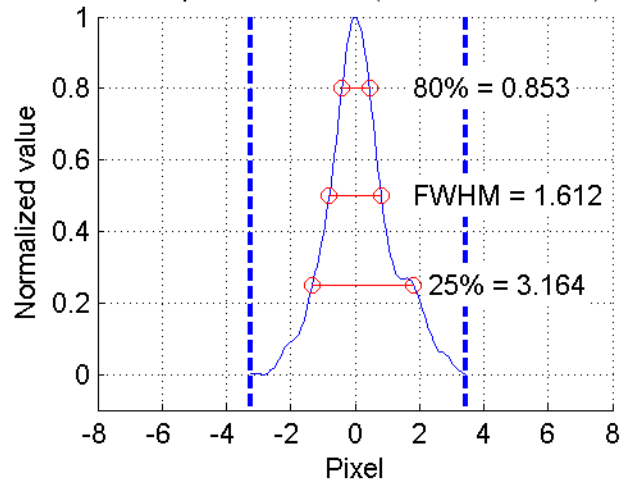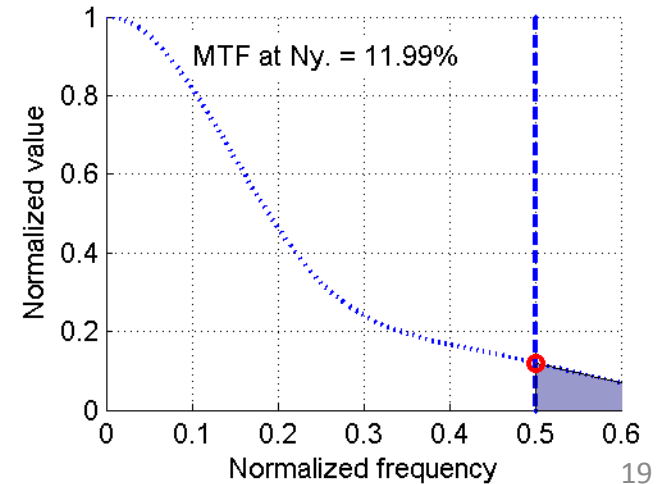
Results from Edge targets with KOMPSAT-3

| Target	Date	Roll	Across			Along		
		Pitch	RER	FWHM	MTF	RER	FWHM	MTF
Salon, France	2013.06.25	5.487	0.4393	1.605	11.09	0.3993	2.008	6.37
		0.434	0.4401	1.593	11.17	0.4036	1.845	7.15
	2014.02.13	-1.725	0.4081	1.750	9.49	0.4151	1.954	6.82
		0.086	0.4225	1.702	9.83	0.4162	1.893	7.89
	2014.03.05	-14.935	0.4236	1.718	8.59	0.4115	1.945	5.68
		-0.513	0.4277	1.673	9.15	0.4158	1.931	6.80
	Average		0.4269	1.674	9.89	0.4103	1.929	6.79
Stennis, USA	2014.01.17	-19.071	0.5341	1.606	13.86	0.5192	1.746	7.51
		-0.874	0.5506	1.523	14.27	0.5186	1.710	7.25
	2014.02.14	-2.431	0.4328	1.638	9.63	0.4217	1.781	9.15
		0.007	0.4341	1.594	12.65	0.4211	1.772	9.40
	2014.02.17	29.690	0.4132	1.690	10.77	0.4177	1.849	8.20
		1.533	0.4151	1.713	8.50	0.4109	1.779	9.20
	2014.03.01	-14.124	0.4554	1.477	13.80	0.4110	1.849	8.58
		-0.629	0.4608	1.512	13.07	0.4051	1.895	7.44
	2014.03.11	-21.903	0.4197	1.721	10.10	0.4251	1.715	9.47
		-0.972	0.4232	1.665	10.44	0.4205	1.792	8.13
	2014.04.30	2.112	0.4321	1.591	12.32	0.4237	1.803	9.61
		0.272	0.4400	1.584	11.76	0.4226	1.827	9.07
	Average		0.4509	1.610	11.76	0.4348	1.793	8.58
PengHu, Taiwan	2014.02.17	-2.236	0.4286	1.670	10.37	0.4159	1.929	7.30
		-0.013	0.4383	1.585	11.72	0.4235	1.879	8.60
	2014.03.19	-27.142	0.4237	1.713	9.38	0.4118	1.882	7.20
		-1.255	0.4231	1.548	10.93	0.4262	1.884	7.88
	2014.04.29	7.293	0.4182	1.658	10.73	0.4070	1.909	8.85
		0.568	0.4261	1.612	11.99	0.4197	1.961	8.09
	Average		0.4263	1.631	10.85	0.4174	1.907	7.99
Total Average			0.4388	1.631	11.07	0.4243	1.856	7.99

RER, FWHM, MTF
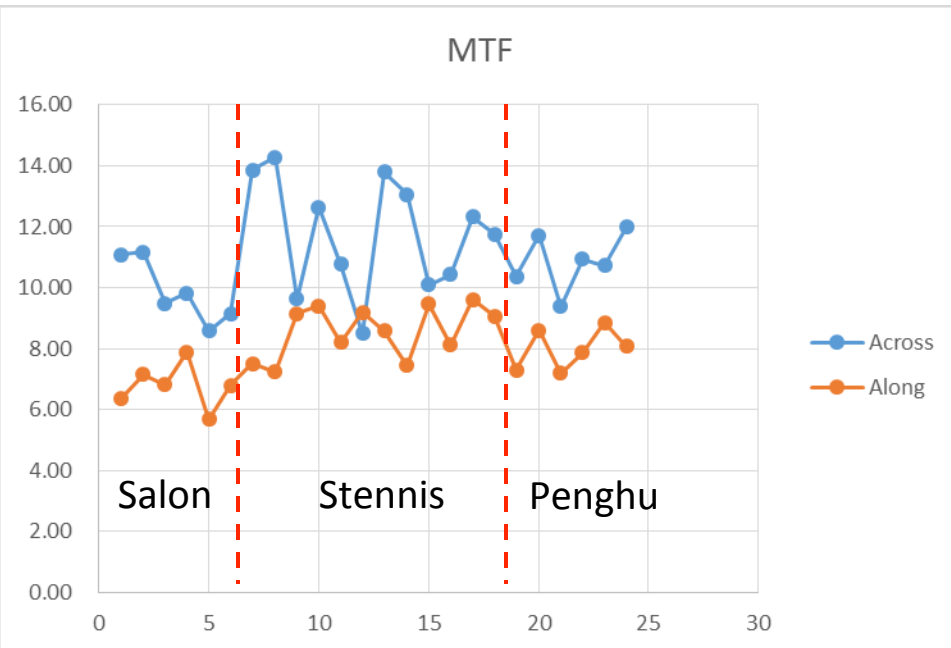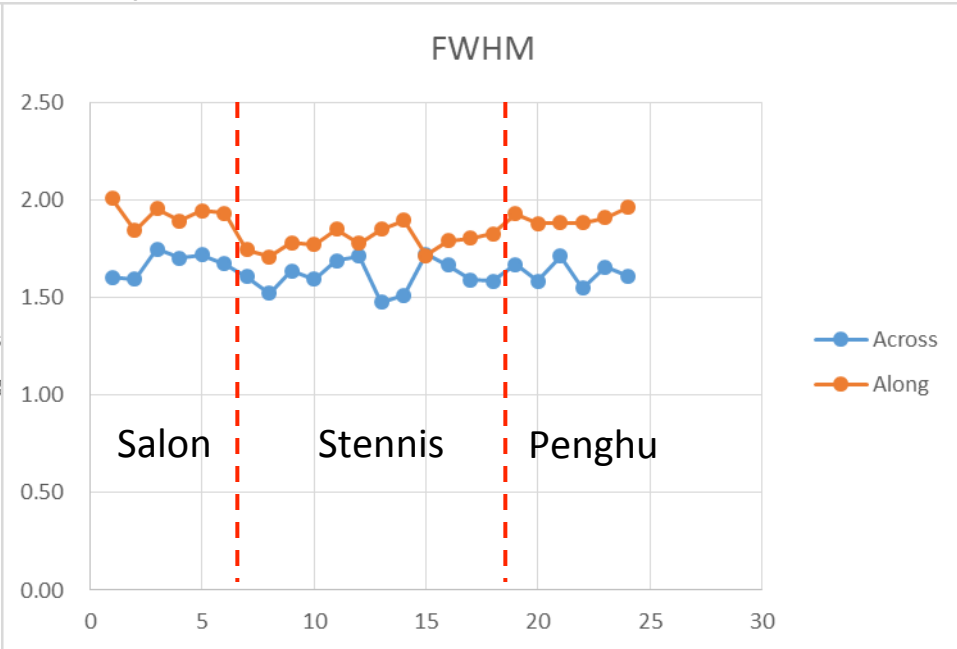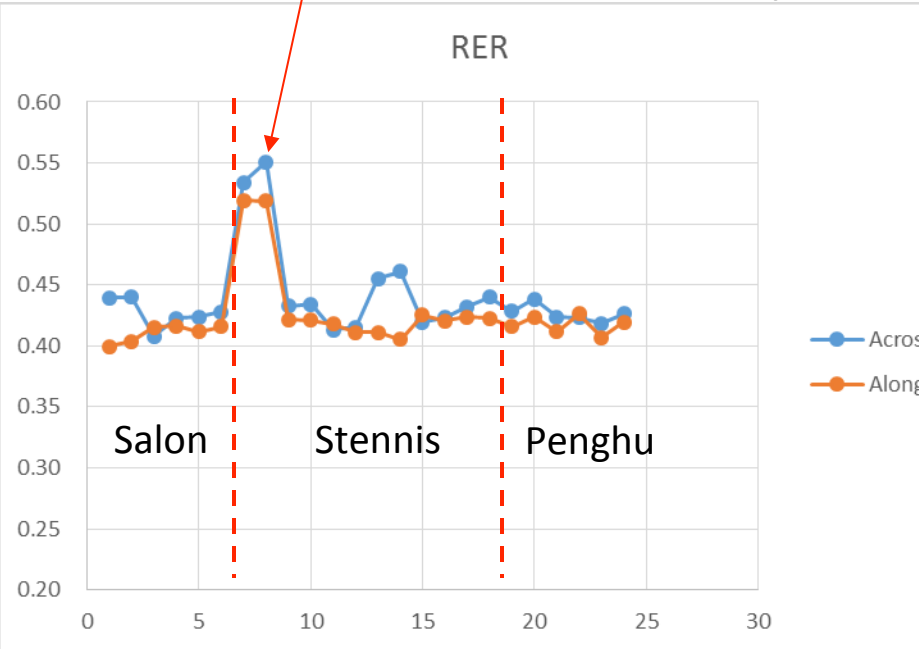
- RER & FWHM is stable.
- MTF is worst.
- Stennis, 01.17.2014
    - ✓ We need to look for the reason.
    - ✓ Imaging conditions
    - ✓ Status of target
    - ✓ MTF measuring code
    - ✓ Relation between RER and FWHM

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Stennis

(2014.01.17) Roll: -19.1, RER: 0.55   (2014.02.14) Roll: -2.4, RER: 0.43
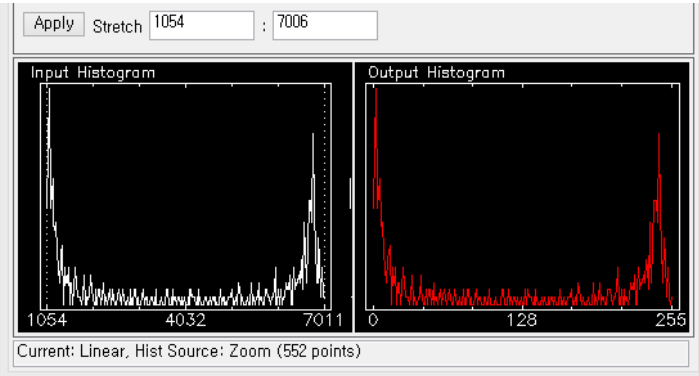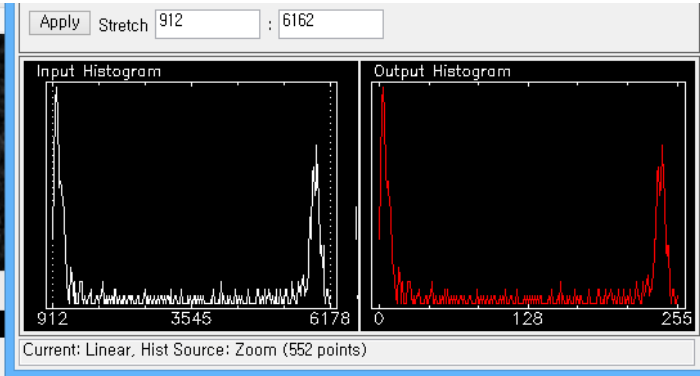
We need more information of the status of Edge target, the Imaging conditions, and the more clearer procedure for getting MTF~!

Issues and Future works

1. Why is RER of Stennis at 2014.01.17 higher than the others?

2. Database for the Standard Edge target in Worldwide [RD1, RD2]
   a. Need to keep and share the Status of Every Edge target [RD4]
   b. On USGS Cal/Val portal (in building)

3. Maintenance and Monitoring be Needed to;
   a. Keep and Share the status of the Edge target [RD4]
   b. Imaging by the several satellites
   c. Keep and Share the standard MTF measuring code

4. USGS EROS Cal/Val Portal (in building)
   a. Database for the Standard Edge targets
   b. Status of Every edge target

5. Imaging by the several satellites
   a. KOMPSAT-3
   b. Pleiades & SPOT
   c. Worldview, GeoEye
   d. etc.

6. Bar, Radial(Siemens) target & Natural target