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Calibration and Validation for KOMPSAT-3

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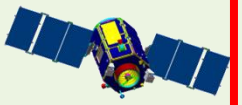
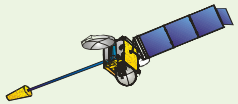
Agenda

- KOMPSAT-3 Cal/Val Overview
  - ✓ KOMPSAT Program in KARI
  - ✓ KOMPSAT-3 Calibration and Validation
  - ✓ Preparation for KOMPSAT-3 Cal/Val
- KOMPSAT-3 Cal/Val in Cal/Val Phase after Launch
  - Radiometric Cal/Val
  - Spatial Cal/Val
  - Geometric Cal/Val
- KOMPSAT-3 image data Quality after Cal/Val
  - ✓ KOMPSAT-2 vs. KOMPSAT-3
  - ✓ Quality of KOMPSAT-3 Product

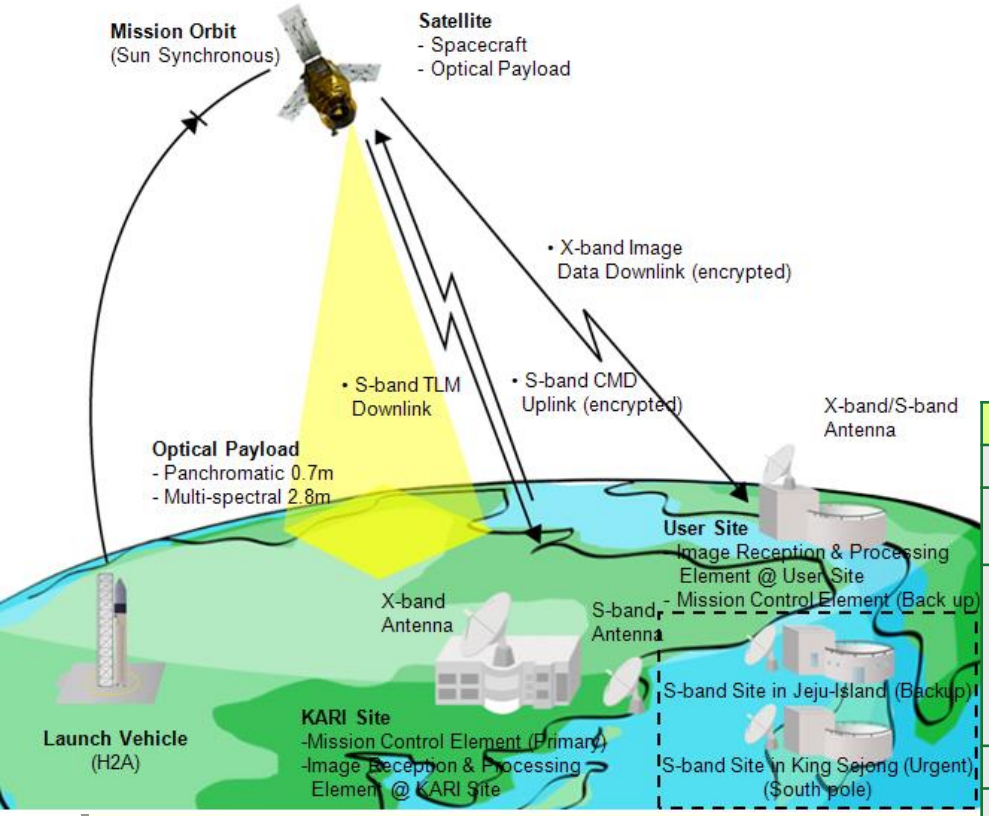
KOMPSAT Program in KARI

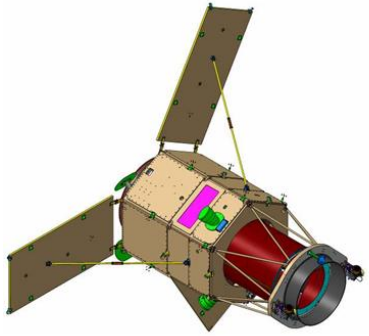
KOMPSAT Program in KARI

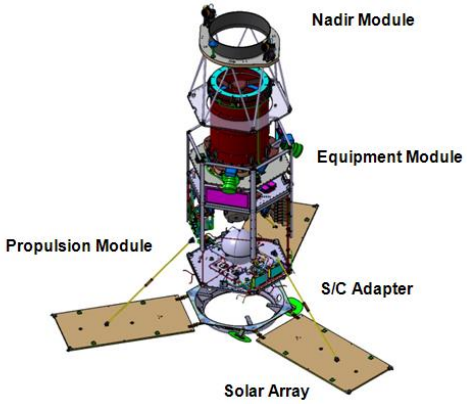
	KOMPSAT-1	KOMPSAT-2	KOMPSAT-3	KOMPSAT-5	COMS	KOMPSAT-3A
						
Payload	EOC, OSMI	MSC	AEISS	COSI	MI, GOCI	KISS
	Visual	Visual	Visual	SAR-X	Meteorology	Visual+MWIR
Launch	1999~2008	2006~	2012.5~	2013.7~	2010~	2014.9
Performance	6.6m (EOC) 1km (OSMI)	1m, 4m 10bit	0.7m, 2.4m 14bit	1m, 3m X-band	500m	0.55m, 2.2m 5.5m (MWIR)
Image mode	Strip	Strip	Spot, Strip, Wide	HR, Strip, Wide		Spot, Strip, Wide
Swath	15km	15km	15km	15km	2,500km	15km
Orbit	Geo-Sync	Geo-Sync	Geo-Sync	Geo-Sync	Geo-Station	Geo-Sync

KOMPSAT-6 (SAR) & COMS-2 will be developed by KARI after KOMPSAT-5 & COMS

KOMPSAT-3 Overview





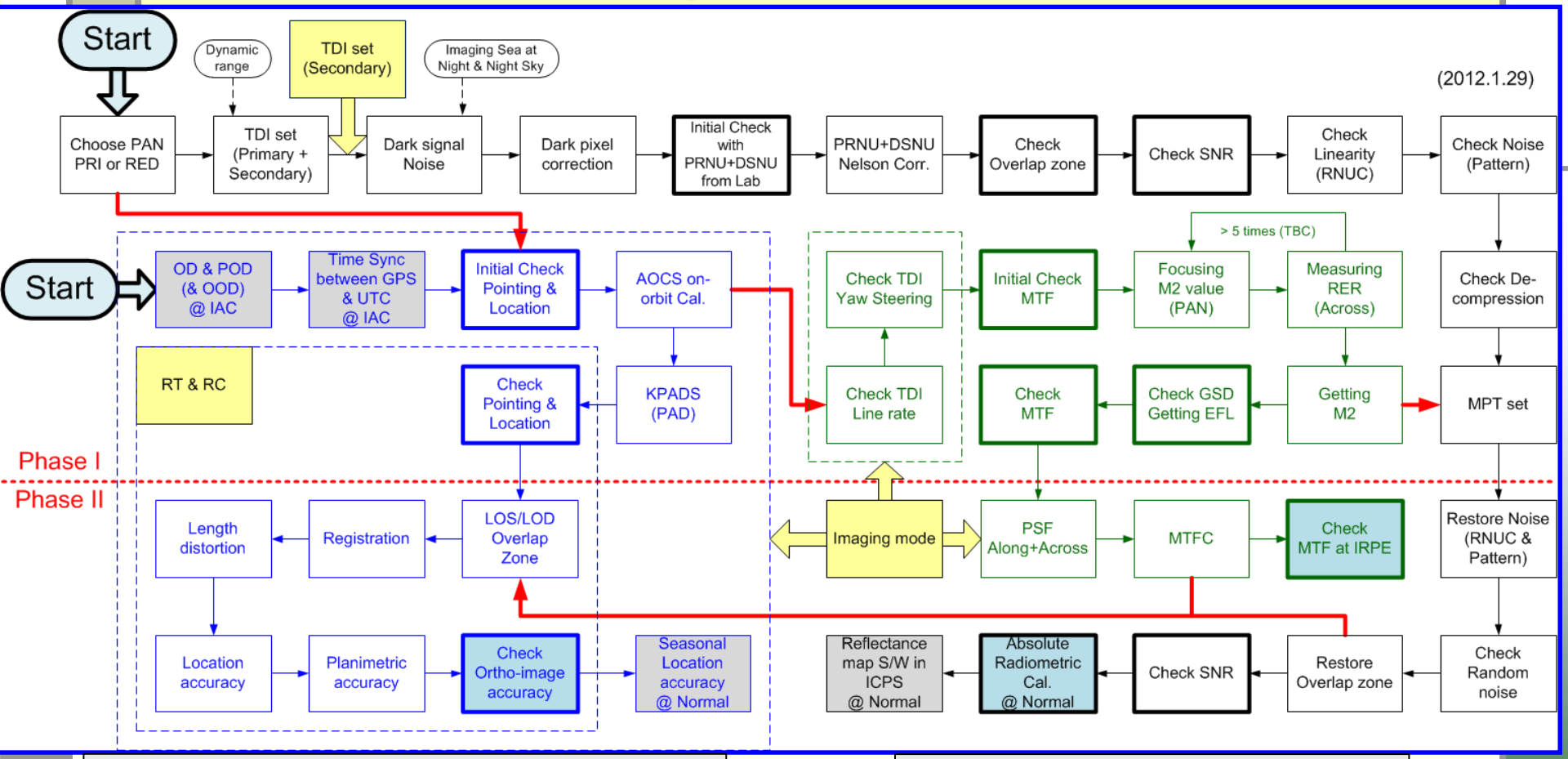


Parameters	Value
Nominal Orbit Altitude at the Equator	685.13km (Sun synchronous orbit)
Inclination	98.13°
Mean Local Time of Ascending Node	13:30
repeat ground track	409 orbit per 28 day
Imaging mode	Strip, S-Stereo, Multi-P, Wide

System Attributes	Requirement
Design lifetime	4 years
Ground Sample Distance (GSD)	PAN : 0.7 m @ altitude 685 km(nadir) MS : 2.8 m @ altitude 685 km(nadir)
Spectral Band	PAN : 450 ~ 900 nm MS1 (Blue): 450 ~ 520nm MS2 (Green): 520 ~ 600nm MS3 (Red): 630 ~ 690nm MS4 (NIR): 760 ~ 900nm
Swath Width	(PAN) 15 km, (MS) 15 km @ nadir
SNR	> 100
Modulation Transfer Function (MTF)	System MTF at Nyquist fr. for PAN : 8% System MTF at Nyquist fr. for MS : 12% (at strip imaging mode)
Effective Focal Length	8562 mm
Size of CCD	(PAN) 8.75µm, (MS) 17.5µm
Radiometric Resolution	14 bits (0 ~ 16383)
CCD	64 TDI Pushbroom (1, 8, 32, 64)

KOMPSAT-3 Calibration and Validation

KOMPSAT-3 Cal/Val work Flow in LEOP



- **Think line box**: Checking K3 Spec. value
- Blue painted box: Final Cal/Val work
- Gray painted box: @ IAC & @ Normal

- Black box: Radiometric Cal/Val
- Green box: Spatial Cal/Val
- Blue box: Geometric Cal/Val

LEOP Cal/Val Phase(CVP) I & II

	System Cal/Val	Product Cal/Val
LEOP Cal/Val Phase	I	II
Work	Calibration & Validation Characterization	Image data Restoration
Document	Cal/Val Plan + Doc. + Procedure + Report	
Working Group	GSC WG (+FOWG)	
Leader	DongHan & Dr. Kim	DongHan Lee
Image data Level	Level 0	Level 1R + Level 1G
Requirement	System Spec.	System Spec. (Quality Req.)
Target	Satellite & AEISS(Camera)	IRPE PMS (Processing system)
Step	After IAC	After CVP I
Duration	2012. 6.8 ~ 8.17	2012. 8.20 ~ 12.31

Performance of KOMPSAT-3 after Cal/Val

	Key Item	Requirement Value	Validated Value	Condition
CVP I	SNR	100	>> 100 (TDI 64)	
	MTF	8%(PAN) 12%(MS)	Across: 8~10% (TDI 64) Along: 6~8% (TDI 64) > 19% (MS)	Strip imaging Level 0
	GSD	0.7m(PAN) 2.8m(MS)	0.7m (PAN)	Strip & Nadir imaging
	Pointing accuracy	1.2km	Across: 90m Along: 1 sec	Strip imaging
	Location accuracy	70m CE90	< 70m CE90	With POD & PAD Strip imaging
CVP II	MTF after MTFC	13%(PAN) 19%(MS)	> 20% (PAN)	Level 0
	Registration	0.5pixel RMS (MS)	0.5pixel RMS (MS)	Strip imaging
	Ortho-image accuracy	3.5m CE90 (Horizontal)	3.5m CE90 (Horizontal)	Strip imaging

Preparation for KOMPSAT-3 Cal/Val

For Radiometric Cal/Val

Pre-Launch ⟷ Post-Launch

H/W

- Radiometric Cal/Val site develop.
  - ✓ Korea and Worldwide
- Equipment
  - ✓ Spectro-radiometer, Visibility meter

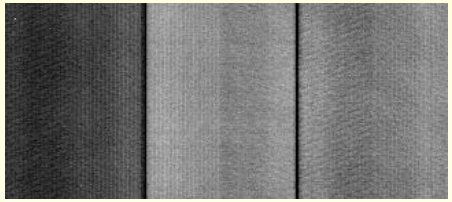
Validation activity

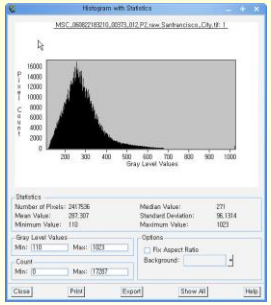
- Statistical value of image
- Visual Inspection
- Cal/Val S/W
- Absolute radiometric Cal.

S/W

- Algorithms development
  - ✓ Band Normalization
    - Dynamic range, Gain/Offset
  - ✓ Uniformity
    - Overlapping/Full image area
    - PRNU+DSNU
  - ✓ Noise checking
  - ✓ SNR

✓ **Band Normalization**



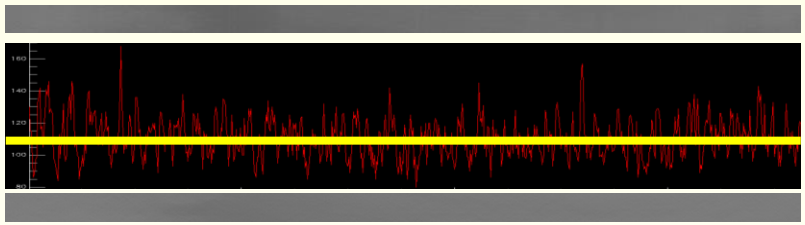


✓ **Uniformity**

L0 Image

Analysis

Evalu/Val



For Spatial Cal/Val

Pre-Launch ⟷ Post-Launch

H/W

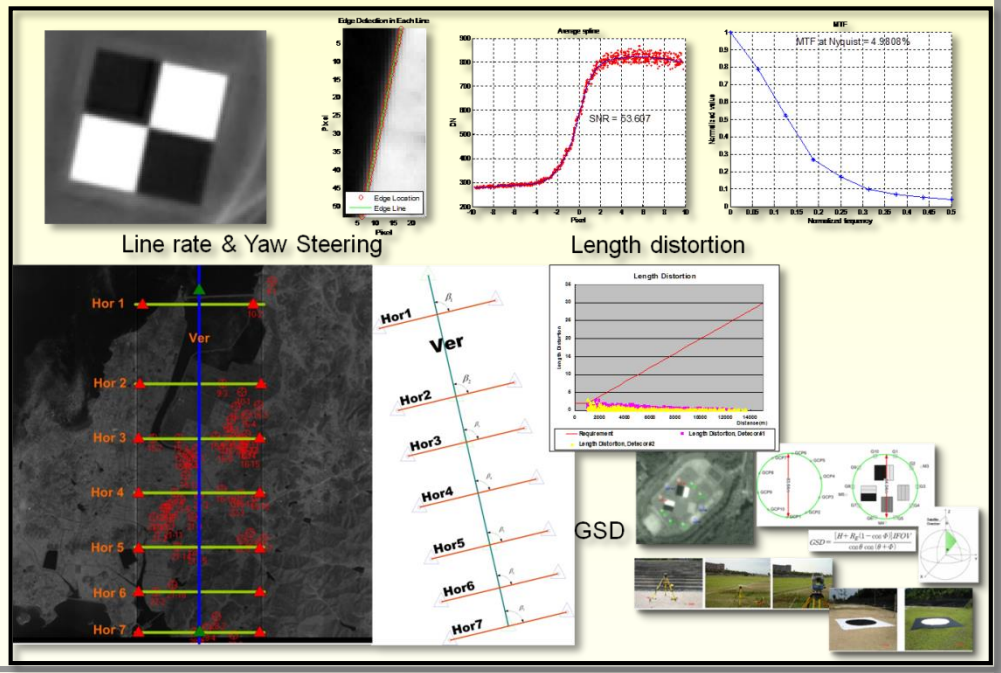
- Spatial Cal/Val site development
  - ✓ Korea(Edge), Mongol(Edge)
- Equipment
  - ✓Star imaging, Night lamp

S/W

- Algorithms development
  - ✓ RER, FWHM, MTF measurement
  - ✓ GSD/Line rate measurement

Validation activity

- MTF/GSD/Line rate value
- Cal/Val S/W, Imatest
- MTF Compensation



For Geometric Cal/Val

Pre-Launch ⟷ Post-Launch

H/W

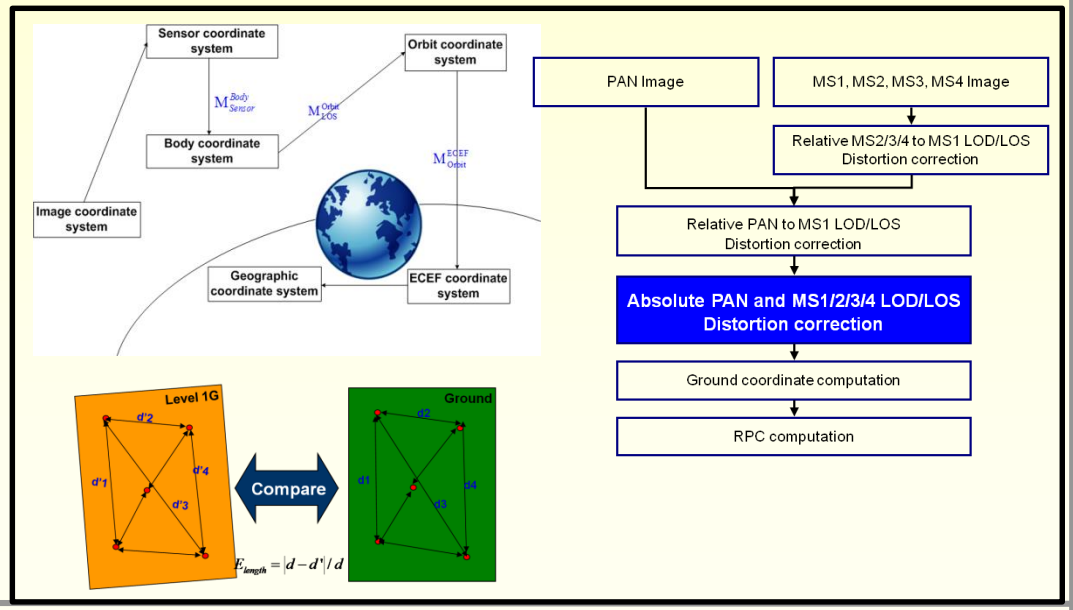
- Geometric Cal/Val site
  - ✓ Precision site : Acc<10cm
  - ✓ Normal site : Acc< 10m
- Equipment
  - ✓ GPS, Total Station

S/W

- Algorithms development
  - ✓ Pointing Accuracy
  - ✓ Location Accuracy
  - ✓ Ortho-image Accuracy

Validation activity

- Direct geo-referencing modeling accuracy
- Length distortion, Planimetric accuracy
- Registration accuracy
- Cal/Val S/W, Commercial S/W

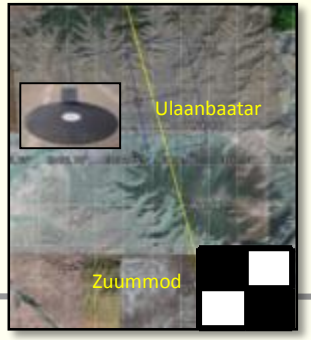


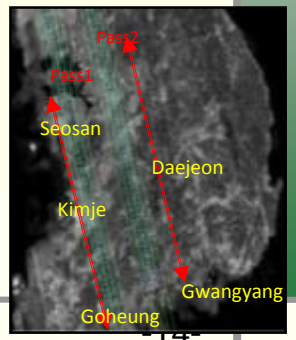
KOMPSAT Cal/Val Site, Target, S/W, Equipment

Item	Cal/Val Parameter, Detailed	Remark
Night Lamp	MTF, PSF	Portable
Star	MTF, PSF	Night
Tarp	Linearity, Radiometric	Portable
GCP DB	Pointing & Location accuracy KPADS, AOCS, Registration Mapping quality	Korea, Mongol
MAP data	Pointing & Location accuracy KPADS, AOCS, Registration	Korea, Mongol, Worldwide
Radiometric e quipment	Spectro-radiometer	Portable
	Sun-photometer	
	Multi-Filter Rotating Shadow band Radi ometer Ultraviolet Multi-Filter Radiometer Temperature measurement equipments	
Geometric equipment	GPS instrument	Portable
	Total station	

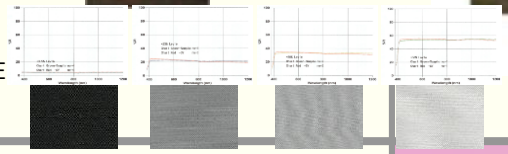
Item	Cal/Val Parameter, Detailed	Remark
S/W	ENVI, ERDAS, MODTRAN, STK, Imatest	Commercial
	Matlab, Visual Studio	
	Cal/Val SW	Develop
	MTF Measurement SW	Develop
GRDB	Geometric Cal/Val site, Ortho image	Develop
	MS SQL DBMS & Server+RAID	
Radiance Map in Worldwide	Radiance map in Worldwide	Develop
	Radiance prediction S/W for ICPS	
Site	GCP DB, DSM site	Korea
	GCP DB, Edge	Mongolia

Red: Developed by KARI Cal/Val team





JACIE



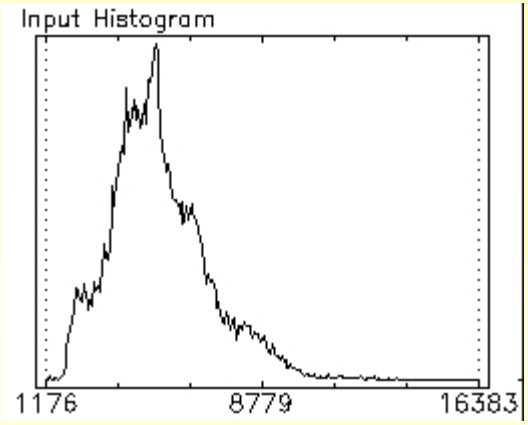
Satellite data Calibration a

Mongolia

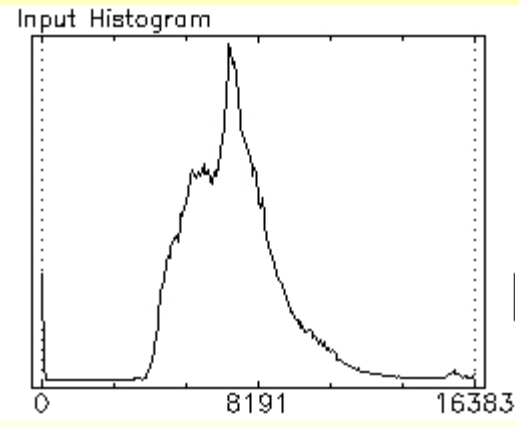
Korea

Radiometric Cal/Val for KOMPSAT-3

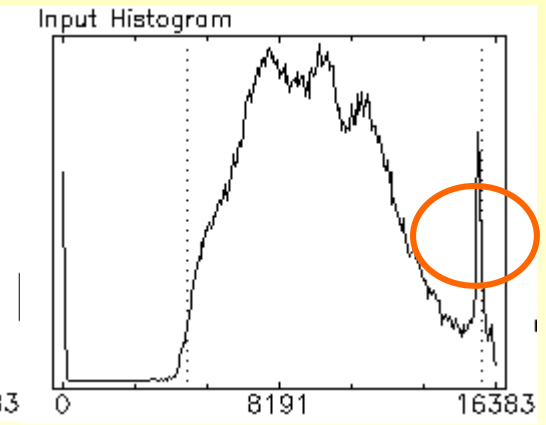
Dynamic range: Las Vegas (2012.06.16)



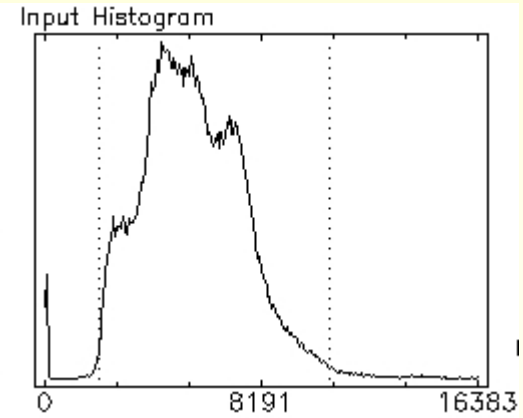
PAN



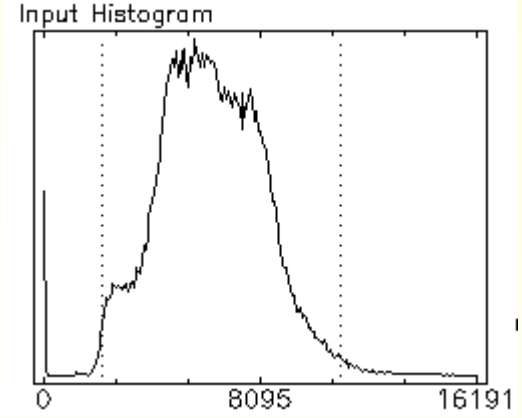
MS1 (Blue)



MS2 (Green)



MS3 (Red)



MS4 (NIR)

MS1 (Blue)

Dynamic range: TDI set #1 & #2 Decision

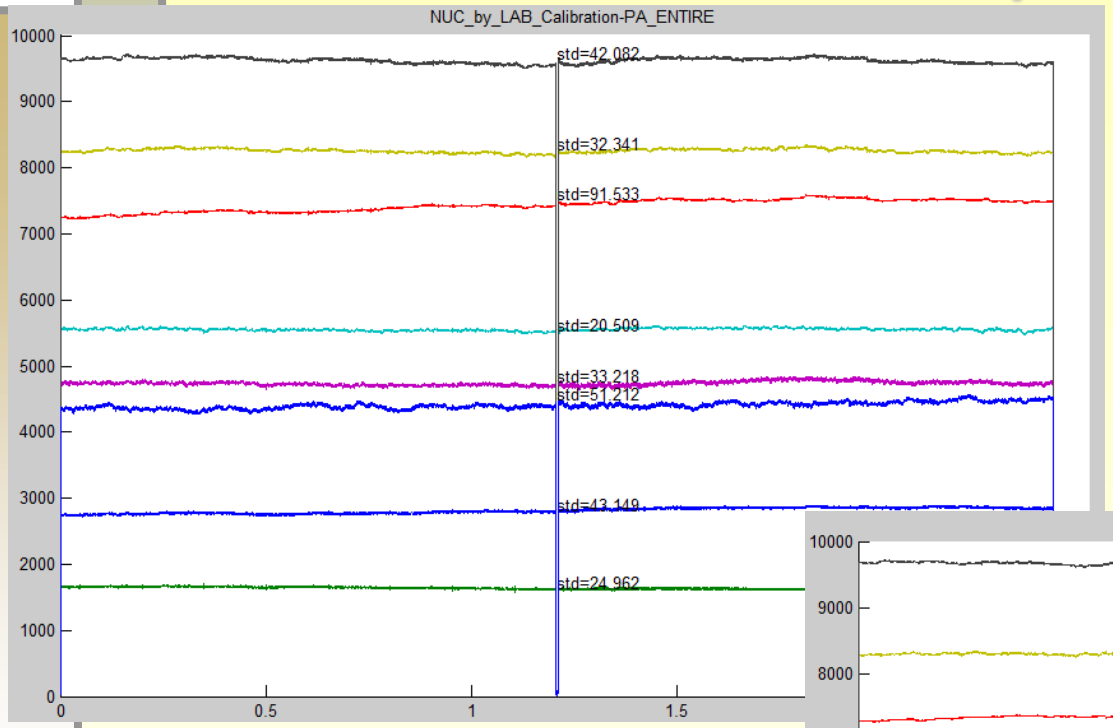
Before Launch, with Lab

TDI set		PAN	MS1 (Blue)	MS2 (Green)	MS3 (Red)	MS4 (NIR)
#1	TDI Line	64	64	32	8	8
	MS Binning		Ave	Ave	Sum	Ave
#2	TDI Line	32	32	8	8	1
	MS Binning		Ave	Sum	Ave	Sum

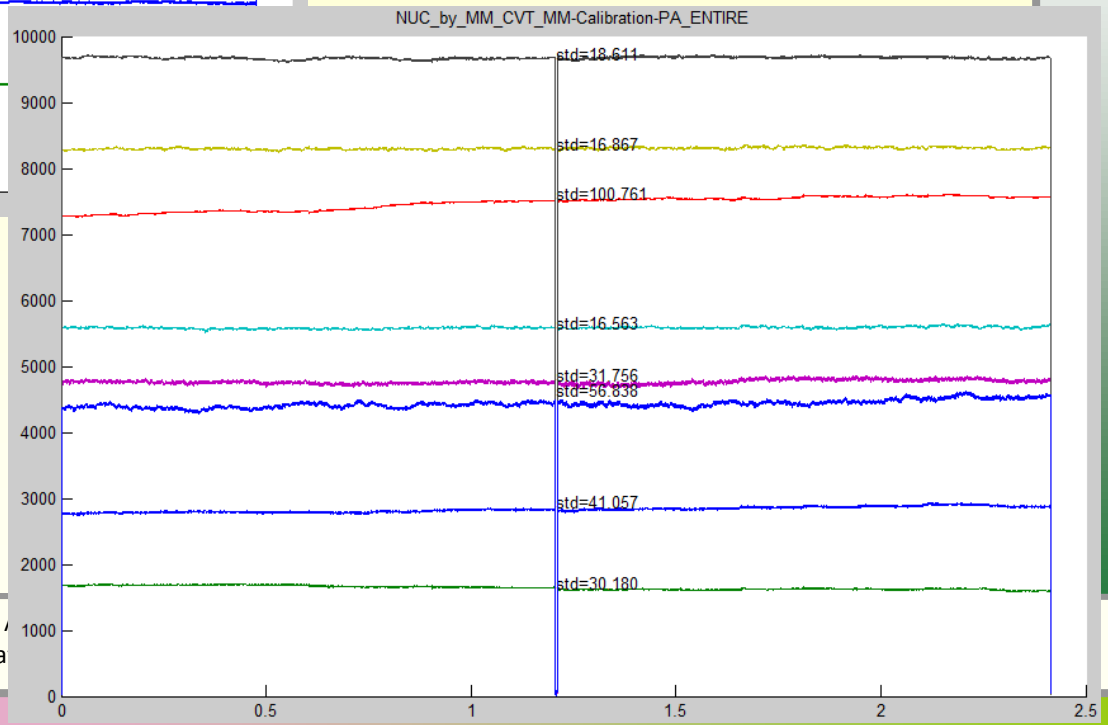
After Launch, with CVT

TDI set		PAN	MS1 (Blue)	MS2 (Green)	MS3 (Red)	MS4 (NIR)
#1	TDI Line	64	64	8	8	8
	MS Binning		Ave	Sum	Sum	Ave
#2	TDI Line	32	32	8	8	1
	MS Binning		Ave	Ave	Ave	Sum

Normalization (PRNU+DSNU)



Before Launch: PAN with Lab table

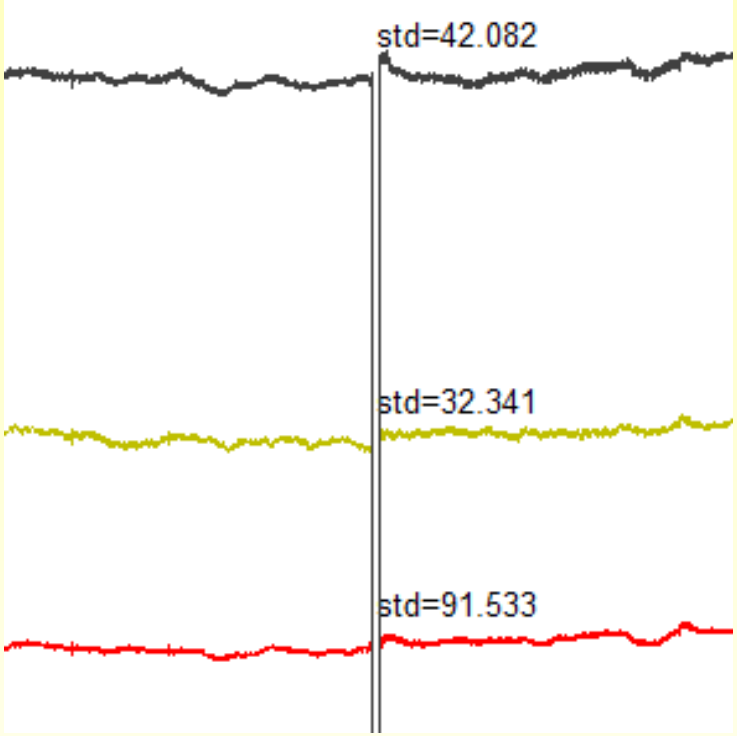


After Launch: PAN with CVT

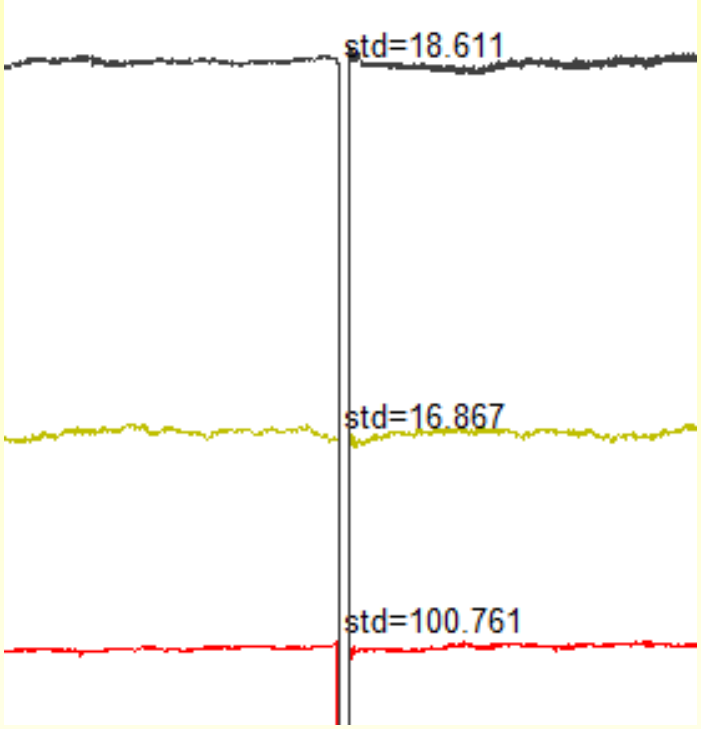
JACIE (2014)

Korea
Satellite da

Normalization (PRNU+DSNU)



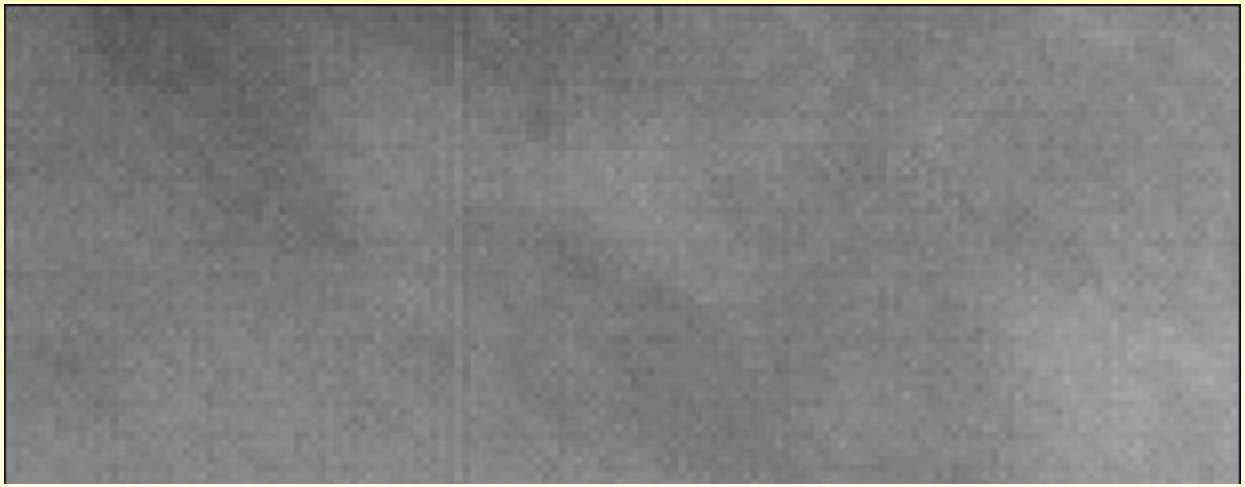
Before Launch: PAN with Lab table



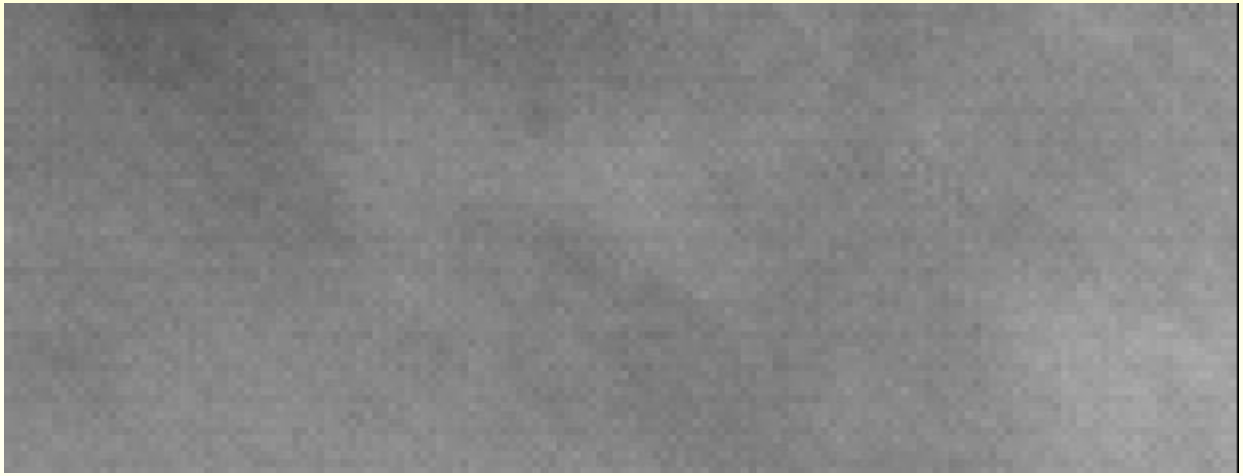
After Launch: PAN with CVT

※ PRNU+DSNU table for PAN, TDI set #1 Upload (2012.07.05)

Normalization (PRNU+DSNU)

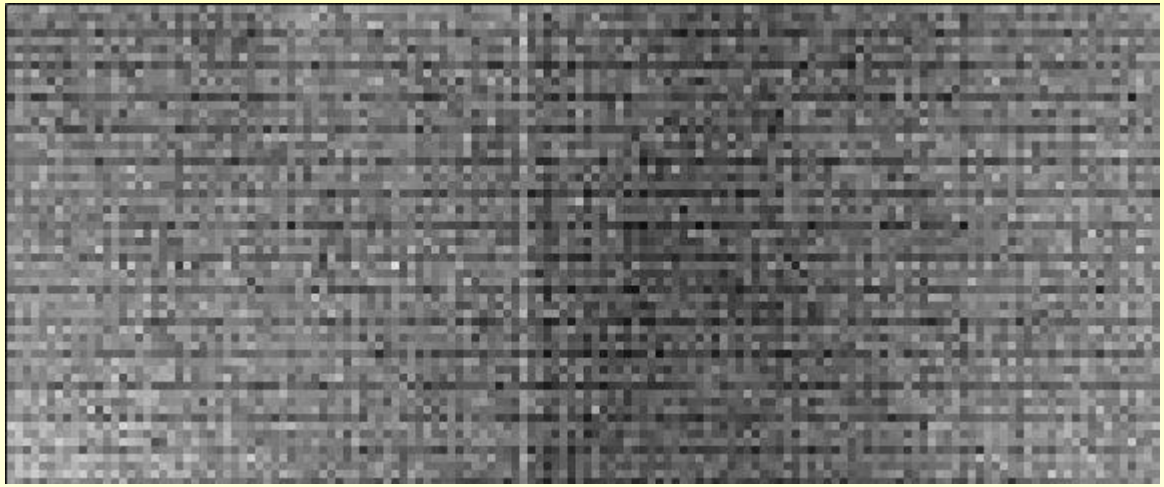


Before Launch:
PAN with Lab table

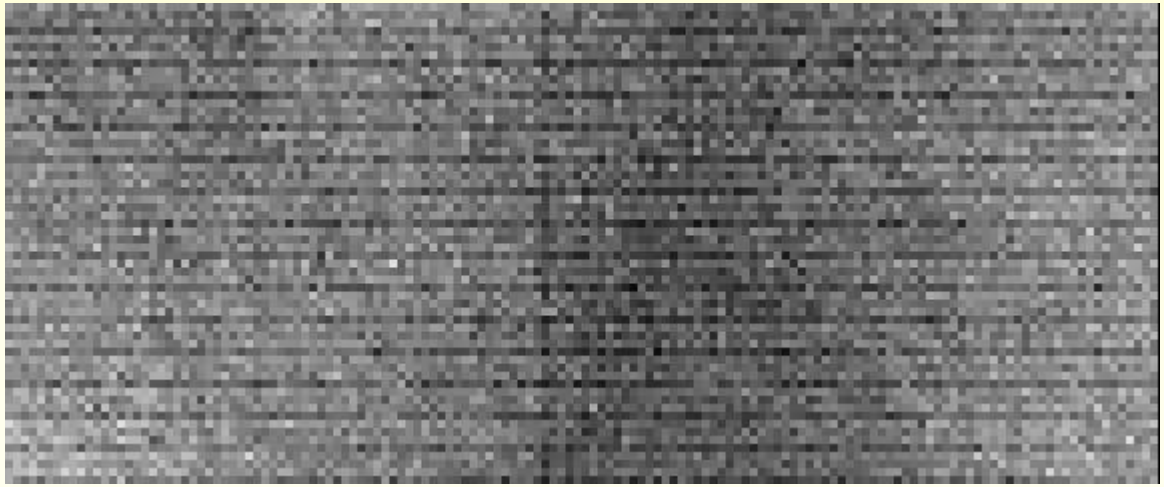


After Launch:
PAN with CVT

Normalization (PRNU+DSNU)



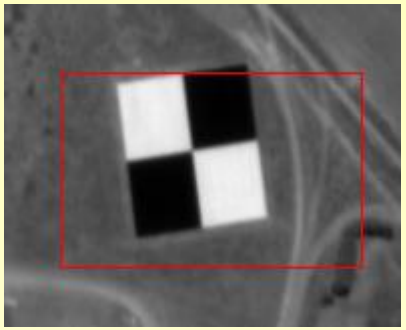
Before Launch:
PAN with Lab table

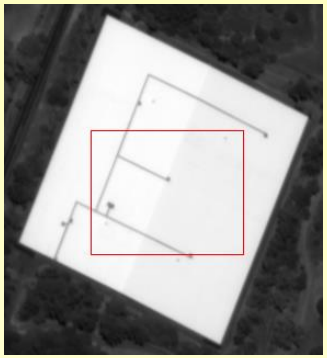


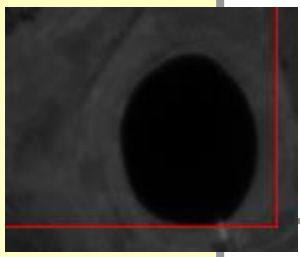
After Launch:
PAN with CVT

SNR

$$SNR = \frac{DN_Difference}{(Std_Dark + Std_Bright)/2}$$

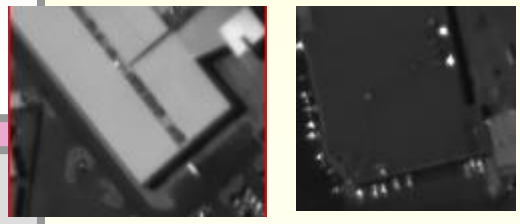




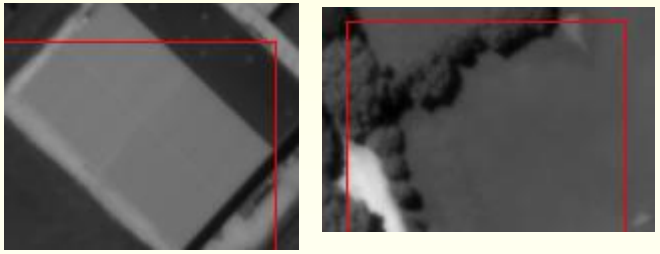


SF, USA

Target	SNR	Bright (DN)	Dark (DN)	Std.Dev
Edge target	179.4	8560	1830	23~54
SF, USA	353.1	13850	1100	14~60
Elpaso, USA	290.6	10600	4150	12~35
Salon, France	108.4	7500	3500	19~57



Elpaso, USA



Salon, France

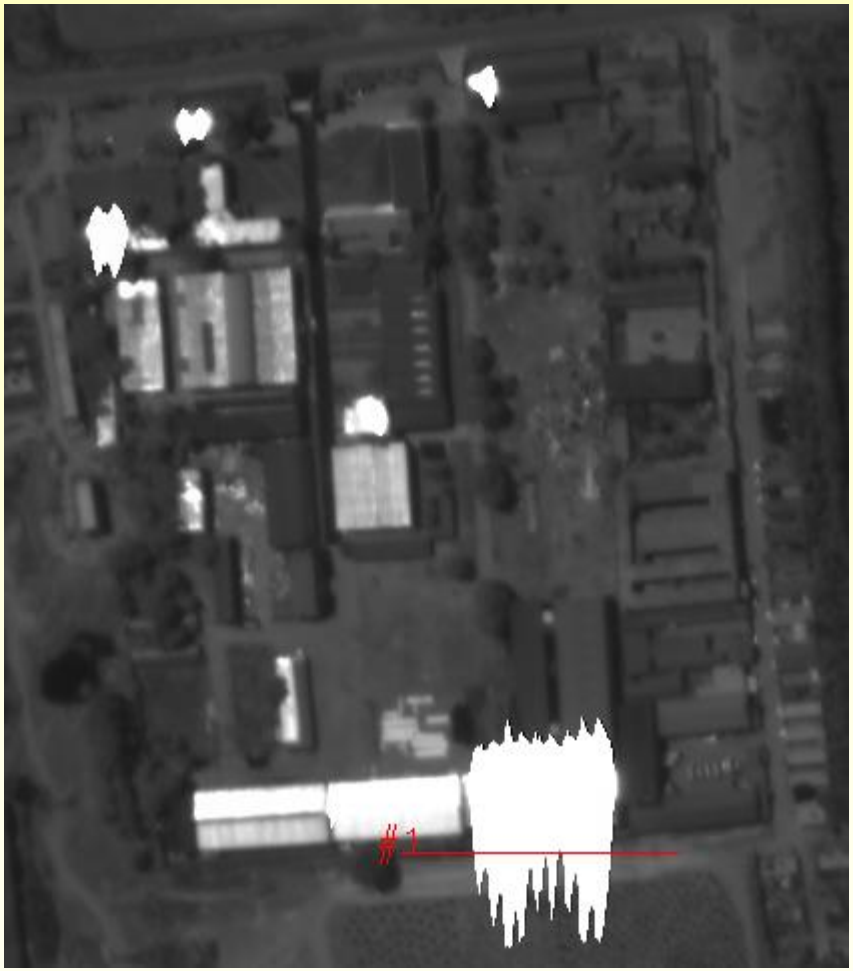
* SNR > 200 (PAN & MS)
* According to Condition of Target

Pattern(Coherent) noise

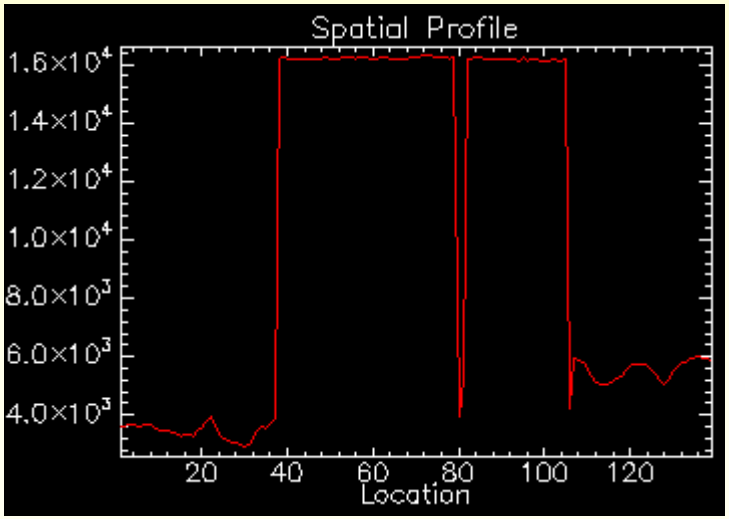
No.	Noise		No~!	PST	Reduced	Remark
1	Horizontal	Low				
2		4 line		O	O	(MM)
3		irregular			O	(MM)
4	Vertical	regular		O	O	(MM)
5		irregular			O	(MM + RNUC)
6	Diagonal	Two		O	O	(KSCA)
7	Pixel burst	Short		O	O	Only MS, (KSCA)
8		Long		O	O	Port difference, (KSCA)
9	Speckle noise		X	O	X	Only MS
10	First pixel noise			O	O	(MM)
11	Blooming		X	O	X	
12	Port DN difference			O	O	Pixel burst Long, (KSCA)

(MM) Modified Median filter
(KSCA) Algorithm by KARI Cal/Val team

Blooming



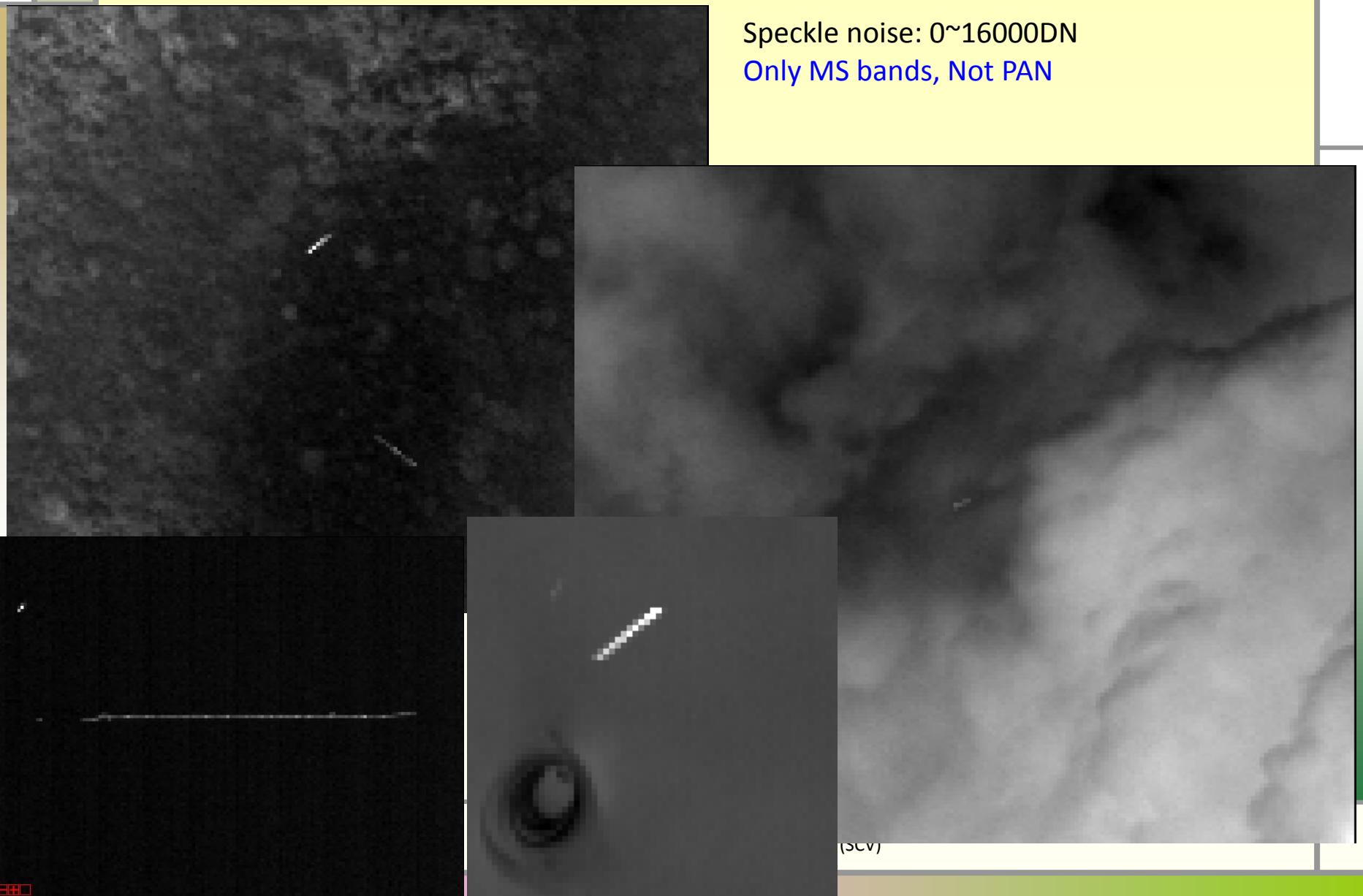
Beijing (2012.06.10)
PAN_4 (2377, 173000)



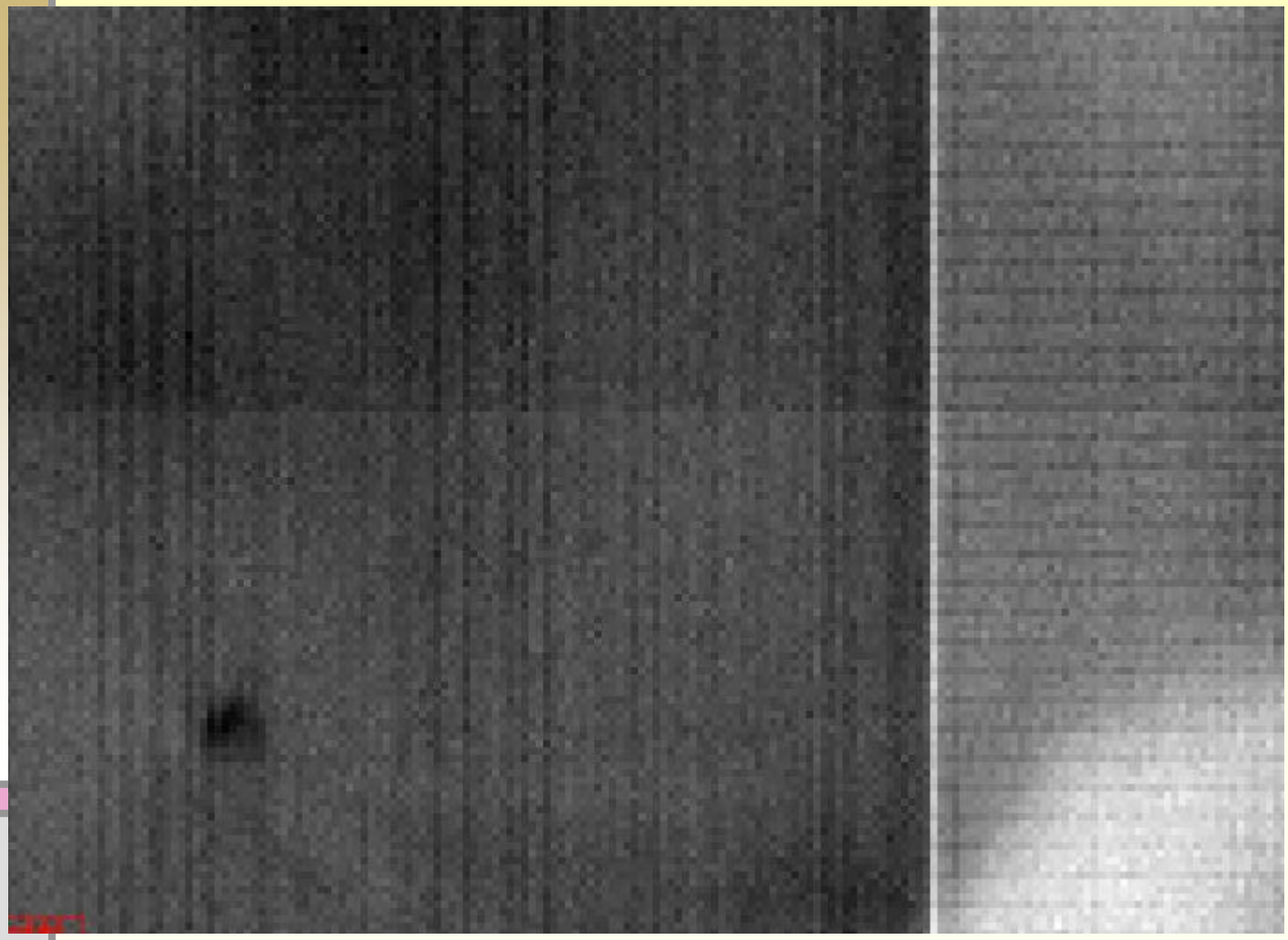
Speckle noise

Speckle noise: 0~16000DN

Only MS bands, Not PAN

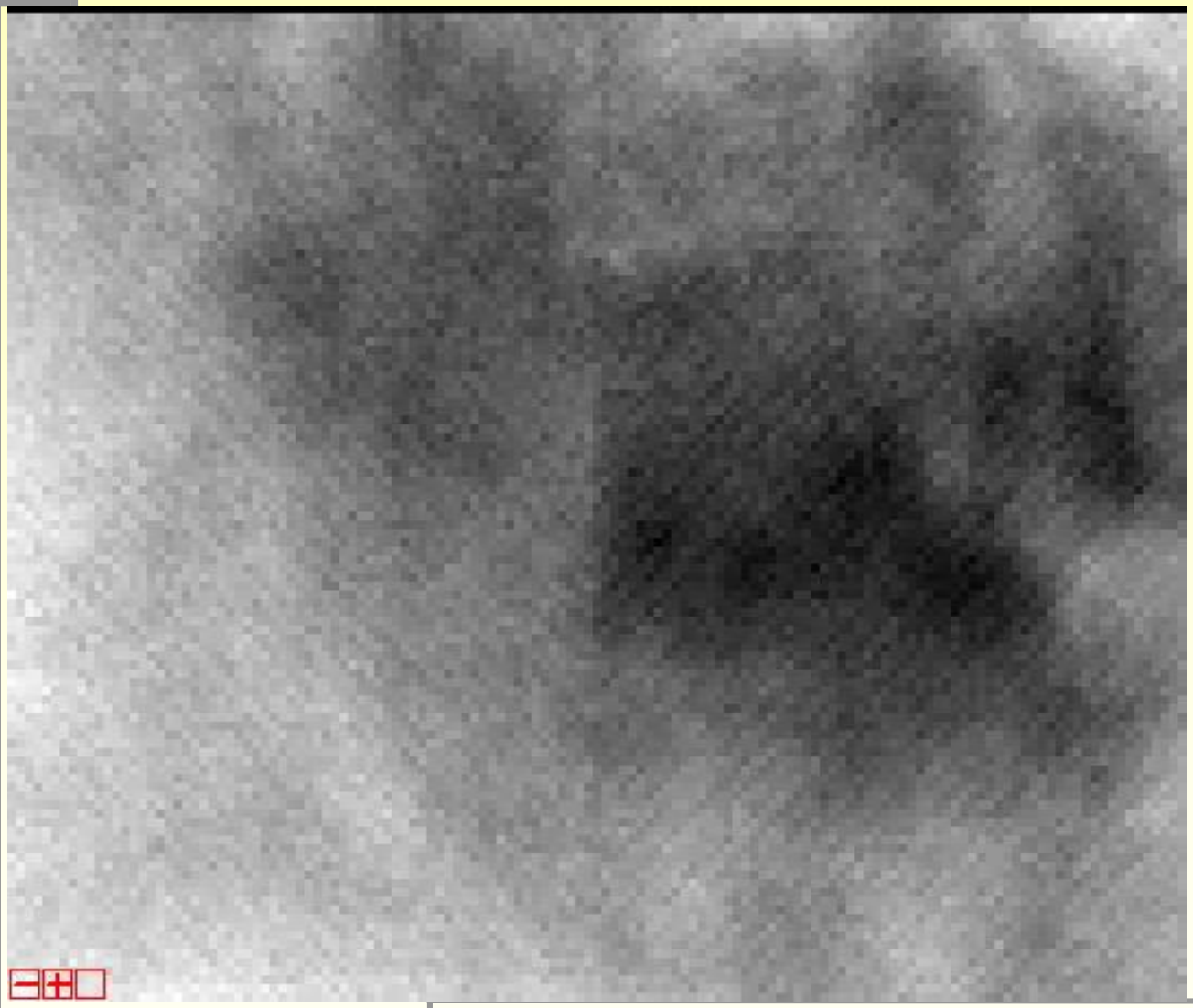


First pixel, Vertical, 4 line noise



PAN_R
2012.06.07
Saudi Desert, P2

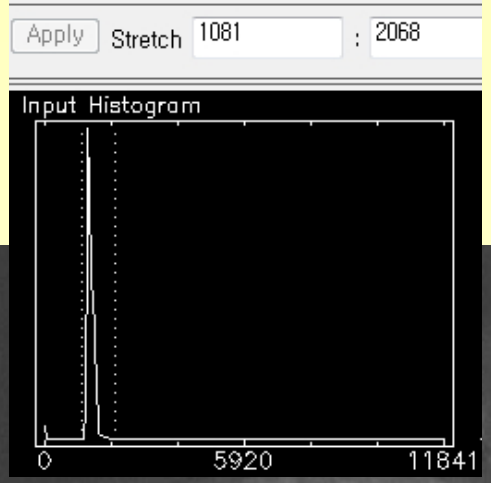
Diagonal noise



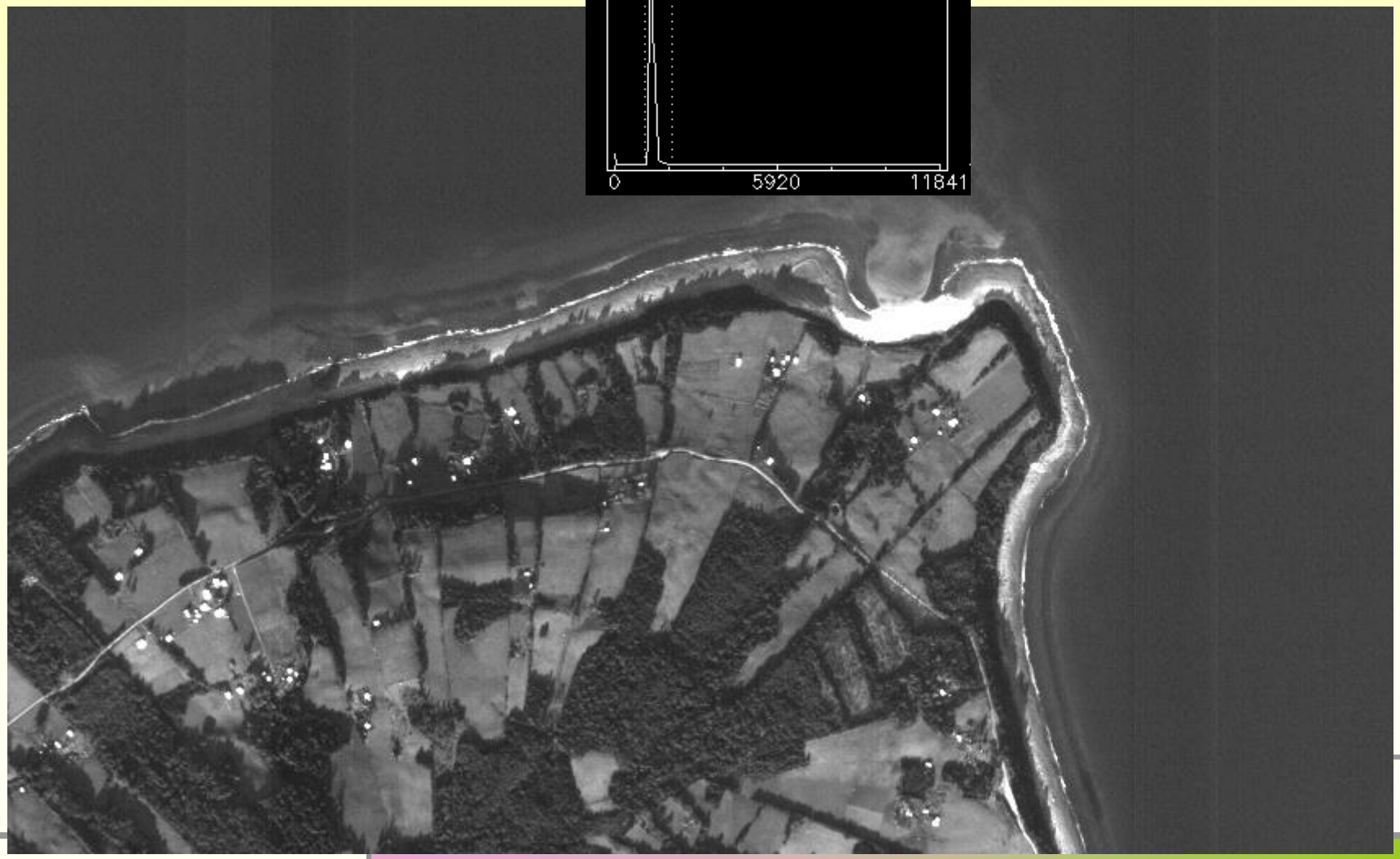
2012.07.06
MS2, Green

Pixel burst

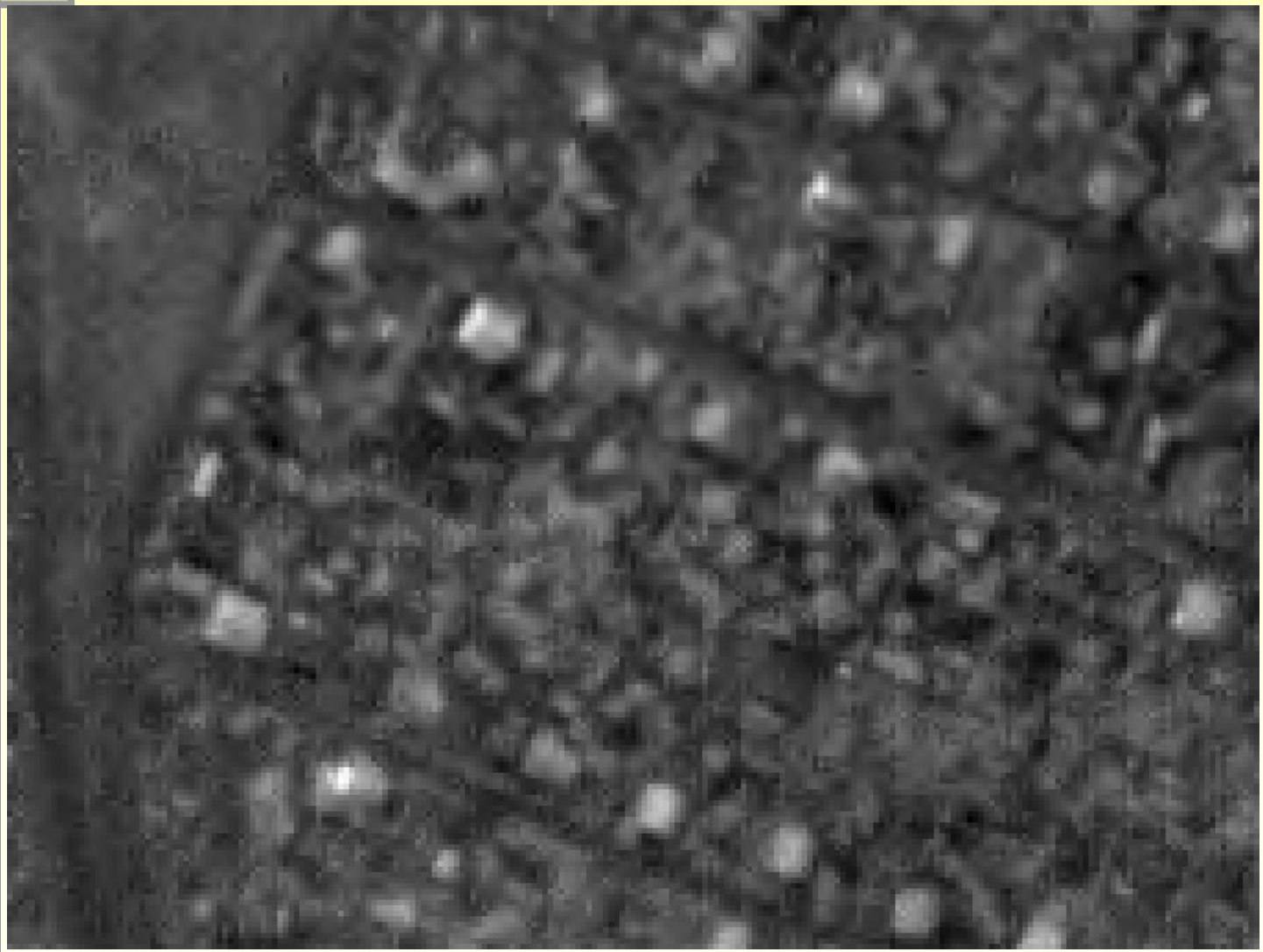
2012.06.15 (Blue), Lat: -42.425, Chile
Roll: -13.3



Only MS bands
Not PAN



Compression noise (8:1)



So, KOMPSAT-3 use ***"5.5"***

Image data Restoration: Reducing Noise

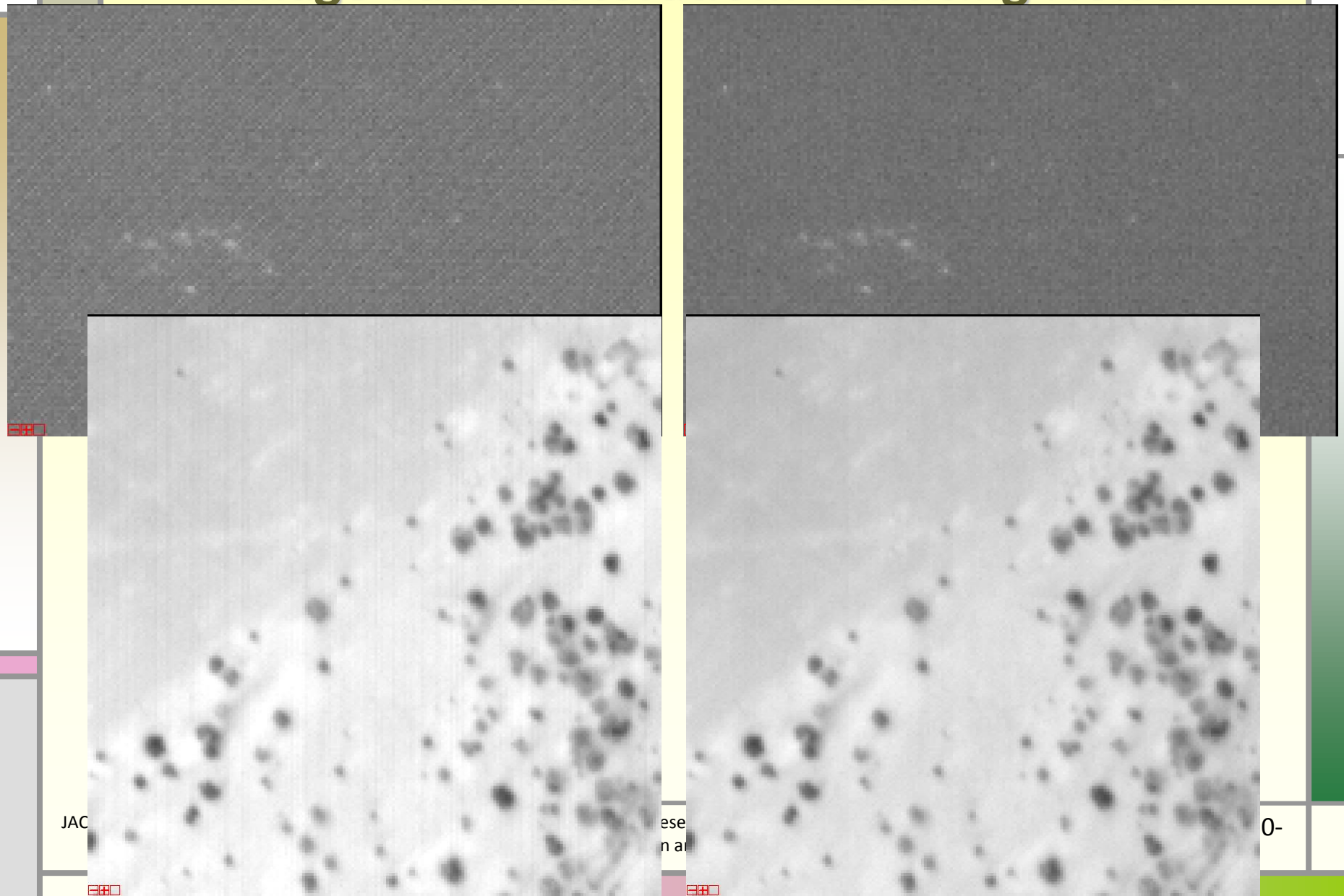
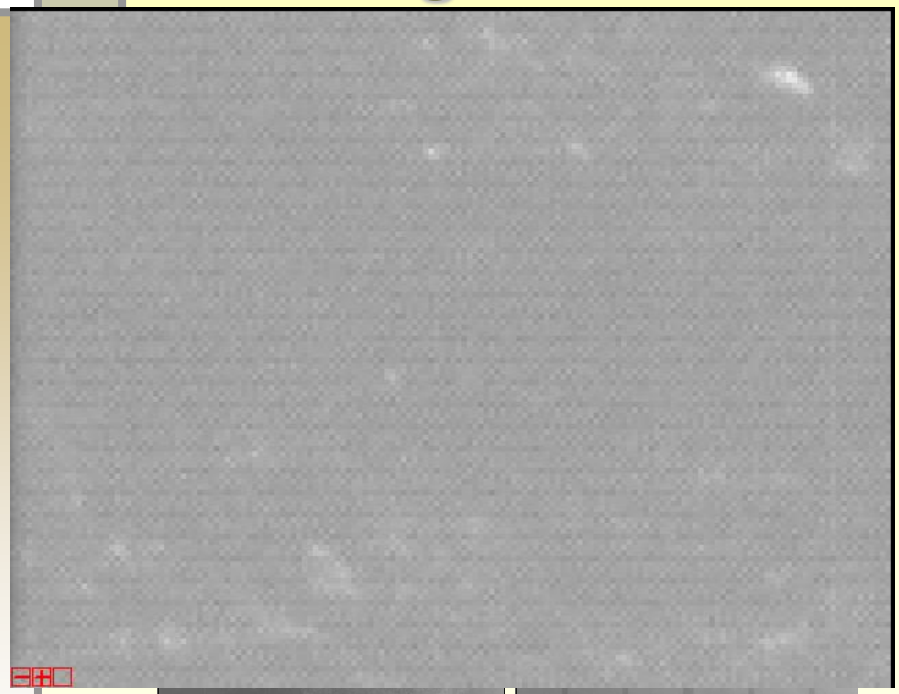
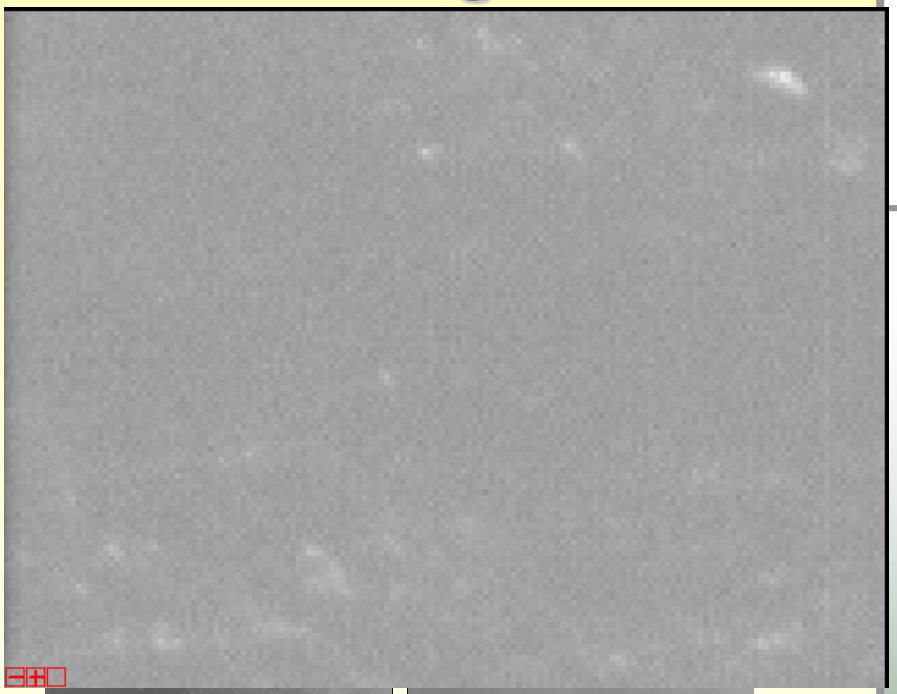
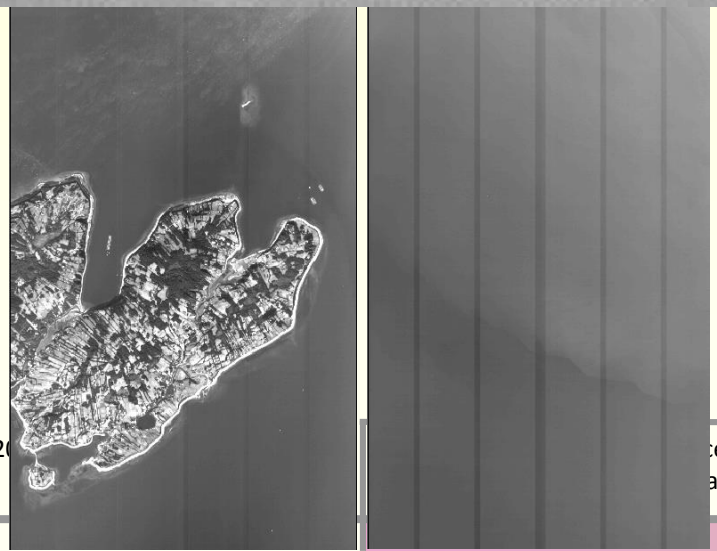


Image data Restoration: Reducing Noise

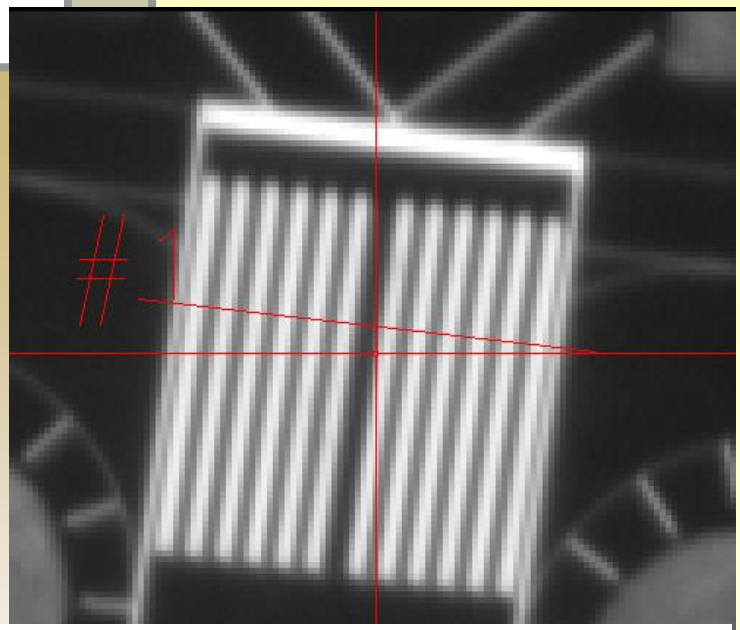


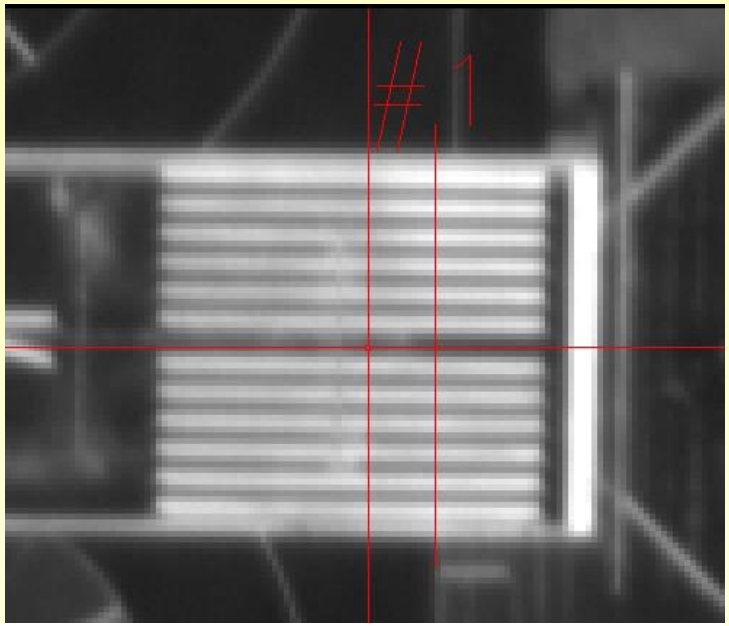




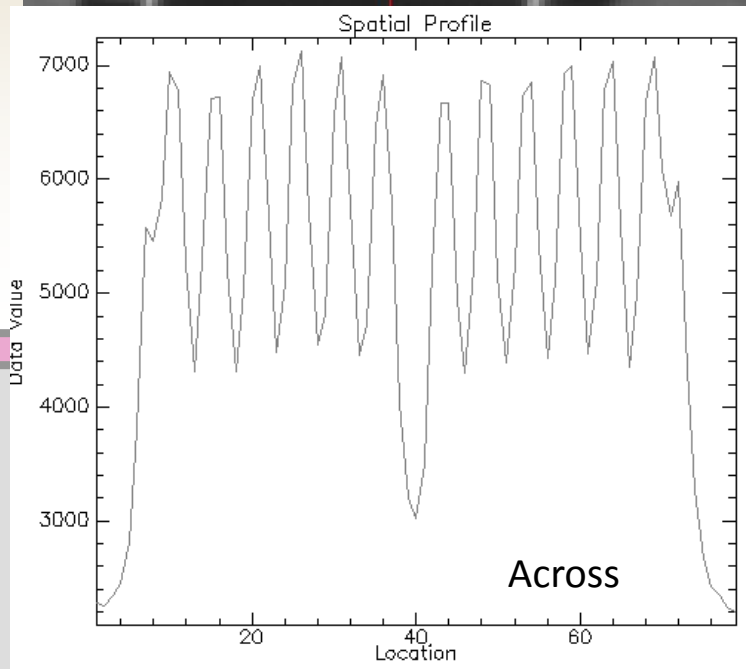
Spatial Cal/Val for KOMPSAT-3

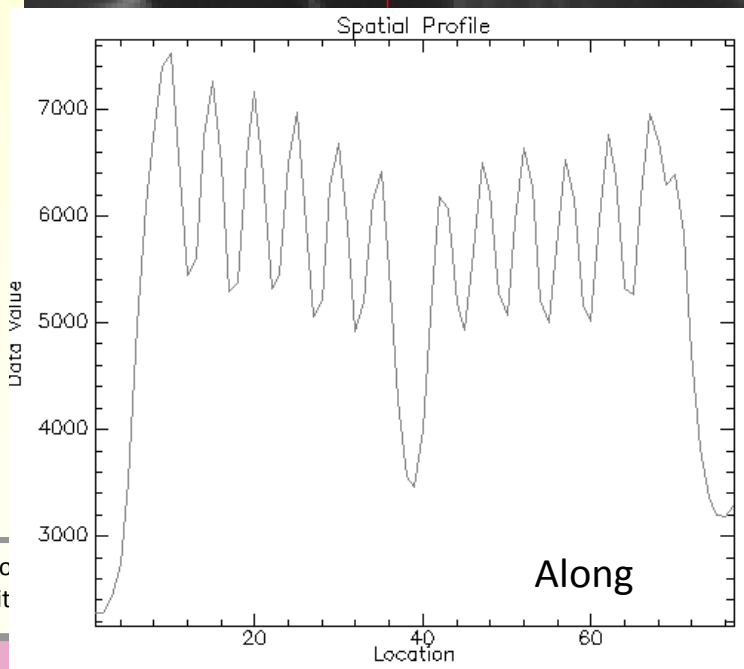
Across & Along





2012.05.29
Philadelphia airport
PAN_4

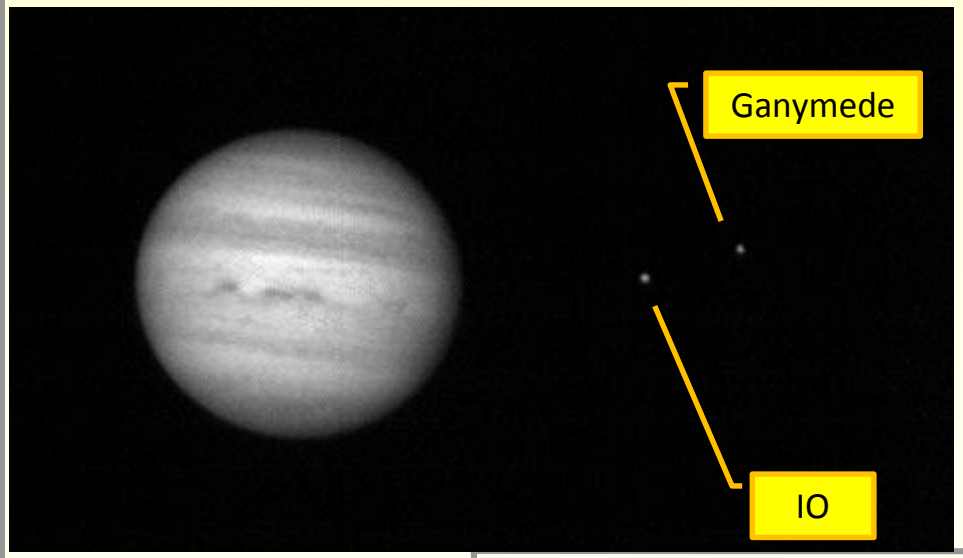




POSTER for Spatial Cal/Val

Please Read the Poster

(028)
"Focusing and MTF Compensation
for KOMPSAT-3 Calibration & Validation"



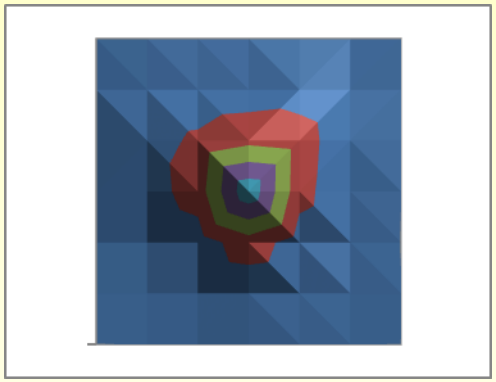
Jupiter~!
2012.07.18, PAN_3

Concept of MTF Compensation (MTFC) (@Poster)

- **Purpose and Necessity of MTF Compensation**
  - Restoration of the distortion of the image data from the Sensor deviation.
  - Enhancement of the sharpness of the image data
  - But, increase the Noise and get the other distortion; Ringing, etc.

- **Highlight the only information in Image data**
  - But, must not distort the information.
  - Change, Remove, Add (X)

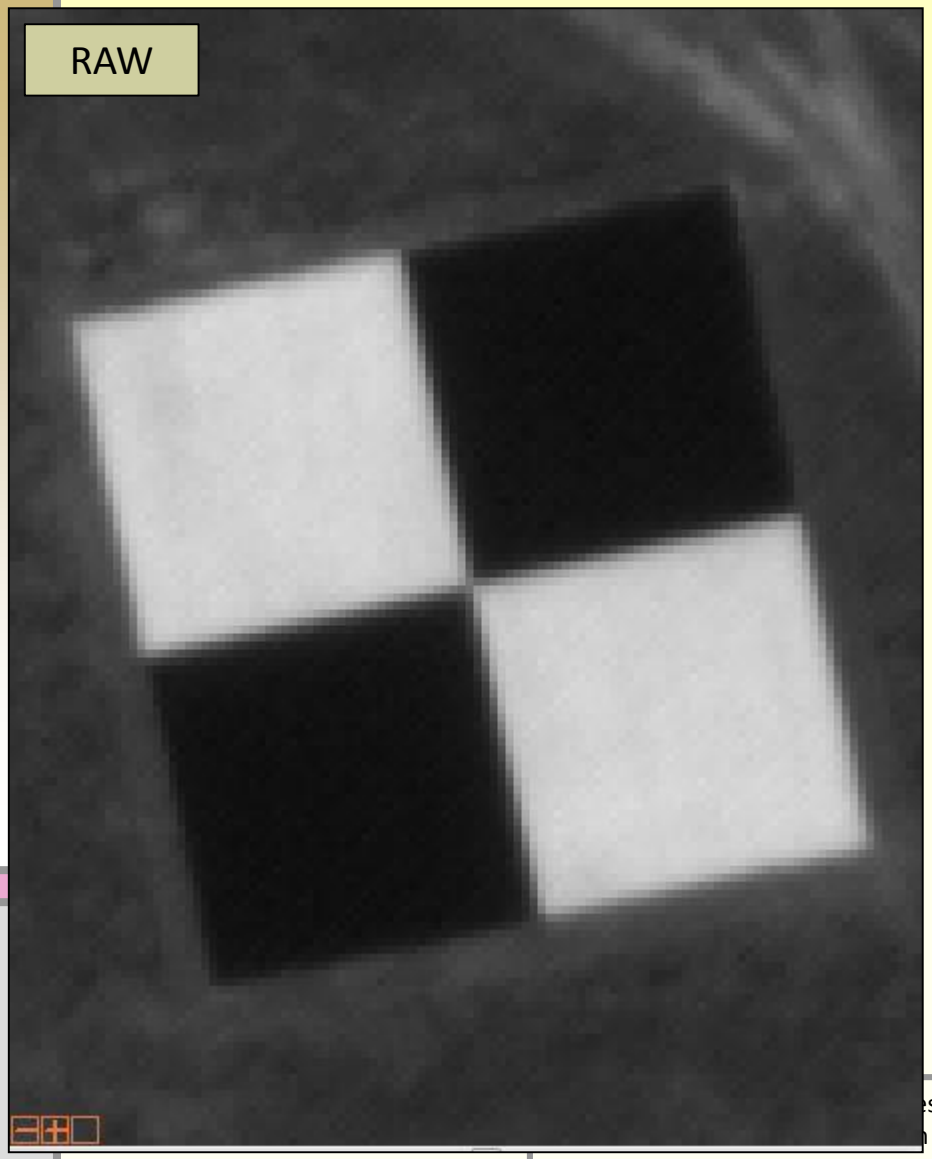
- **Suppress the Noise against MTFC**
  - Match the MTFC with the De-noising filter
  - Don't read any information as the Noise.
  - Don't read any noise as the Information.

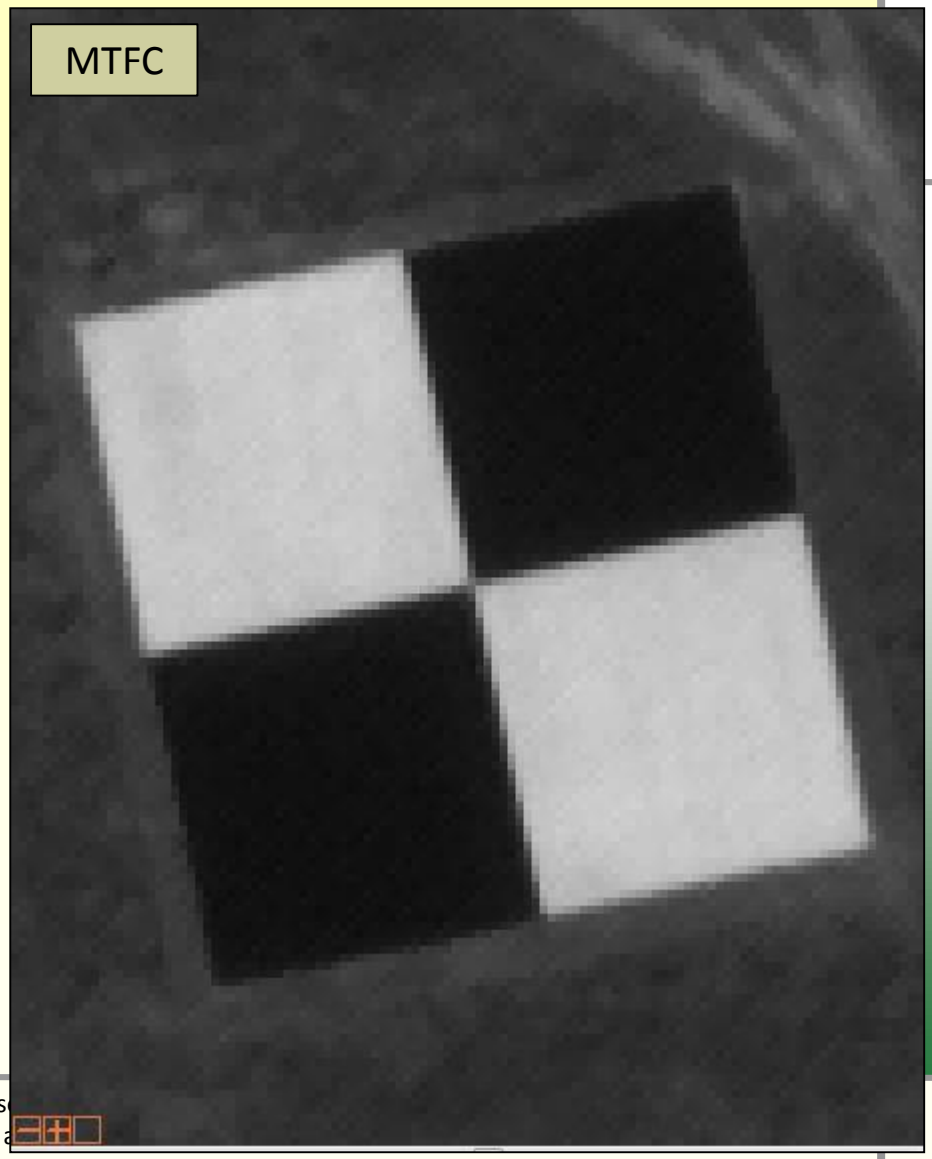


KOMPSAT-3 PSF from Star

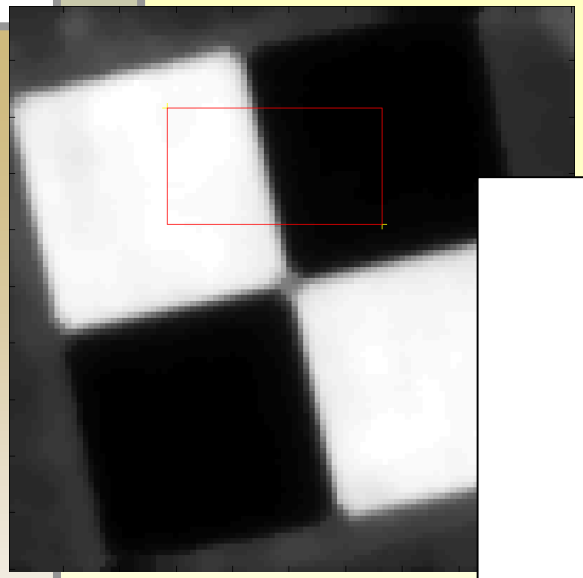
- **MTFC algorithm must have the specific character of the Sensor.**
  - PSF (Point Spread Function) has to be measured by the optimum method (Star).
  - Optimal MTFC algorithm (Wiener filter, Lucy Richardson, Sparse Prior, etc.)

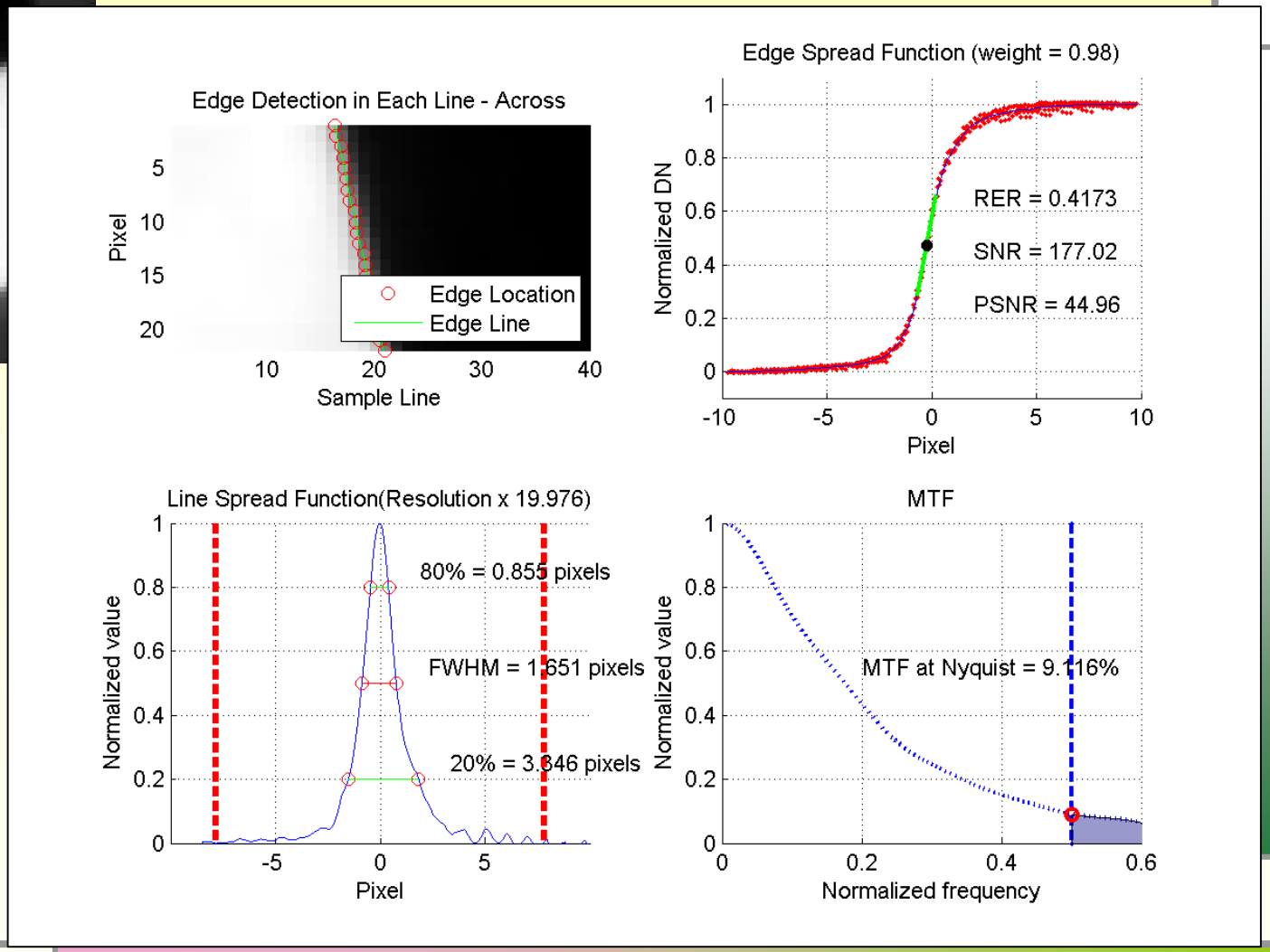
MTFC of KOMPSAT-3 (I like it~!) (@ Poster)





RAW image (Across) (@ Poster)

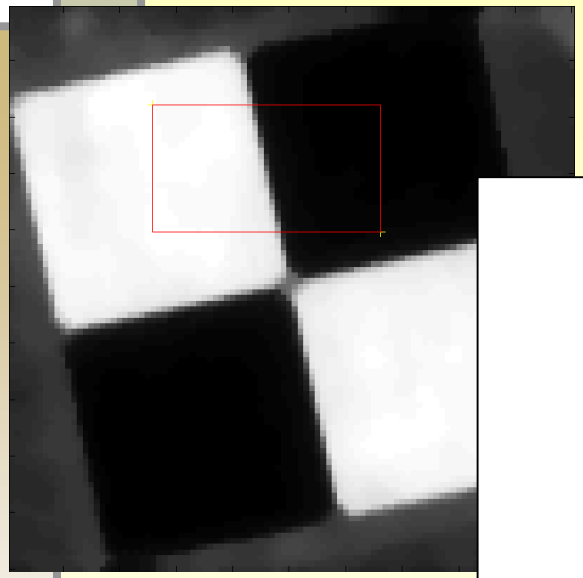


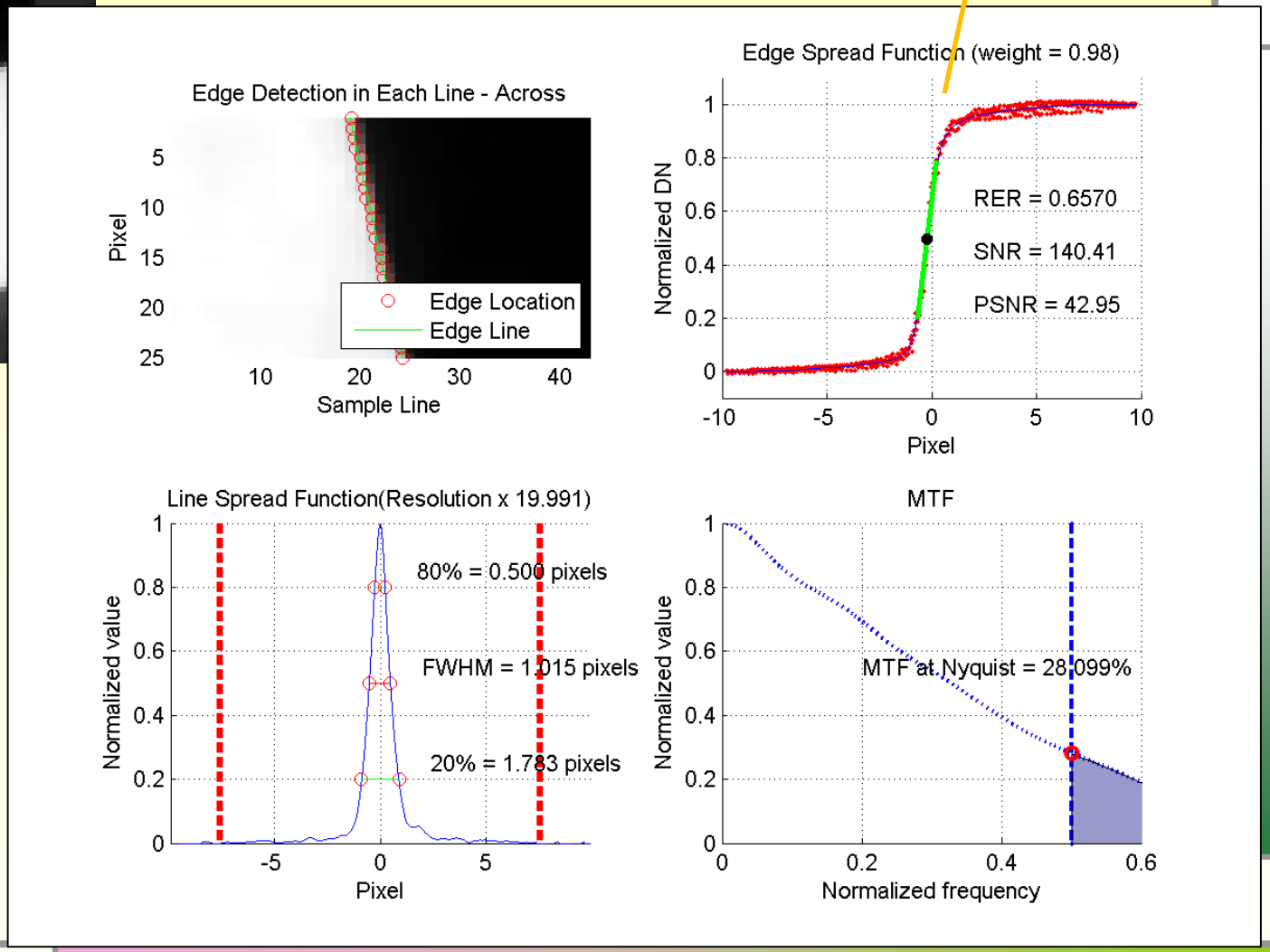


JACIE (2014)

MTFC image (Across) (@ Poster)

No Ringing~!





JACIE (2014)

De-Noised

< Dynamic Range=2405(732~3137)DN, impulsive range=50 DN, PSNR=33.64dB >

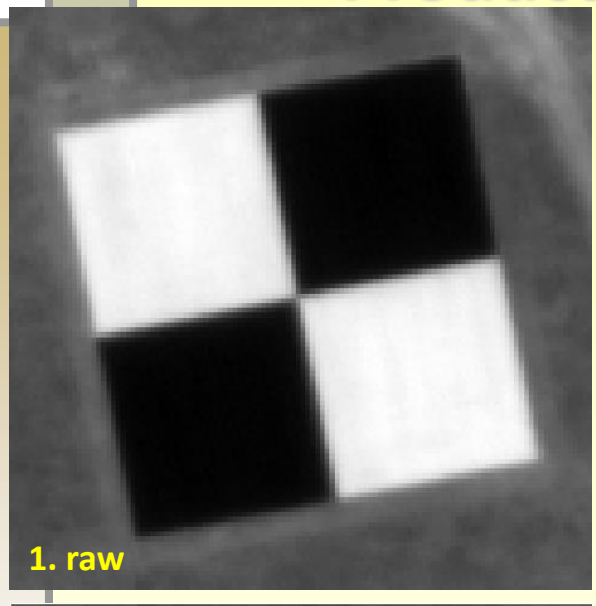
MTFC & No De-Noised

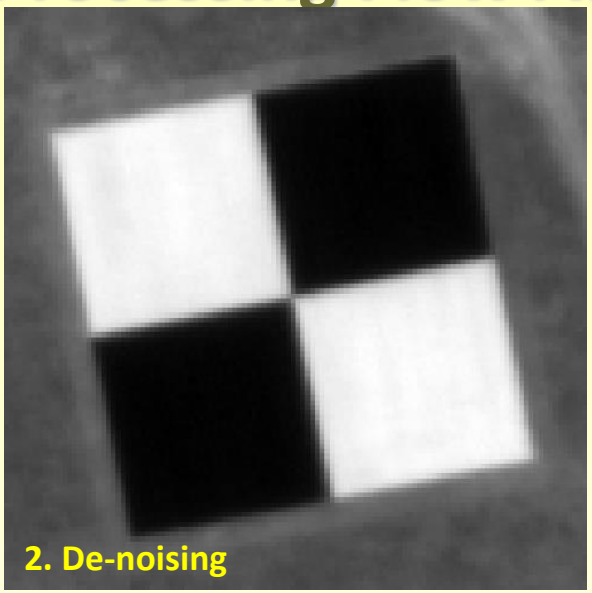
<Dynamic Range=2405(732,~137)DN, impulsive range=127 DN, PSNR=25.54dB>

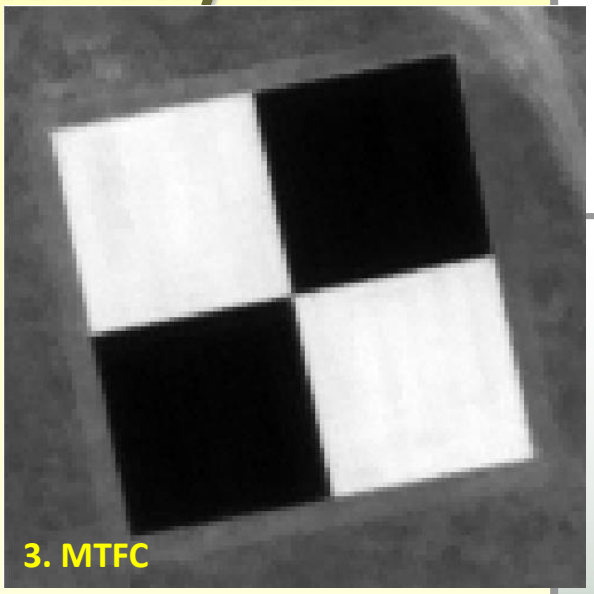
MTFC & De-Noised

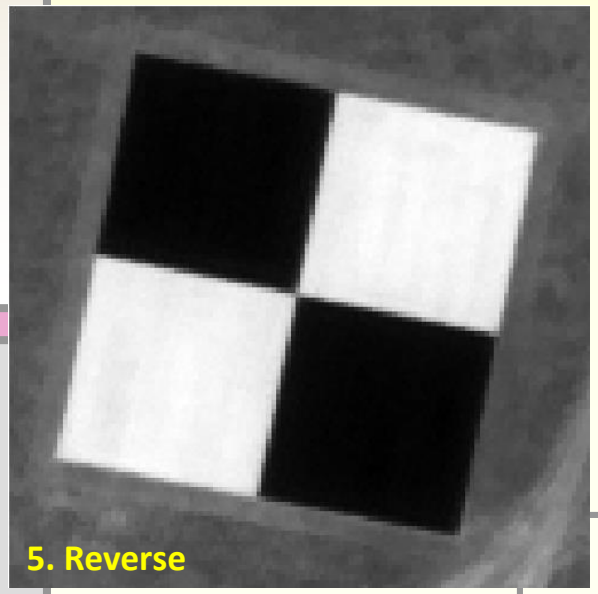
< Dynamic Range=2405(732~3137)DN, impulsive range=20 DN, PSNR=41.60dB >

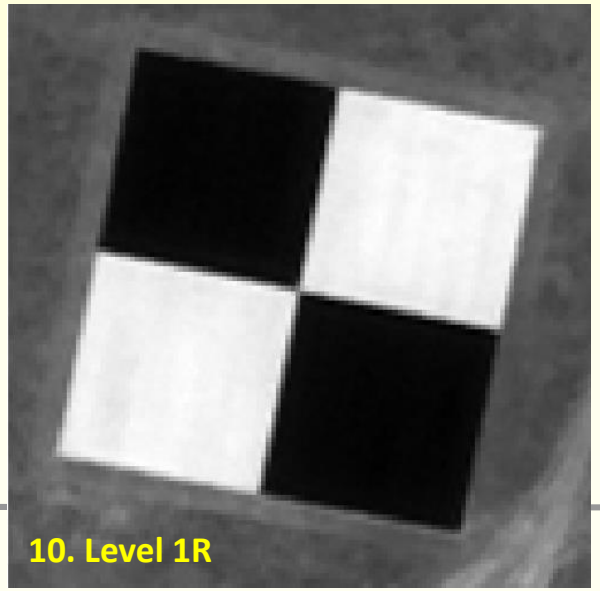
Product Processing Flow After Cal/Val

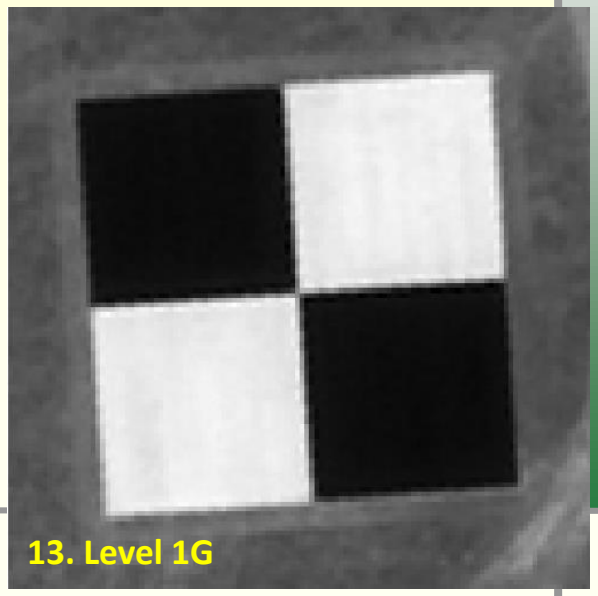












MTFC image

MTFC image

KOMPSAT-3, San Francisco (before Cal/Val), 2012.08.10

Geometric Cal/Val for KOMPSAT-3

Presentation for Geometric Cal/Val

Please the Next Presentation

(035)
"Overview of KOMPSAT-3
Geometric Calibration and Accuracy"

KOMPSAT-2 vs. KOMPSAT-3

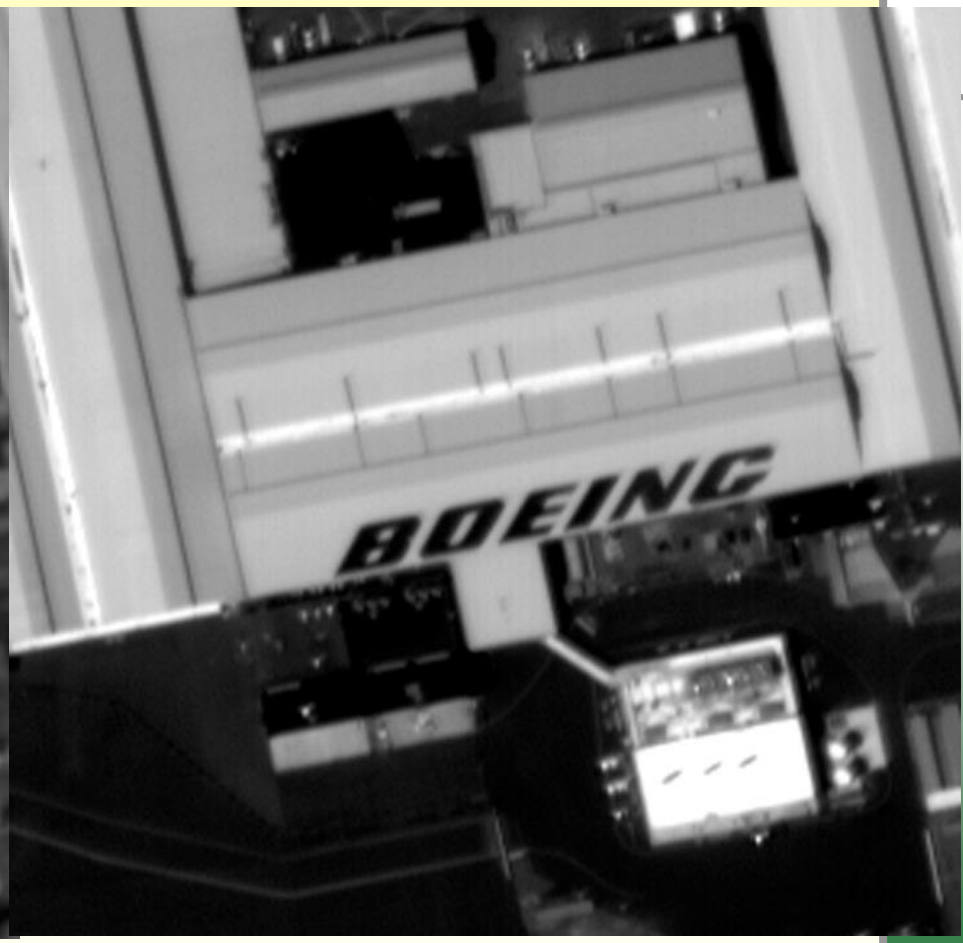
K2 & K3 image data Quality

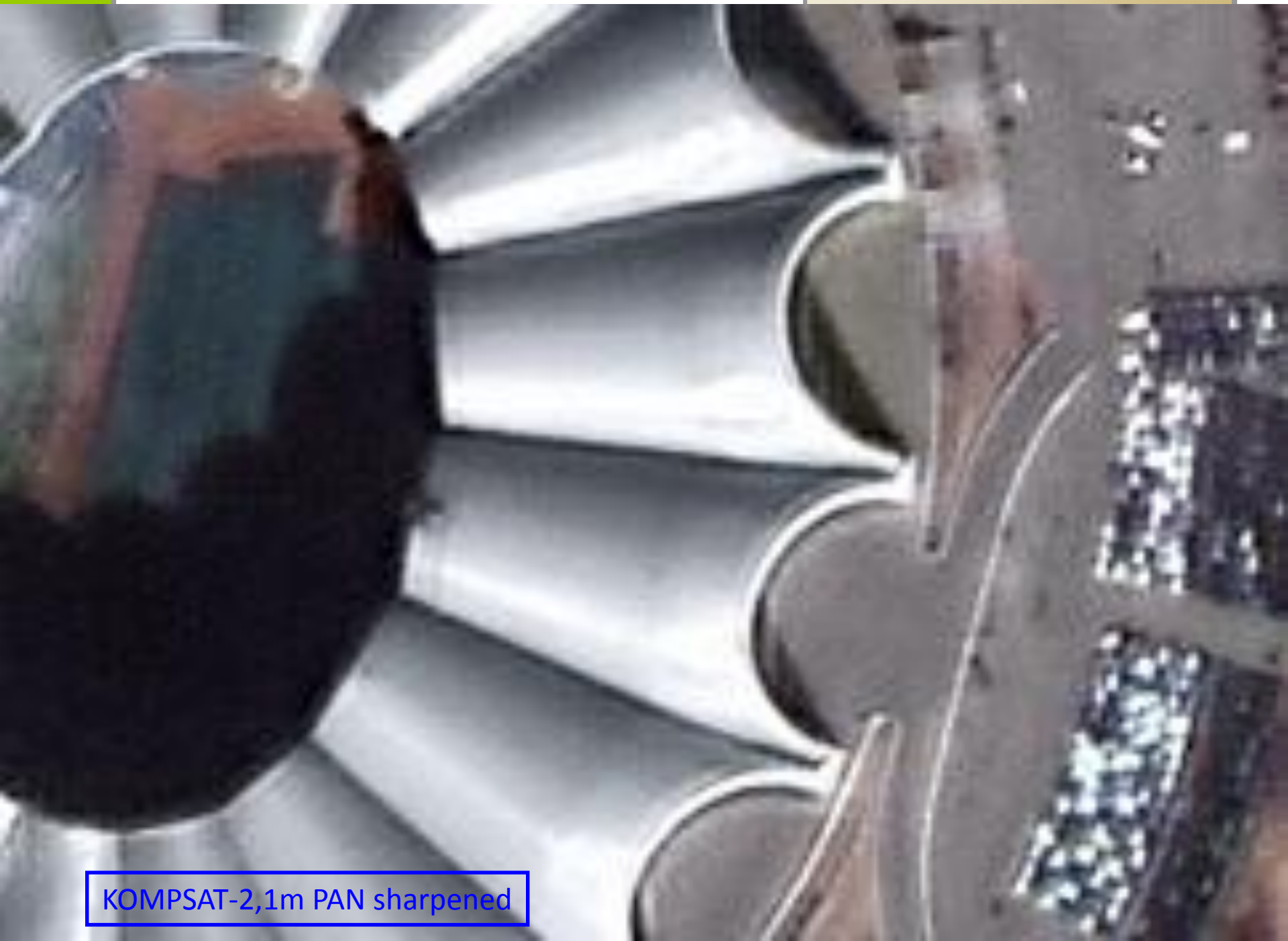
	KOMPSAT-2 Design	Requirement from user	KOMPSAT-2 (Now)	KOMPSAT-3 after Cal/Val
GSD (PAN)	1m	1m	1m	0.7m
MTF	8%	8%	6%	(8)~10%
MTFC			10~12%	13~20%
SNR (Noise)	>100 (<1%)	>100 (<0.2%)	>100 (<0.2%)	> 200
Radiometric resolution	10bit (1024)	10bit (1024)	10bit (1024)	14bit (16384)
Dynamic range		200	200	
Linearity	4% (10~90%)	<1%	1% (15~90%)	< 1% (5~95%)
Location without GCP	80m CE90	80m CE90	< 80m CE90	< 70m CE90
Mapping (Ortho)	25.4m CE90	5m CE90 (Planimetric)	1:5,000~10,000	1:5,000
Length distortion	< 2% (300pixel)	< 2pixel	< 2pixel	< 2pixel
Registration	±0.3pixel 2σ	0.5pixel 3σ	0.5 pixel 2σ	0.5 pixel 2σ
Imaging mode	Strip		Strip	Strip+Multi+…

Compare of Design for image: K2 & K3

	KOMPSAT-2	KOMPSAT-3	Image data Quality
Star Tracker Location	BUS Frame	Optical Bench	Geometric
Solar Panel	Driving Wing (2)	Static (3)	Geometric
Time Sync.	GPS receiver Local time	UTC	Geometric
Compression	Jpeg like	Wavelet	Radiometric (Noise)
Imaging mode	Strip	Strip+Multi+Stereo	Geometric
CCD	Butting zone	Overlap zone	Geo & Radio
Focal length	Bi-Focal	Uni-Focal	Geometric
PAN : MS	On Each frame	On One frame	Geometric
Radiometric resolution	10bit	14bit	Radiometric
X-band Trans Ant.	9°	15°	Geometric
Spectral band (PAN)	510 ~ 900nm	450 ~ 900nm	Application
NUC table loading	HDD	Memory	Operation
NUC	Analog	Digital	Radiometric

KOMPSAT-2 vs. KOMPSAT-3




KOMPSAT-2,1m PAN sharpened

KOMPSAT-3, 0.7m PAN sharpened

Quality of KOMPSAT-3 Product

Quality of K3 Product (Draft)

Please the Next Presentation

(029)
"Definition of KOMPSAT-3 product Quality"

Thank you for KOMPSAT~!