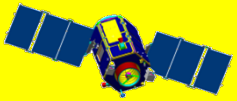

KOMPSAT-1


KOMPSAT-2


KOMPSAT-3


KOMPSAT-5


KOMPSAT-3A

KARI 한국항공우주연구원

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# Calibration and Validation, and Image data Quality for KOMPSAT-3

September 30, 2014

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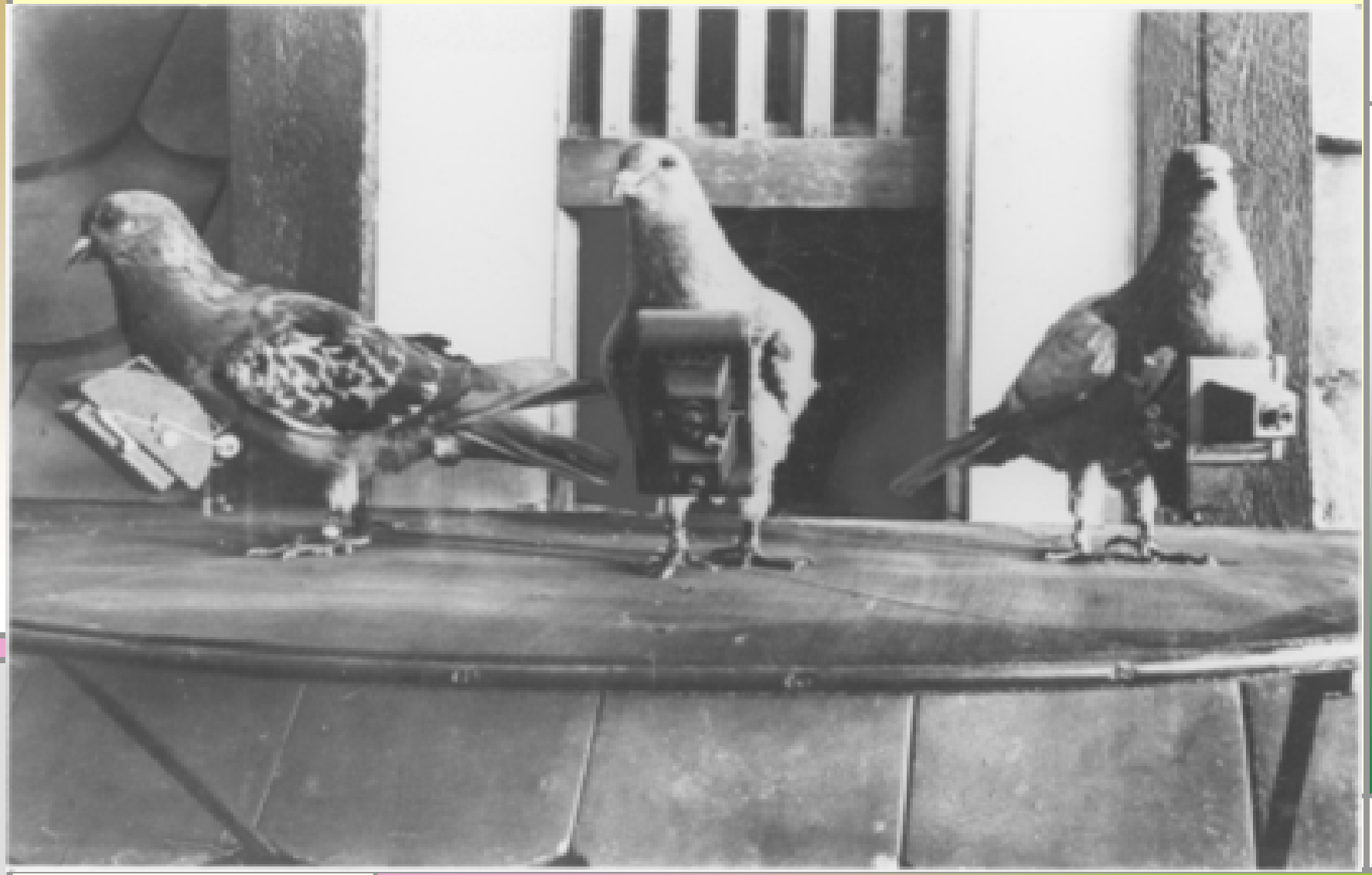
# Mom~! & Dad~!
# of Artificial Remote Sensing Satellite



# Agenda

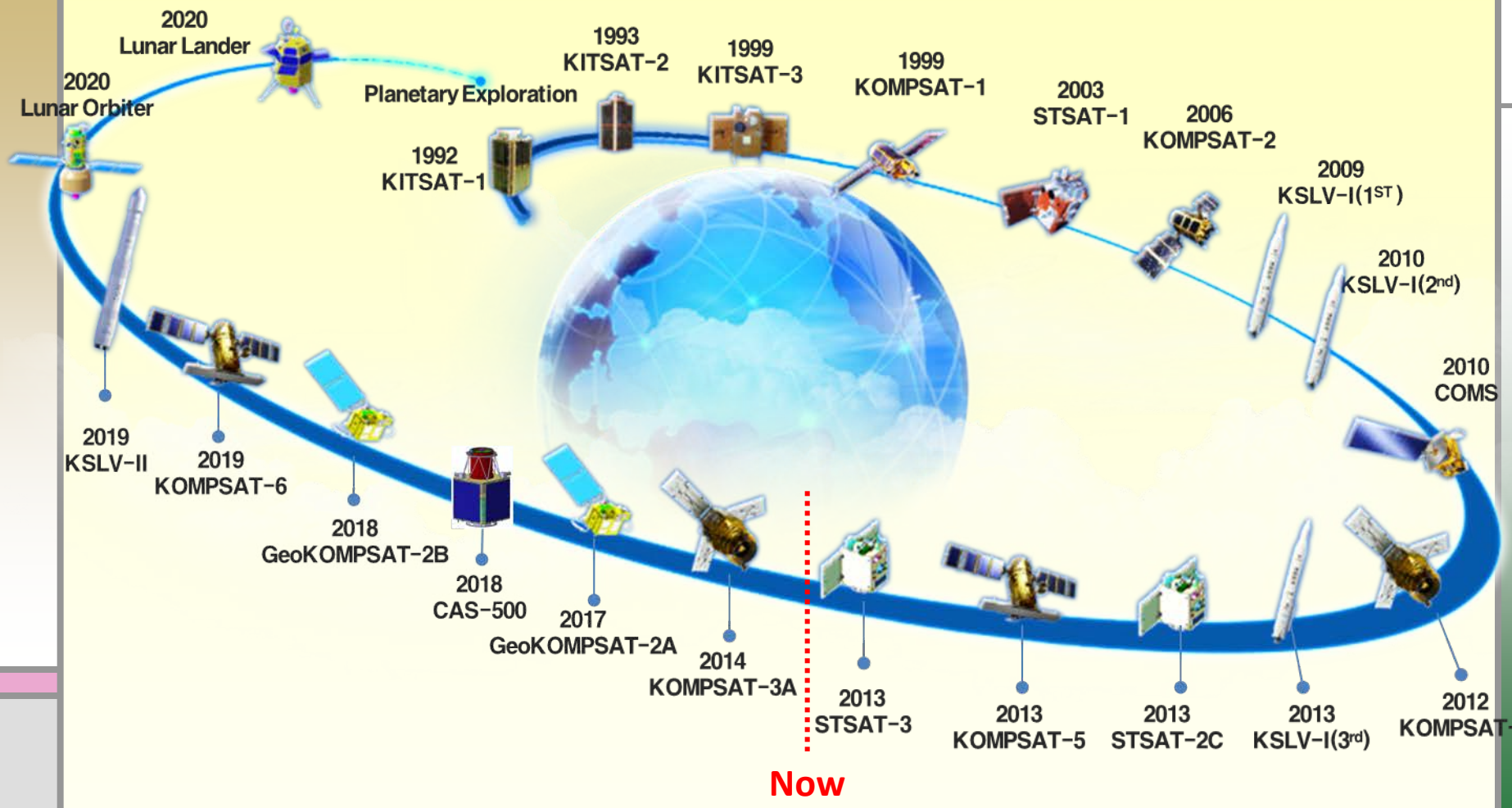
## KOMPSAT-3 Calibration and Validation

KOMPSAT-3 Image data Quality

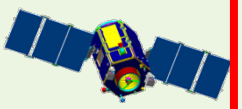
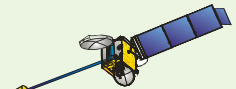
# KOMPSAT Program in KARI

# KOMPSAT-3 Cal/Val

# Space Program in Korea



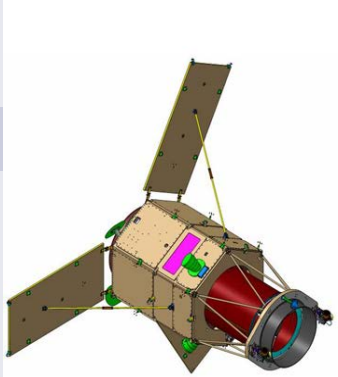
# KOMPSAT Program in KARI

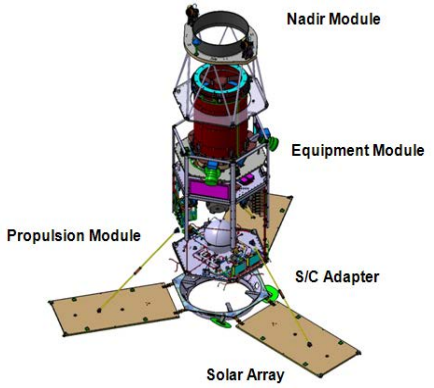
| | KOMPSAT-1 | KOMPSAT-2 | KOMPSAT-3 | KOMPSAT-5 | COMS | KOMPSAT-3A |
|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |
| Payload | EOC, OSMI | MSC | AEISS | COSI | MI, GOCI | KISS |
| | Visual | Visual | Visual | SAR-X | Meteorology | Visual+MWIR |
| Launch | 1999~2008 | 2006~ | 2012.5~ | 2013.7~ | 2010~ | 2014.OO |
| Performance | 6.6m (EOC)<br>1km (OSMI) | 1m, 4m<br>10bit | 0.7m, 2.4m<br>14bit | 1m, 3m<br>X-band | 500m | 0.55m, 2.2m<br>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 | Sun-Sync | Sun-Sync | Sun-Sync | Sun-Sync | Geo-Station | Sun-Sync |

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

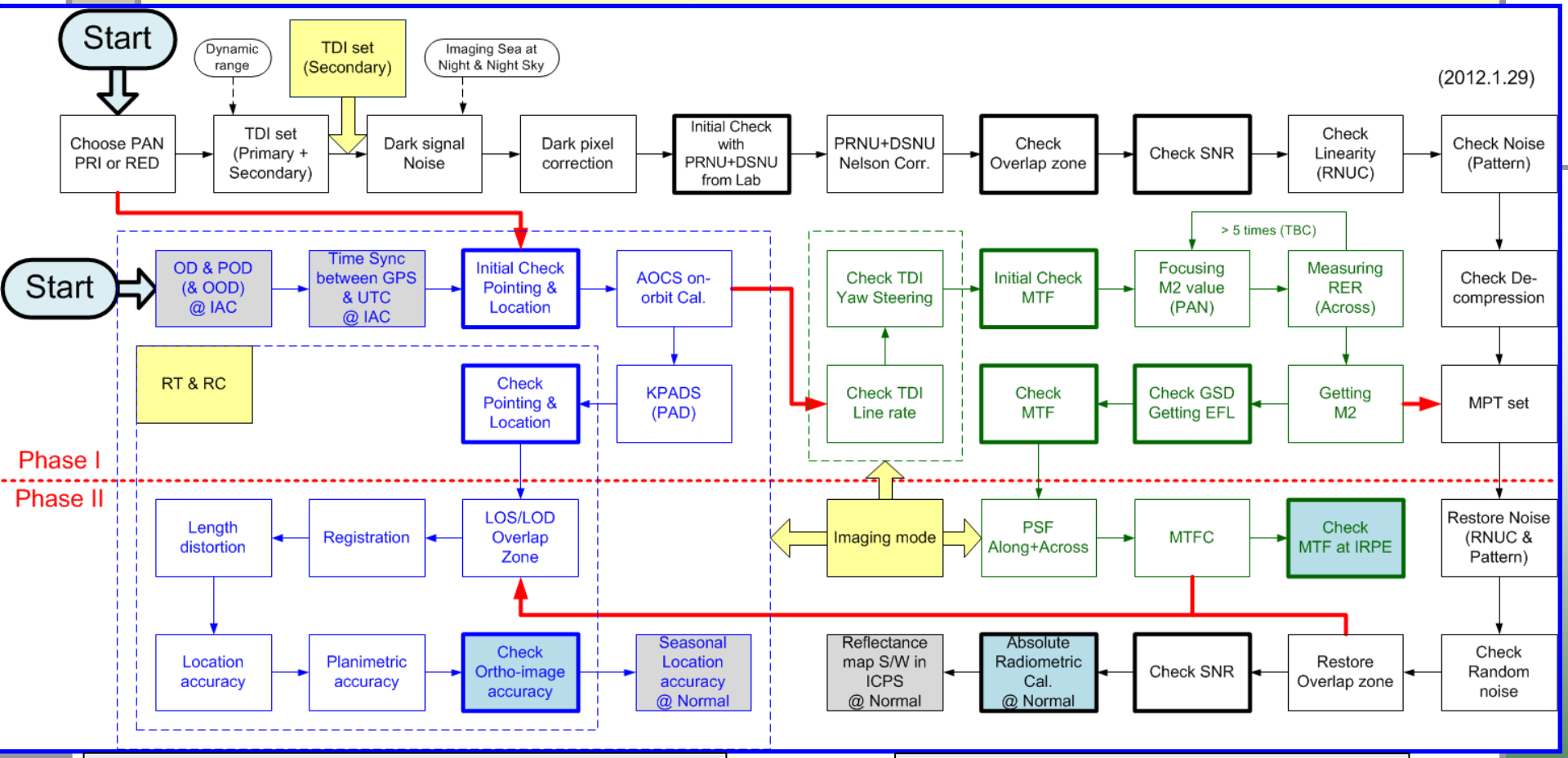
# KOMPSAT-3 Overview

| | |
|---|---|
| Ground Sampling Distance | (PAN) 0.7 m @altitude 685km(nadir)<br>(MS) 2.8 m @altitude 685km(nadir) |
| Swath Width | 16 km (nadir) |
| Spectral Bands | PAN : 450 ~ 900 nm<br>MS1 (Blue) : 450 ~ 520 nm<br>MS2 (Green) : 520 ~ 600 nm<br>MS3 (Red) : 630 ~ 690 nm<br>MS4 (NIR) : 760 ~ 900 nm |
| Dynamic Range | 14 bits / pixel |
| Modulation Transfer Function | (PAN) 8%, (MS) 12% |
| Signal to Noise | > 100 |
| Location Accuracy | < 70 m CE90 ( < 30 m RMSE is expected) |
| Orbit | Sun Synchronous Orbit<br>• Altitude : 685.13 ± 1km<br>• Inclination : 98.14 ± 0.05 degree<br>• MLTAN : 13:30 +10/-15 min |





# 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

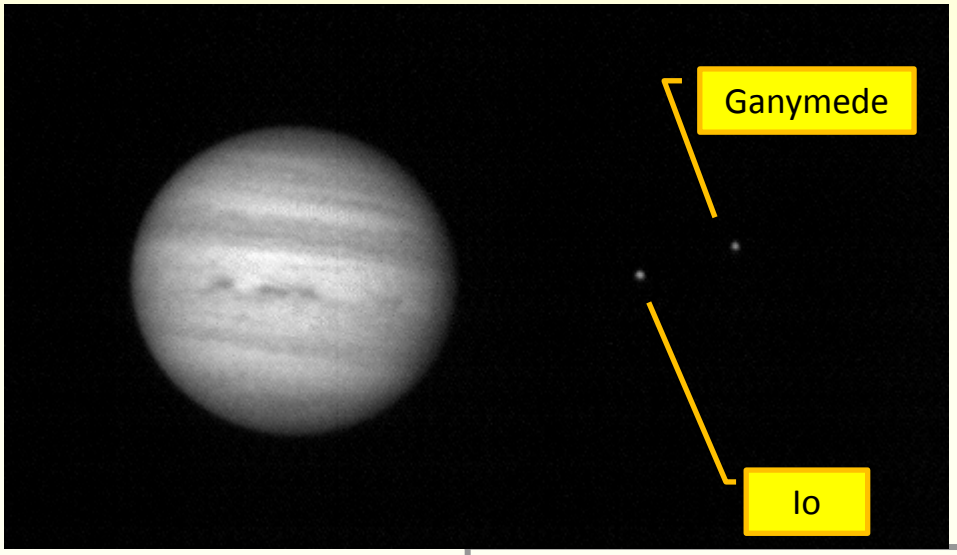
# Performance of KOMPSAT-3 after Cal/Val

| | Key Item | Requirement Value | Validated Value | Condition |
|---|---|---|---|---|
| Cal/Val Phase I | SNR | 100 | >> 100 (TDI 64) | |
| | MTF | 8%(PAN)<br>12%(MS) | Across: 8~10% (TDI 64)<br>Along: 6~8% (TDI 64)<br>> 19% (MS) | Strip imaging<br>Level 0 |
| | GSD | 0.7m(PAN)<br>2.8m(MS) | 0.7m (PAN) | Strip & Nadir imaging |
| | Pointing accuracy | 1.2km | Across: 90m<br>Along: 1 sec | Strip imaging |
| | Location accuracy | 70m CE90 | < 70m CE90 | With POD & PAD<br>Strip imaging |
| Cal/Val Phase II | MTF after MTFC | 13%(PAN)<br>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 |

# Radiometric Cal/Val for KOMPSAT-3

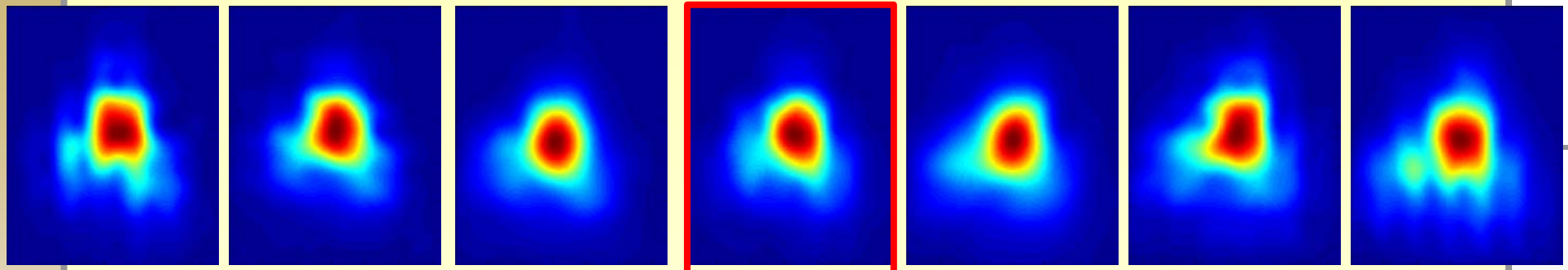
# Geometric Cal/Val for KOMPSAT-3

# Spatial Cal/Val for KOMPSAT-3




Jupiter~!
2012.07.18, PAN_3

# Focusing with Star image data



FMC = -1.0°C | FMC = -0.5°C | FMC = -0.2°C | FMC = 0.0°C | FMC = +0.2°C | FMC = +0.5°C | FMC = +1.0°C

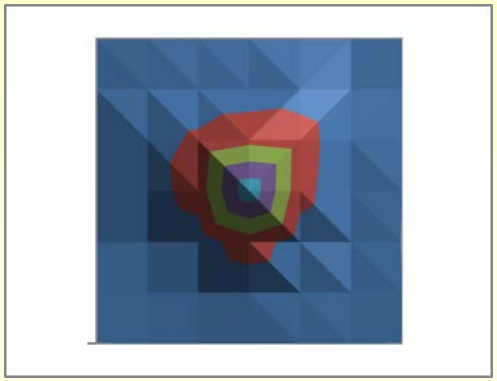
| FMC Temperature(℃) | | FWHM - Across | | | FWHM-Along | | | MTF(%) | |
|---|---|---|---|---|---|---|---|---|---|
| at Star | at Ground | 20% | 50% | 80% | 20% | 50% | 80% | Across | Along |
| -1.46 | -1.00 | 2.881 | 1.666 | 0.997 | 2.816 | 1.803 | 1.115 | 12.52 | 7.85 |
| -0.96 | -0.50 | 2.750 | 1.665 | 0.957 | 2.644 | 1.745 | 1.082 | 11.41 | 9.13 |
| -0.67 | -0.21 | 2.834 | 1.580 | 0.926 | 2.765 | 1.789 | 1.065 | 13.22 | 7.37 |
| -0.46 | 0.00 | 2.907 | 1.650 | 1.000 | 2.458 | 1.587 | 0.901 | 12.44 | 12.69 |
| -0.26 | 0.20 | 2.612 | 1.650 | 0.997 | 2.994 | 1.813 | 1.072 | 12.14 | 8.02 |
| 0.04 | 0.50 | 3.207 | 1.747 | 1.011 | 2.896 | 1.808 | 1.124 | 10.54 | 7.67 |
| 0.54 | 1.00 | 3.122 | 1.773 | 1.065 | 2.929 | 1.801 | 1.019 | 10.76 | 7.82 |

# Concept of MTF Compensation (MTFC)

- **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)

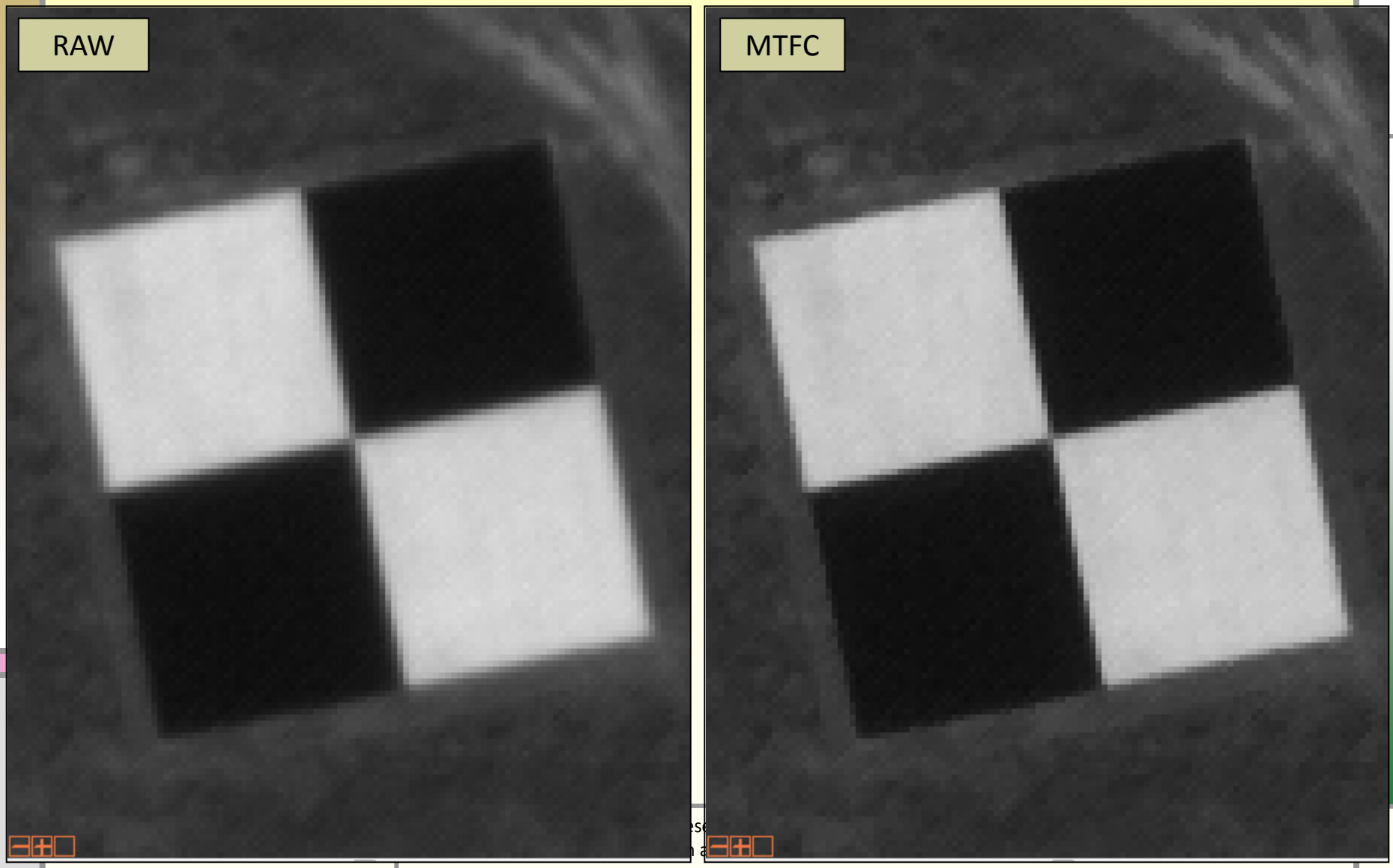
- **Suppress the Noise against MTFC**
  - Match the MTFC with the De-noising filter
  - Don't read any information as the Noise.
  - Don't read any noise as the Information.



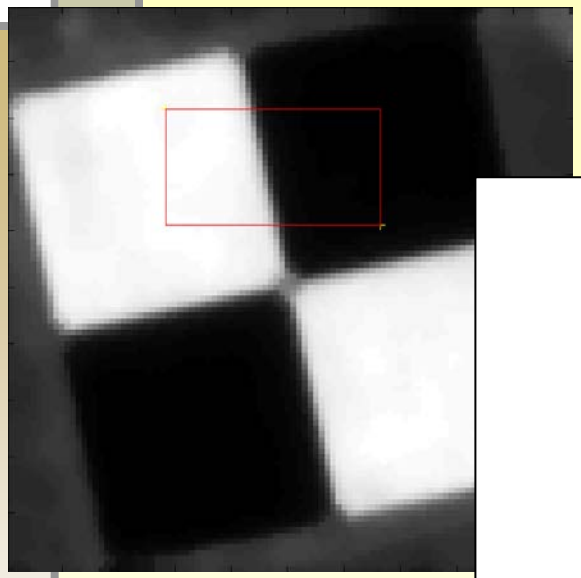
KOMPSAT-3 PSF from Star

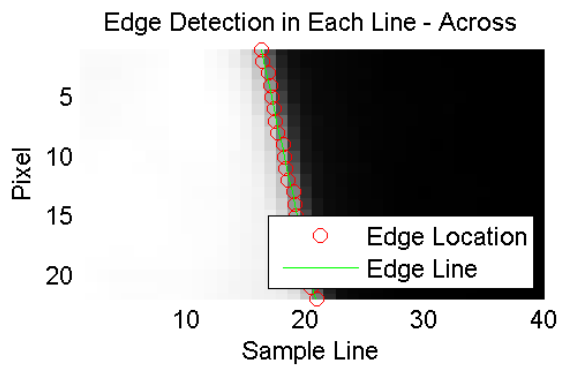
- **MTFC algorithm must have the specific character of the Sensor.**
  - PSF (Point Spread Function) has to be measured by the optimum method (Star).
  - Optimal MTFC algorithm (Wiener filter, Lucy Richardson, Sparse Prior, etc.)

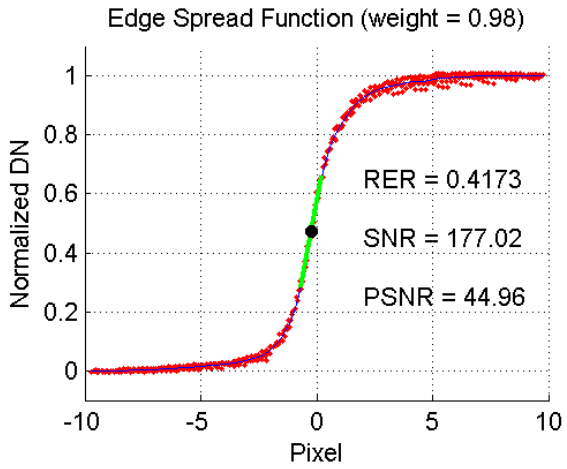
# MTFC of KOMPSAT-3 (I like it~!)

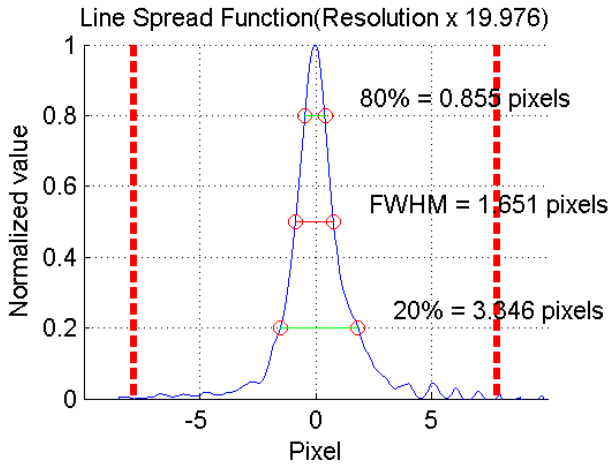


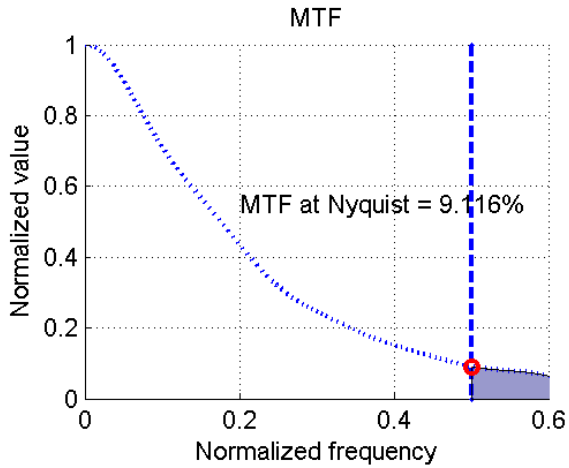
# RAW image (Across)



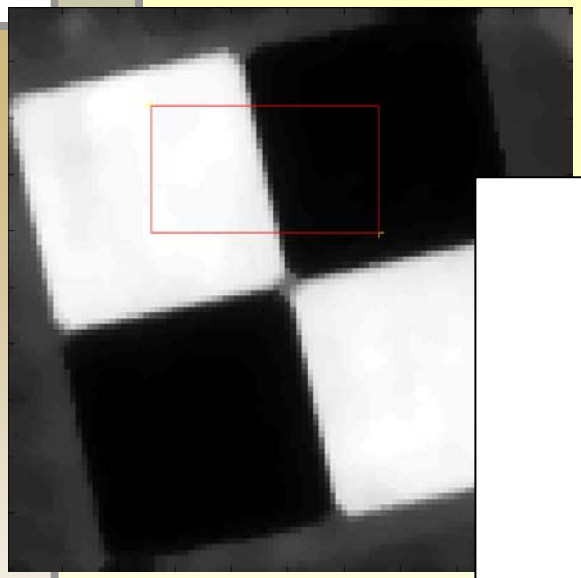


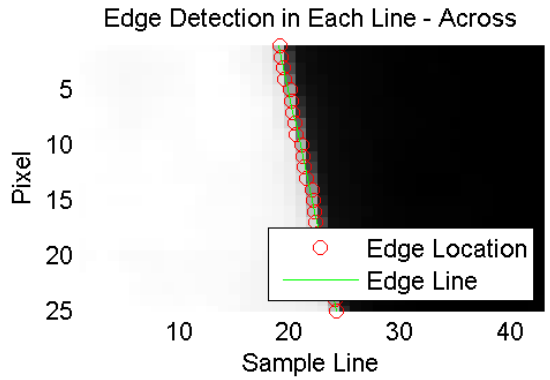



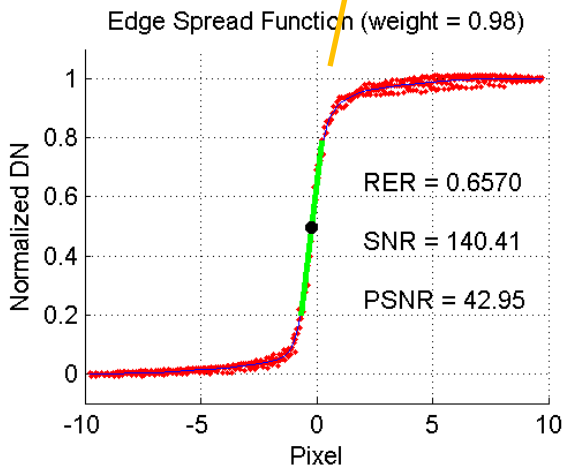



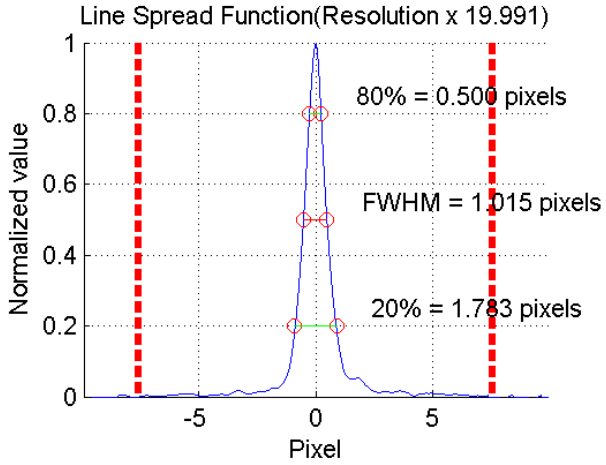
# MTFC image (Across)

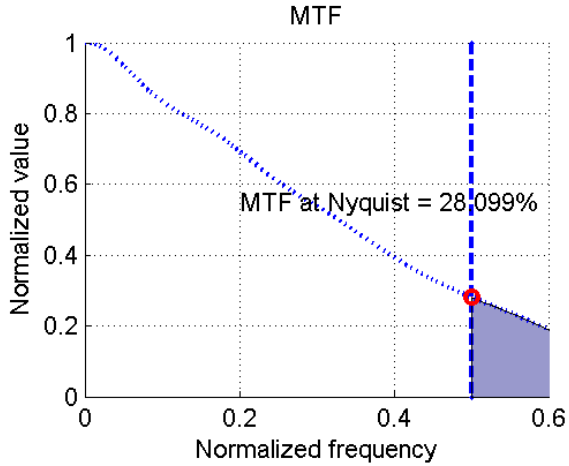


No Ringing~!

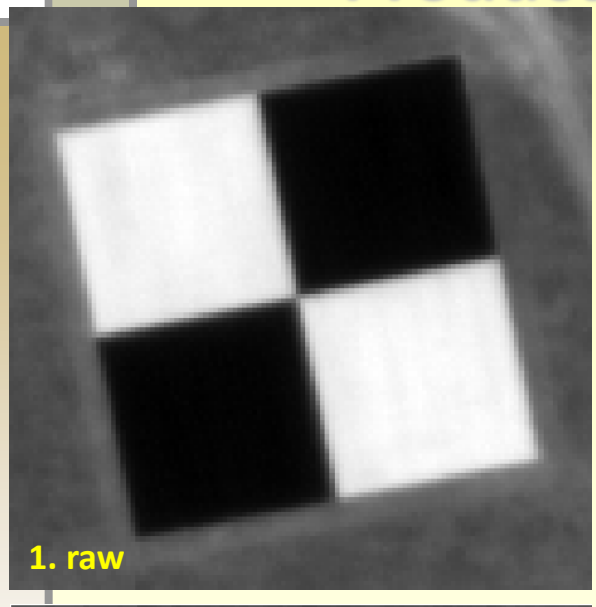


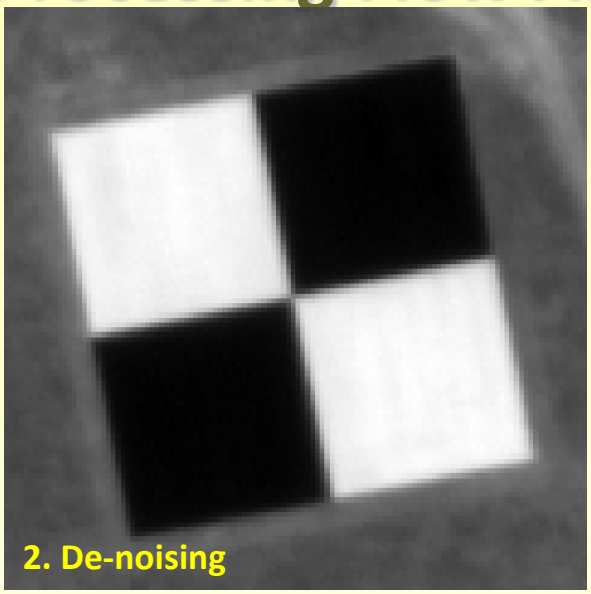



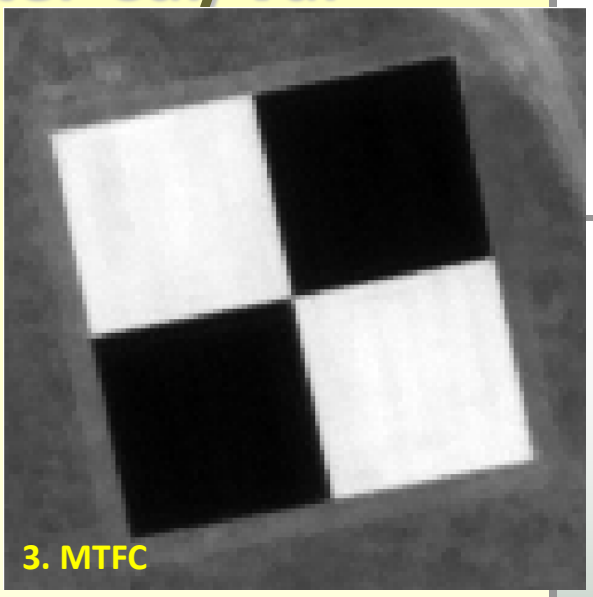



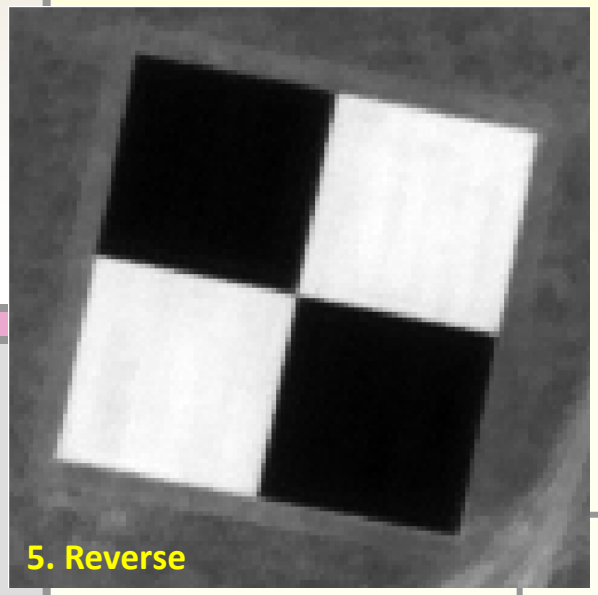



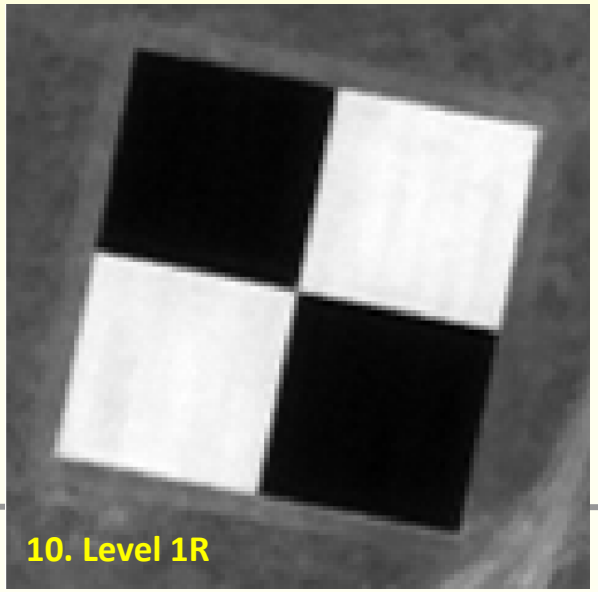
# Product Processing Flow After Cal/Val

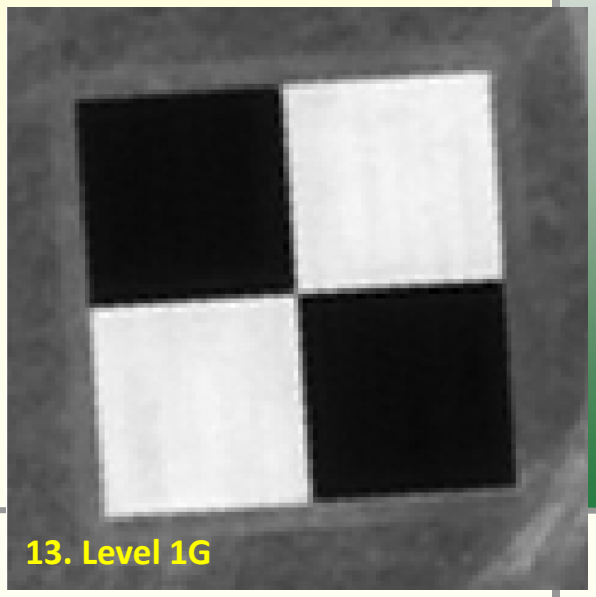


Tornado, KOMPSAT-3, Louisville Mississippi USA,
imaging date: 2014.05.05

Google Map

KOMPSAT-3


# Agenda

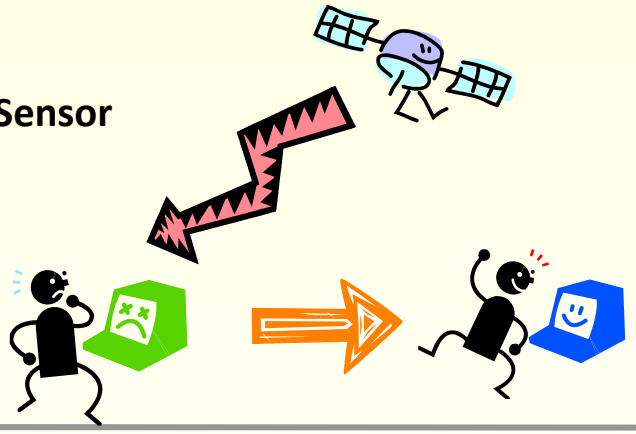
KOMPSAT-3 Calibration and Validation

**KOMPSAT-3 Image data Quality**

# Image data Quality for User in KARI

- **Image data Quality for Users**
  - There is a technical gap between the requirement for manufacturing the satellite and the requirement for the image data quality for Users.
  - Need & Define the item and the quantitative value for the image data quality for Users
    - Almost Users have eyes without the concept of the quantitative image data quality~!
  - There are Two kind of the Quality items for Users;
    - Representative items: MTF, SNR, GSD, Absolute radiometric Gain/Offset, Radiometric resolution, etc.
    - Different valued items per each image data: Noises, etc.

- **With only technology of manufacturing of Satellite and Sensor, the requirements of Users cannot be complied.**
  - Periodical monitoring of the image data Quality
  - Optimal ground processing for the Satellite and the Sensor
  - Continually talking and feed back with Users



# KOMPSAT-3 Product (Image data) Quality (IQ) during Normal operation

# Quality Checking for K3 Product (Draft)

## QR (Quality Report) for KOMPSAT-3 Image Data

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| QR No. | | QR-K3-20130314-0001 | | | | | | | | | |
| User No. | | SI | | | | | | | | | |
| Product ID | | K3_20130310175432_04341_19891327_L1R | | | | | | | | | |
| S/W Version | | PMS. V1.0.130306.001 | | | | | | | | | |
| Processing Date | | 2013-03-06 | | | | | Processed By | | KARI, Gil-Dong Hong | | |
| Anomalies Image | | Band (◎- Level 2, ●- Level 3) | | | | | Constraint (TBR) | | | Check | Comments |
| | | MS | | | | PAN | Level 1 | Level 2 | Level 3 | | |
| | | B | G | R | N | | | | | | |
| Dynamic range | | | | | | | > 1000 | 500-1000 | < 500 | | |
| Saturation | | | | | | | < 1% | 1-2% | > 2% | | |
| Abnormal Pixel (except Blooming) | | | | | | | ~2 | 3~10 | > 10 | | |
| Equalization: inter-Detector (NUC) | | | | | | | 20DN | 20~50DN | > 50DN | | |
| Pattern noise | diagonal, horizontal, vertical, First pixel | | | | | | none | isolated noise | recurrent noise | | |
| | Center Pattern | | | | | | none | isolated noise | recurrent noise | | |
| | Pixel burst (Port difference) | | | | | | 20DN | 20~50DN | > 50DN | | |
| Compression noise | | | | | | | none | isolated blocks | recurrent blocks | | |
| Registration (MS-MS) | | | | | | | < 0.5 | 0.5-0.75 | > 0.75 | | |
| Registration (MS-PAN) | | | | | | | < 0.5 | 0.5-0.75 | > 0.75 | | |
| Location accuracy | | | | | | | < 70m | 70-150m | > 150m | | |
| Comments / Image chip | | | | | | | | | | | |
| Review Date | | | | | | | Reviewed By | | | | |
| Review Comments | | | | | | | | | | | |

- NO GSD, MTF, SNR on QR~!!

Isolated & Recurrent (TBR)

| | Isolated | Recurrent |
|---|---|---|
| Number | 2~4 | >= 5 |
| Area of 1 part | 100x100 | 100x100 |
| DN difference | 20~50 DN | > 50 DN |

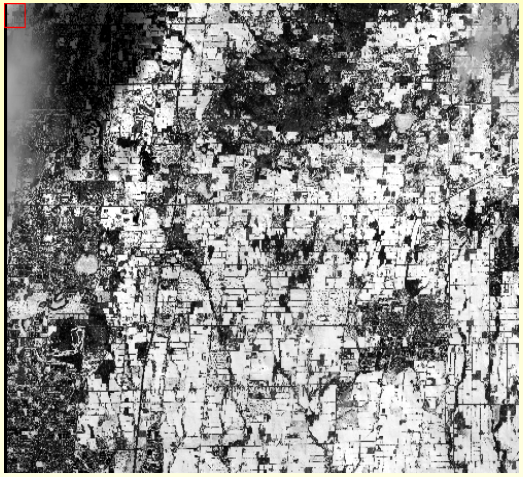
Level 1: Accepted
Level 2: To be Proposed
Level 3: Rejected

※ Cloud, Water, Snow area: to be take off for constraints: saturation, compression, NUC and pattern noise

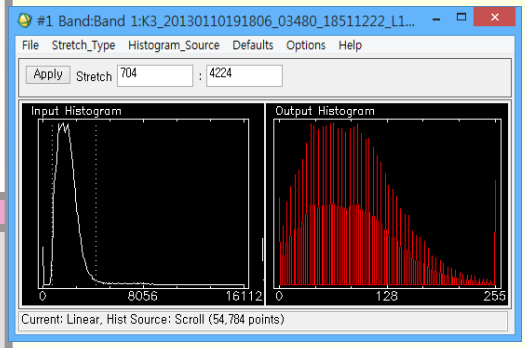
# (IQ) Dynamic Range

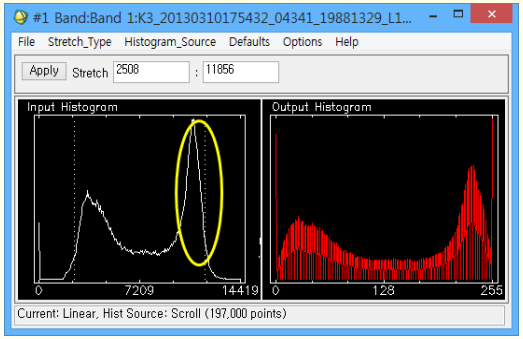
| Anomalies Image | Constraint (TBR) | | |
|---|---|---|---|
| | Level 1 | Level 2 | Level 3 |
| Dynamic range (0 ~ 16363) | > 1000 | 500~1000 | < 500 |

K3_20130110191806_03480_18511222_L1R



K3_20130310175432_04341_19881329_L1R




Histogram of Linear 2% in Scroll window in ENVI

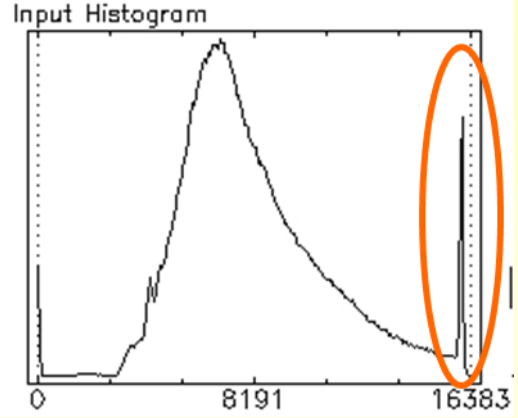
- Linear 2% in Scroll window in ENVI (TBR)
  - ✓ DN(Max – Min)
  - ✓ “3500” = 4224 - 704
- Except the next area
  - ✓ Uniform bright area
  - ✓ Forest, Farm, Desert, Ice, Mountain, Big river, Big lake, etc.
  - ✓ Snow, Cloud, Ocean, etc.
- Only ROI requested by User

❖ User want a sufficient dynamic range in the satellite radiometric resolution.
  - ✓ KOMPSAT-3: 14bit
  - ✓ Not stretching in the Processing system

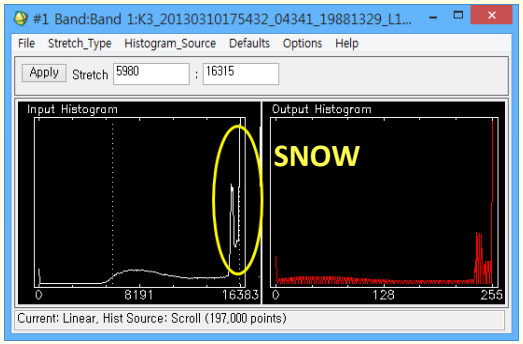
※ For User, what is the threshold for this?

# (IQ) Saturation

| Anomalies Image | Constraint (TBR) | | |
|---|---|---|---|
| | Level 1 | Level 2 | Level 3 |
| Saturation | < 1% | 1~2% | > 2% |




MS Green band: Saturation in SF (2012.06.05)




K3_20130310175432_04341_19881329_L1R_B

- Basically, >16383 DN, but
  - ✓ The Saturated area has a width of DN after the Processing system
- Except the next area
  - ✓ Snow, Ice, Cloud, Salt desert, etc.
- Only ROI requested by User

❖ User never want a saturated image data product.
- ✓ Several exposures of Satellite be needed according to the imaging area.
- ✓ KOMPSAT-3 has Two TDI stages.
- ✓ KOMPSAT-3 data collection planning system has a Radiance (Reflectance) calculating module in Worldwide.

※ For User, what is the threshold for this?

# Compression noise (Additional Cal/Val item)

| Anomalies Image | Constraint (TBR) | | |
|---|---|---|---|
| | Level 1 | Level 2 | Level 3 |
| Compression noise | none | isolated | recurrent |

| | Isolated | Recurrent |
|---|---|---|
| Number | 2~4 | >= 5 |
| Area of 1 part | 100x100 | 100x100 |
| DN difference | 20~50 DN | > 50 DN |

K3_20130210093832_03927_04161188_L1R_B

- Compression ratio is '5.5' by CCSDS 122.0-B-1 (Wavelet)
  - ✓ PAN has a little
  - ✓ MS has a lot
  - ✓ Uniform area nearby high frequency area in city

❖ User don't want the compression noise
- ✓ KOMPSAT-3 has been changed
  - PAN: '5.5'
  - MS: '3'
- ✓ KOMPSAT-3 has little compression noise with the Compression ratio '3'.

※ SNR on the Right side is larger than the Left.
※ But, User don't want the Right side.
※ For User, what is the threshold for this?

# Issues and Discussion

# Additional Cal/Val items during Normal period

- User's requirement for the Image data Quality may be different and higher than the requirements in KOMPSAT-3 system Specification.

| Item | Title | Content | Status |
|---|---|---|---|
| **Pixel burst** | On Only MS | Develop, Test and Apply the de-noising algorithm of it | Done |
| **Port Difference** | On Only MS | Develop, Test and Apply the de-noising algorithm of it | Done |
| **Center Pattern Difference** | Different noise between each CCD Detector | After reducing Compression noise, and updating RNUC and De-noising, the Center difference has been reduced. | Done |
| **RNUC (Residual NUC)** | Non-linearity behind DN 1500 | New RNUC table has been updated in the Processing system. | Done |
| **Compression noise** | Many Compression noise in MS with Compression ratio '5.5' | Updated by PAN '5.5' and MS '3' | Done |

# Issues and Discussion

- QR (Quality Report), that is the Internal report in KARI to monitor the KOMPSAT-3 Product (Image data) Quality, is Draft just now.

- Definite quantitative value for the image data Quality has to be determined.
  - ✓ For, and From User
  - ✓ Items
  - ✓ For User, what is the threshold for them?

- The main purpose of KOMPSAT-3 is just 'Detecting and Recognizing'.
  - ✓ High resolution remote sensing satellite (GSD @ nadir = 0.7m)
  - ✓ Any difference of the image data Quality according to Resolution?
  - ✓ If no, what is the representative item of the image data Quality for them?

- In case of KOMPSAT-3 & KOMPSAT-2,
  - ✓ After Cal/Val, all Requirements of the image data Quality were Complied.
  - ✓ But User didn't comply the Quality of K3 & K2 Product,
  - ✓ and then, Additional Cal/Val works for User have been done and doing~!

- We need more works for it~!

# Representative & Product Quality (?)

- These are my Questions and Concerns.
- Is there standard and general Representative and Product Quality for Users?

| | Car | Computer | Imagery | Remark |
|---|---|---|---|---|
| **by Purpose** | Bus, Sedan, SUV, Truck, etc. | Server, Desktop, Laptop, Tablet, etc. | SAR, IR, Visual, Resolution, etc. | |
| **by Budget** | Bentz, BMW, Lexus Toyota, Honda Hyundai, Kia | ? | WV, GeoEye Pleiades, KOMPSAT SPOT, Landsat | |
| **Representative** | Model, Engine size, Transmission, etc. | CPU, Memory, HDD (SSD), Weight, OS, etc. | GSD, MTF, SNR, etc. | Performance (Specification) |
| **Product Quality (IQ)** | Scratch, Driving, etc. | Dead pixel, OS, S/W, KB, Mouse, etc. | Noise, etc. | User can look at & recognize |

# Importance of Quality

- There are several Use (Purpose) for Users according to the Image data Quality.
- With GSD, MTF & SNR, the Image data Quality cannot be explained more clearly to Users.
  - ✓ New representative estimator for it has to be needed.

| | Car | Computer | Camera | Imagery |
|---|---|---|---|---|
| **General Spec. (Same)** | Similar Speed, 5 persons, 4 door, Extra parts | OS (Windows), Functions | No. of Pixel | GSD, Radiometric Resolution, Swath width (MTF, SNR) |
| **Expensive (High Quality)** | Comfortable, Safety, Stability, Extra function (?) Sports car | Comfortable, Fast, Clear monitor, More storage, Light (Use) Design, Develop, High technic) | DSLR, Size of CCD (CMOS) Clearness (MTF), Lens, Extra function | High Quality, Clearness, Ortho-rectified, Noise, (NIIRS) (High MTF & SNR) |
| **Cheap (Low Quality)** | Just Cheap, Mileage, Second car, First car for children | (Use) Office, Game, Internet, Education | Digital camera, Smart phone, Light, Easy, Small | Low Quality (Low MTF & SNR) |

# Thank you for KOMPSAT~!