GOCI-II Lunar Calibration and MTF Plan

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Contents

Introduction of GOCI & GOCI-II

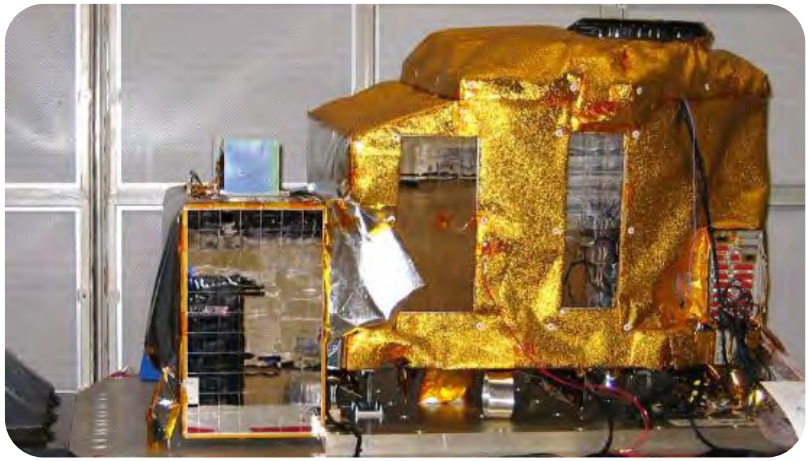
Introduction of GOCI

Chollian Satellite

COMS Communication, Ocean & Meteorological Satellite

- Developments of COMS(H/W) and GDPS(S/W) : 2003
- Establishment of KOSC (Ground System) : 2005
- The first Korean Geostationary multipurpose Satellite
- Launch date : June 27 2010
- . Lifetime : 7 years
- Payloads (3 Missions)
  - Geostationary Ocean Color Imager (GOCI)
  - Meteorological Imager
  - Ka-band Communication

Introduction of GOCI

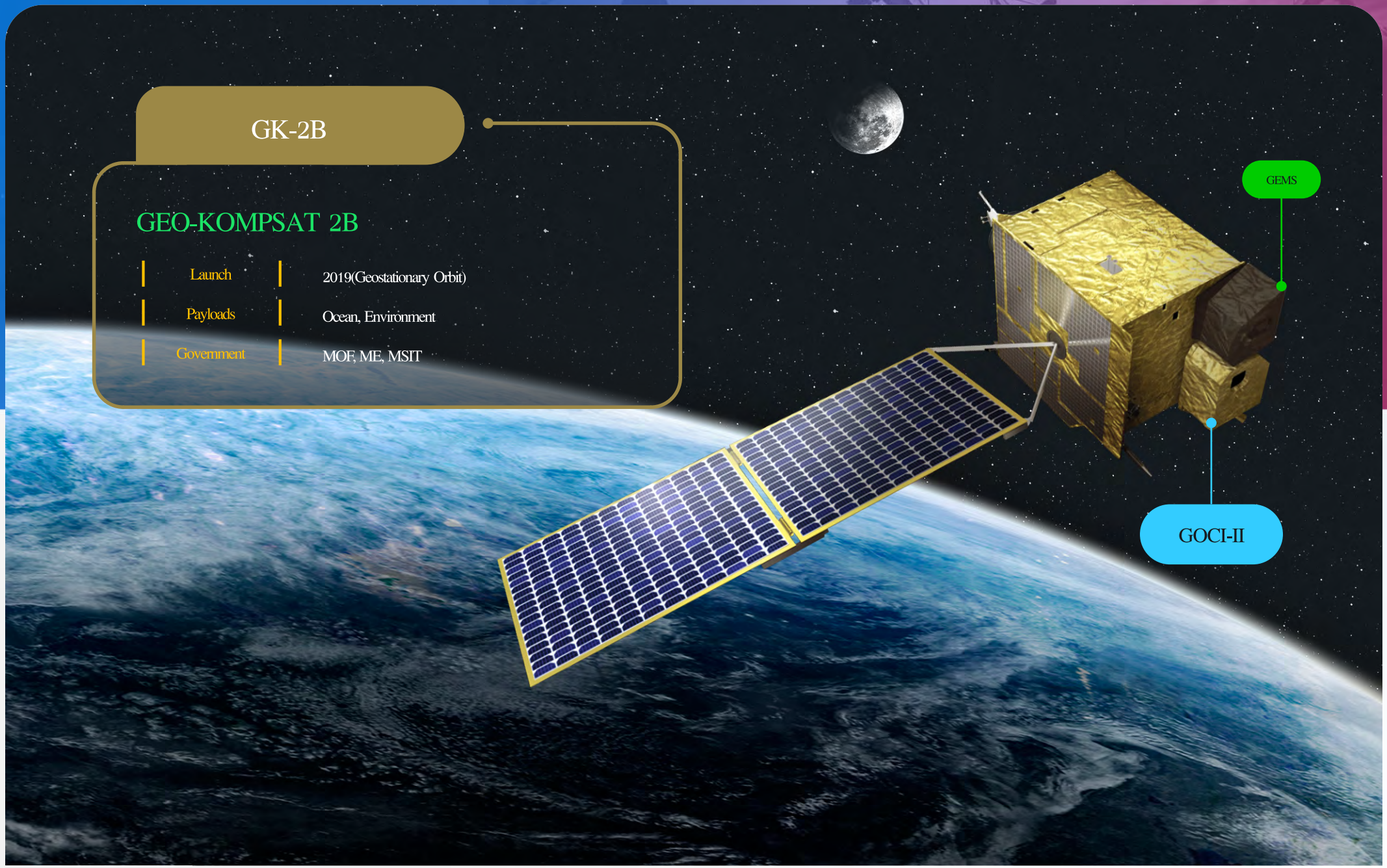


Geostationary Ocean Color Imager

- GSD(Ground Sampling Distance) : 500m * 500m
- Target Area : 2,500km * 2,500km (Center : 130°E 36°N)
- Included Nations : Korea, China, Japan, Russia, etc.
- Temporal Resolution : 1hour (8 times / day)

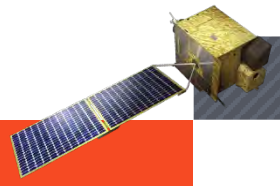
Band	Central wavelengths	Band Width	SNR	Primary Application
B1	412nm	20nm	1,070	Yellow substance and turbidity
B2	443nm	20nm	1,190	Chlorophyll absorption maximum
B3	490nm	20nm	1,170	Chlorophyll and other pigments
B4	555nm	20nm	1,070	Turbidity, suspended sediment
B5	660nm	20nm	1,010	Baseline of fluorescence signal, Chlorophyll, suspended sediment
B6	680nm	10nm	870	Atmospheric correction and fluorescence signal
B7	745nm	20nm	860	Atmospheric correction and baseline of fluorescence signal
B8	865nm	40nm	750	Aerosol optical thickness, vegetation, water vapor reference over the ocean

The next generation, GOCI-II



Development of GOCI-II

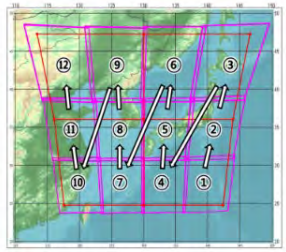
Performance Comparison



Items	GOCI	GOCI-II
Spectral Resolution	8 bands	13 bands
Spatial resolution	500m	250m (equator)
Number of observations	8 times/day	10 times/day
Target Area	Local	Local & Global

Observation Mode

Local

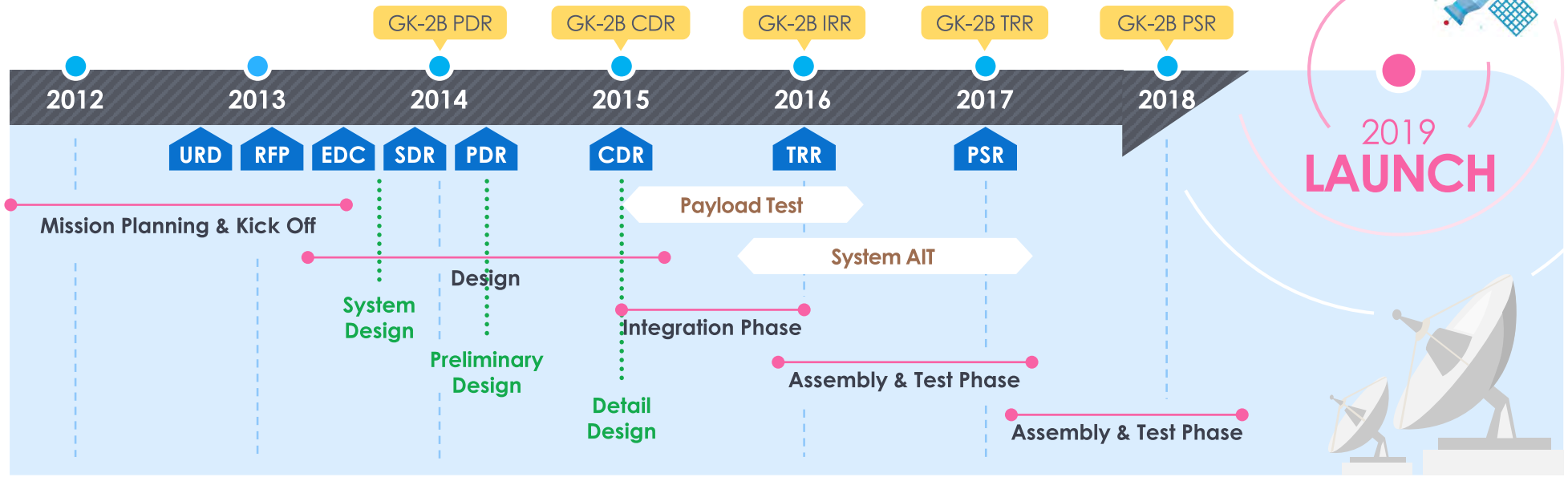


(User-definable)

Full Disk

(Red line)

Satellite Development Schedule



GOCI-II Spectral Bands

Radiance : W/m²/μm/sr

GOCI Band	GOCI-II Band	Band center	Bandwidth	Nominal Radiance	Maximum Ocean radiance	Threshold Radiance	Maximum Cloud Radiance	NEdL	SNR @ Nominal radiance
-	**1**	380 nm	20 nm	93	139.5	143.1	634.4	0.093	998
1	**2**	412 nm	20 nm	100	150	152	601.6	0.095	1050
2	**3**	443 nm	20 nm	92.5	145.8	148	679.1	0.081	1145
3	**4**	490 nm	20 nm	72.2	115.5	116	682.1	0.059	1128
-	**5**	510 nm	20 nm	64.9	108.5	122	665.3	0.055	1180
4	**6**	555 nm	20 nm	55.3	85.2	87	649.7	0.049	1124
-	**7**	620 nm	20 nm	53.3	64.1	65.5	629.5	0.048	1102
5	**8**	660 nm	20 nm	32	58.3	61	589	0.03	1060
6	**9**	680 nm	10 nm	27.1	46.2	47	549.3	0.03	914
-	**10**	709 nm	10 nm	27.7	50.6	51.5	450	0.03	914
7	**11**	745 nm	20 nm	17.7	33	33	429.8	0.02	903
8	**12**	865 nm	40 nm	12	23.4	24	343.8	0.015	788
-	**13**	643.5 nm	483 nm	-	-	-	-	-	-

Field of Regard

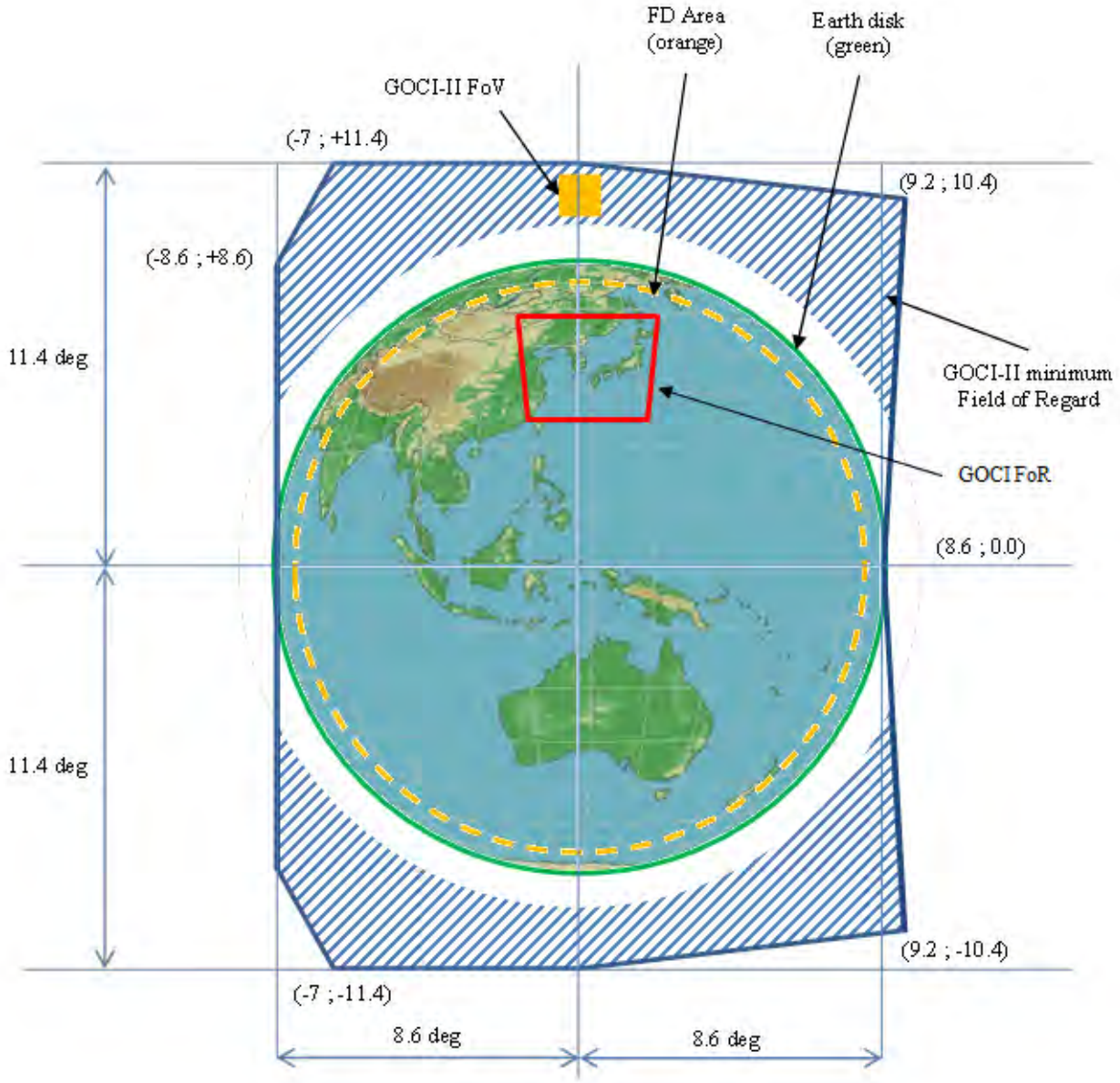
◆ Targeted Field of Regard

◆ SN FoR (±11.4 deg)

- 8.7 deg Earth Disk
- 1.1 deg Instrument FoV
  set as margin
- 1.1 deg useful FoV
  for moon and star
- 0.5 deg margin
  for pointing bias

◆ EW FoR (±8.6 deg)

- 8.06 deg FD area
- 0.5 deg margin
  for pointing bias



GOCI-II Lunar Calibration Plan

Advantages of Lunar Calibration

As an on-board calibration light source, the Moon, and lunar calibration have several advantages:

1. Optical properties of the Moon as reflective diffuser are very stable in the order of $1*10^{-8}$/year for irradiance, and $1*10^{-7}$/year for radiance (Kieffer 1997).
2. On the basis of the Moon visibility among the instruments on different spacecrafts, inter-satellite calibration can be achieved without temporal limitation (no necessity of the Moon observation on same time) (Eplee et al., 2011).
3. On-ground characterization such as BSDF characterization of Solar Diffuser is not required.
4. Dedicated on-board system is not generally required.

Technical issues of the Moon and lunar calibration of GOCI-II

1. Due to the limited observability of the moon and phase angle variation, effective lunar calibration can be generally performed one or two times per month.
2. Lunar spectral irradiance model (ex. ROLO) with regarding various corrections factors such as distance among Sun-Moon-Satellite, libration, phase angle, oversampling, and etc. is required.
3. In single image acquisition of the Moon, only a portion of pixels implemented on GOCI-II detector can be used for the lunar calibration.
4. Reference spectral irradiance of the Moon for single pixel based on ROLO model is under development with early stage. At this moment, ROLO model can only provide the single value of integrated lunar irradiance as sum of radiances over all lunar pixels (IOCCG Report No. 14).

Feasibility Assessment of Moon Imaging (1/2)

5 Moon imaging criteria with hierarchical priority

(Priority 1) Moon in GOCI-II FoR (Field of Regard)
- No spacecraft maneuver (esp. roll maneuver) is planned

(Priority 2) GOCI-II Nominal Operation Duration
- 05:15 ~ 19:45 (KST)

(Priority 3) Moon phase: more than 50% of illuminated area (100% in Full Moon)
- First quarter → Waxing gibbous → Full Moon → Waning gibbous → Last quarter

(Priority 4) Moon imaging time shall not be fully overlapped with the operation time of another payload on GK2B
- Allocated GOCI-II operation timeline is 15 to 45 min in every hour

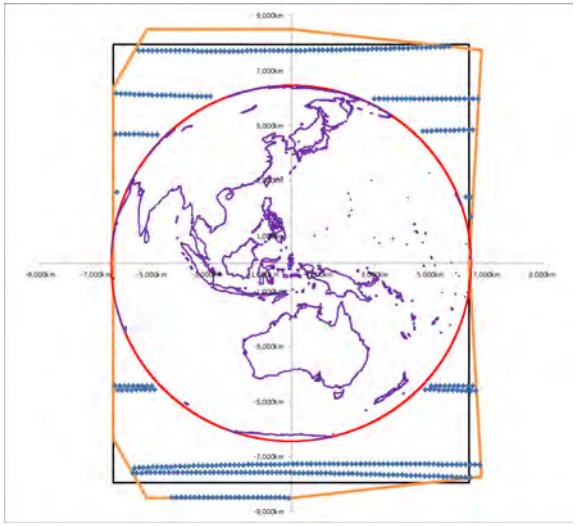
(Priority 5) Continuous single observable duration shall be equal to or longer than 10 min per day

Additional criteria regarding image quality of the Moon

(Priority 6) Rejection of Earth straylight Area
- Moon image can be affected by Earth straylight
- Potential Earth straylight region : 1 deg from Earth disk

(Priority 7) Optimum Moon phase angle range for DAMD* monitoring
- Relative uncertainty of ROLO model w.r.t. phase angle : ~1%
- Required determination of optimal phase angle range

(*DAMD : Diffuser Ageing Monitoring Device)



Monthly lunar intrusion in GOCI-II FOR (Jan. 2019)

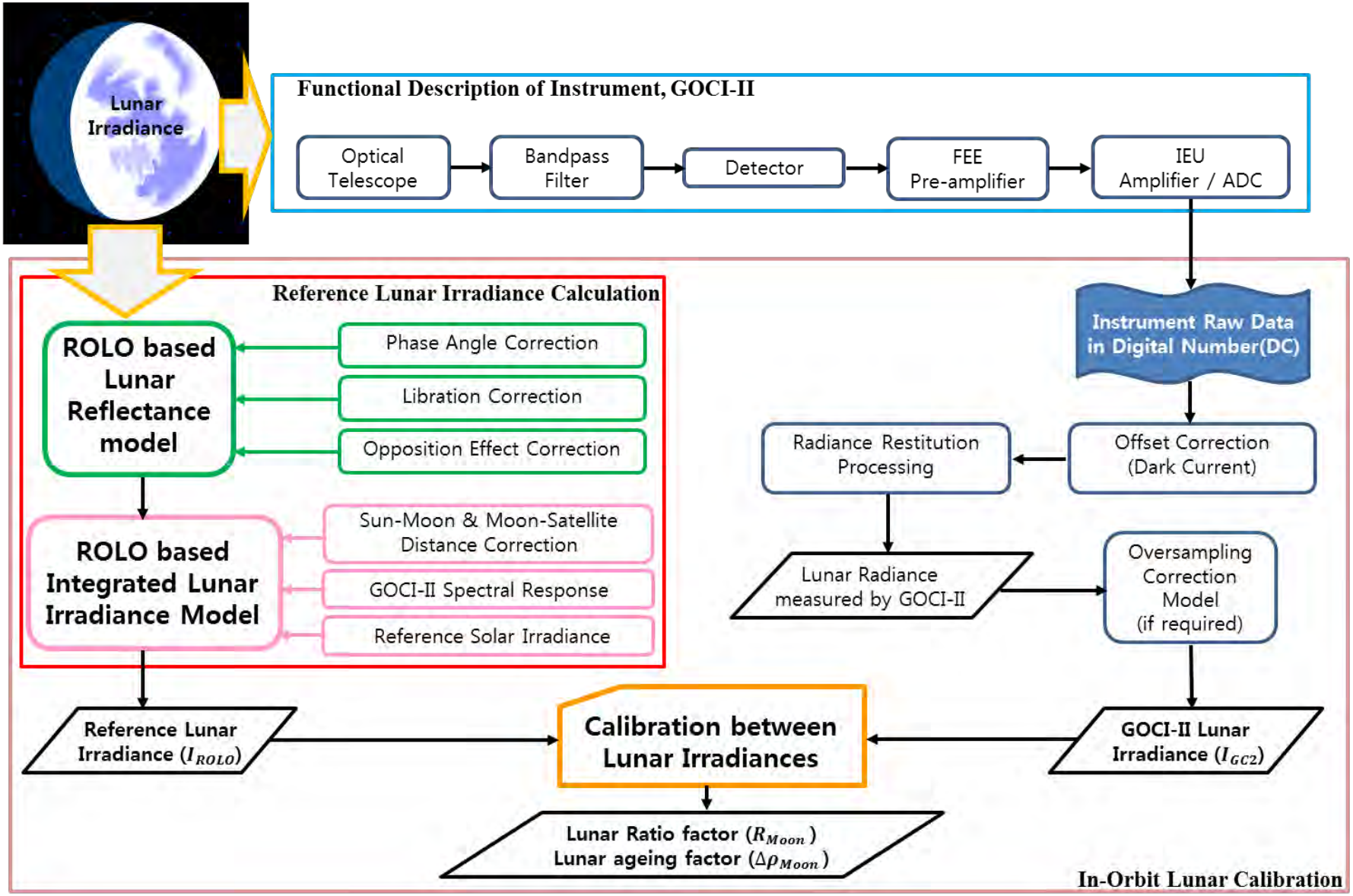
Feasibility Assessment of Moon Imaging (2/2)

Moon imaging timeline in year of 2019

Month in '2019	Observable days for monthly Moon imaging (day)	Observable times for recommended monthly Moon imaging	Start time of recommended monthly Moon imaging (yyyy-mmm-dd hh:mm, KST)	End time of recommended Moon imaging (yyyy-mmm-dd hh:mm, KST)	Observable time for selected Monthly Moon imaging (min, approx.)
Jan.	2	1	2019-Jan-15 07:15	2019-Jan-15 07:45	30
Feb.	3	1	2019-Feb-20 13:15	2019-Feb-20 13:45	30
Mar.	1	2	2019-Mar-20 11:15 2019-Mar-20 12:15	2019-Mar-20 11:36 2019-Mar-20 12:32	38
Apr.	1	2	2019-Apr-20 12:29 2019-Apr-20 13:15	2019-Apr-20 12:45 2019-Apr-20 13:45	46
May	1	1	2019-May-18 11:16	2019-May-18 11:45	29
Jun.	2	1	2019-Jun-14 09:15	2019-Jun-14 09:45	30
Jul.	2	2	2019-Jul-21 15:15 2019-Jul-21 16:15	2019-Jul-21 15:39 2019-Jul-21 16:30	39
Aug.	2	2	2019-Aug-17 13:15 2019-Aug-17 14:15	2019-Aug-17 13:45 2019-Aug-17 14:28	43
Sep.	1	1	2019-Sep-18 15:15	2019-Sep-18 15:45	30
Oct.	2	1	2019-Oct-11 10:34	2019-Oct-11 10:45	11
Nov.	4	1	2019-Nov-11 10:32	2019-Nov-11 10:44	12
Dec.	3	2	2019-Dec-09 09:15 2019-Dec-09 10:15	2019-Dec-09 09:45 2019-Dec-09 10:29	44

ROLO model implementation for GOCI-II

GOCI-II lunar calibration procedure



GOCI-II Lunar Calibration

- ✓ Because lunar disk observed in single GOCI-II lunar image is only a portion of all detector pixels, and ROLO model can provide the integrated lunar irradiance only, absolute in-orbit calibration to update radiometric gain for each pixel is normally not suitable to lunar calibration.

- ✓ With this technical limitation, lunar ageing factor ($\Delta\rho_{Moon}$) to compensate the degradation of the radiometric performance defined by the lunar calibration can be defined as follows:

$$\Delta\rho_{Moon} = \frac{I_{ROLO}}{I_{GC2}}$$

- ✓ With lunar aging factor and PRNU (Pixel Response Non-Uniformity), variation of the radiometric performance for each pixel can be assessed.

G2GS Lunar Calibration Module

GOCI-II Lunar Calibration Module

Algorithm

- Lunar Irradiance Calculation
  - Based on ROLO Model
- Moon Pixel Selection
  - ROI Selection + DN Threshold
    - ROI Selection for Earth Contamination
    - DN Threshold for Extraction of Moon Pixel only
- Interpolation for spacecraft position determination
  - Linear interpolation at Lunar Observation Time

Verification

- Using MI/COMS Moon images (provided by KMA)

GOCI-II Lunar Calibration Module - Verification

Calculation of ROLO Irradiance

Contents	Reference	Lunar Calibration Module	P / F
Abs Phase Angle	1.092966255e+00	1.092966255e+00	Pass
ROLO Irradiance	9.644399507e-04	9.644399509e-04	Pass
Reference Irradiance	7.558361117e-04	7.558361120e-04	Pass

Calculation of Lunar Image Irradiance

Contents	Reference	Lunar Calibration Module	P / F
Moon Irradiance	6.897984906e-04	6.897984907e-04	Pass

Slope Factor

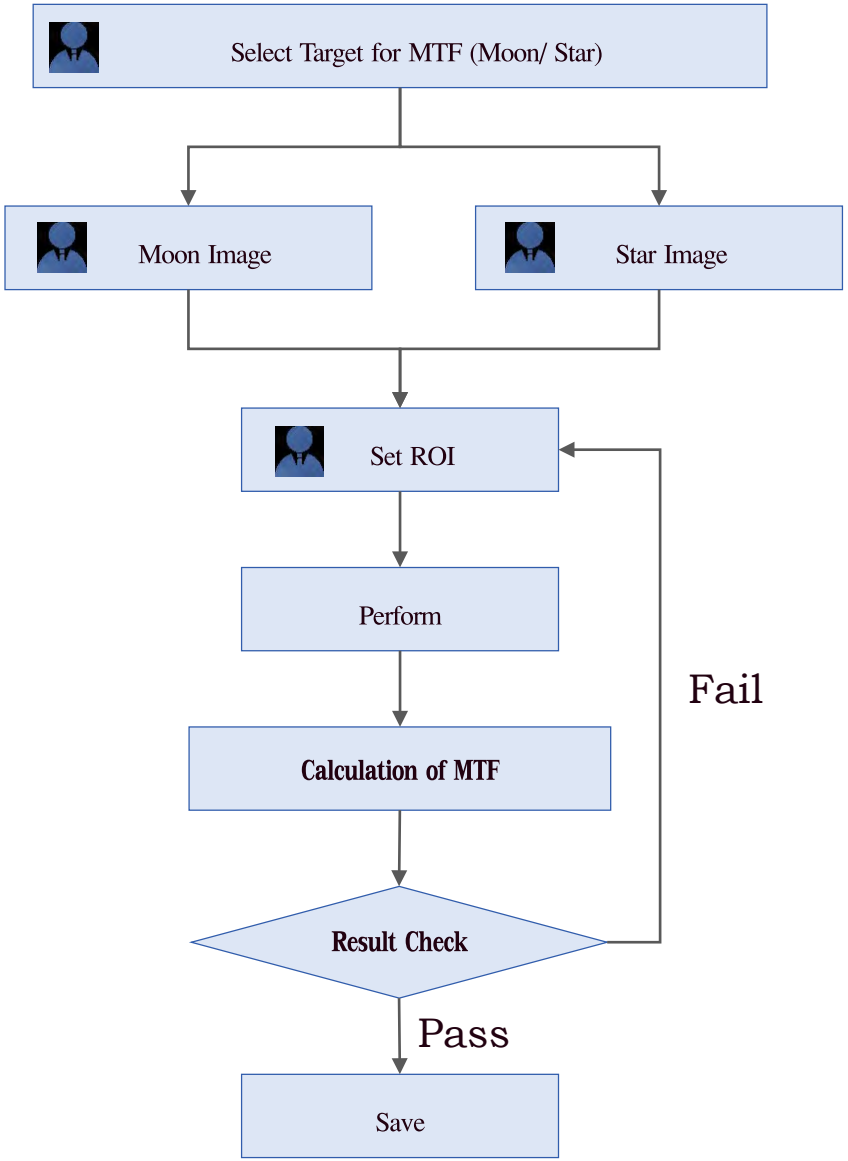
Contents	Reference	Lunar Calibration Module	P / F
Slope Factor	9.126297083e-01	9.126297087e-01	Pass

GOCI-II MTF Measurement Plan

GOCI-II MTF Measurement Plan

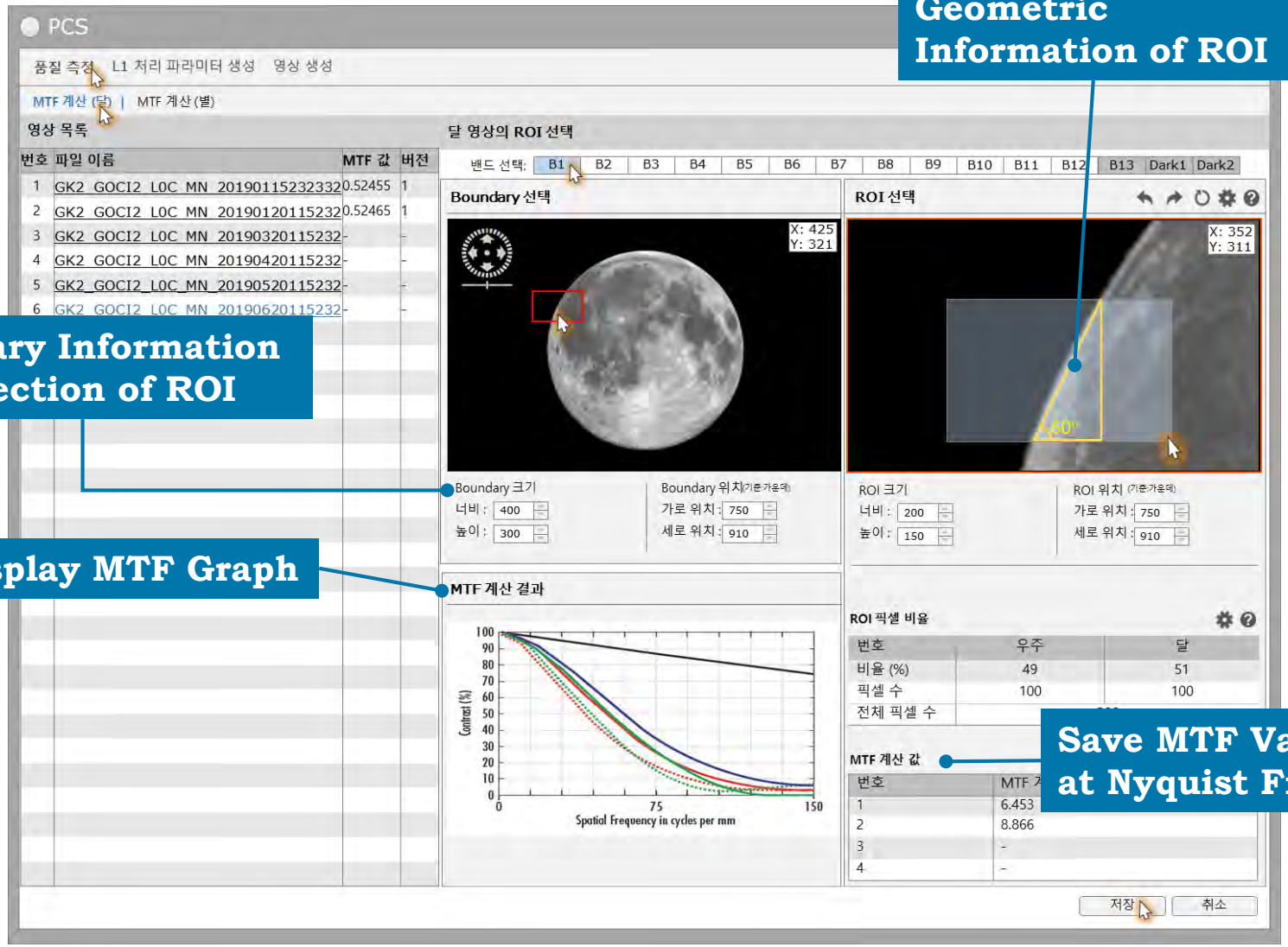
- **MTF Measurement from Moon Image**
  - Input – Moon Image (L0C)
  - Output – MTF of Moon Image
  - Using Lunar Edge as Slant-Edge Source
  - Algorithm
    - ① Set a ROI including Lunar Edge
    - ② Calculate ESF & LSF
    - ③ Calculate MTF

- **MTF Measurement from Star Image**
  - Input – Star Image (L0C)
  - Output – MTF of Star Image
  - Using Star Image as Point Source
  - Algorithm
    - ① Set a ROI including Star
    - ② Calculate PSF
    - ③ PSF Normalization
    - ④ Calculate MTF



GOCI-II MTF Measurement Plan

GUI for MTF Measurement

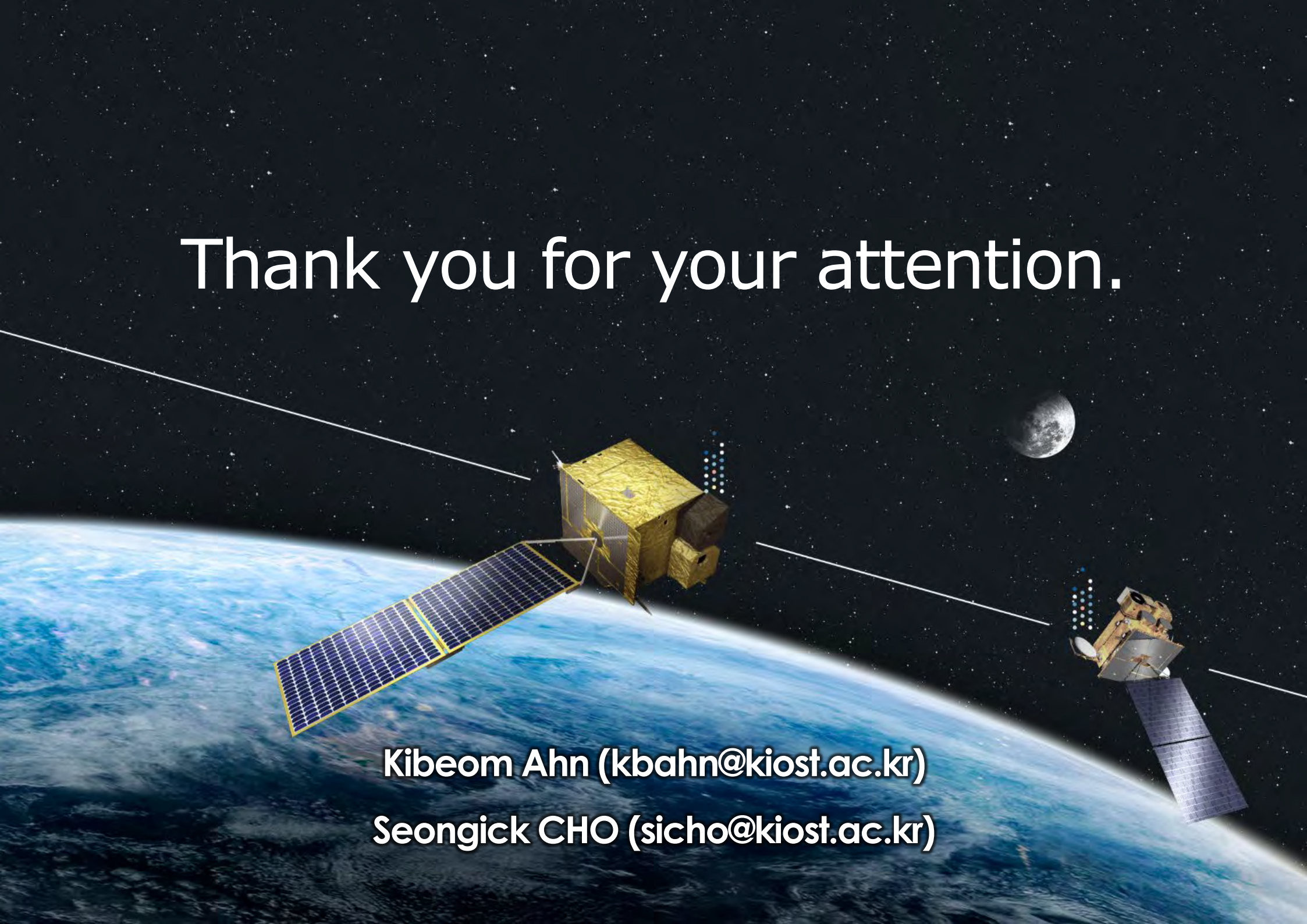


Conclusion

Conclusion

- ✓ Technical feasibility of the Moon observation was confirmed
- ✓ Theoretical adaptation of ROLO model is accomplished for GOCI-II
- ✓ Prototype implementation of ROLO model for GOCI-II
  : Verification using MI/COMS Moon images (provided by KMA)
- ✓ In the next step, followings are planned to be completed with in-depth analysis:
  - Recommendation of the Moon imaging time after the determination of reference phase angle
  - Instrument oriented reference lunar irradiance model
  - Technical Feasibility to implement reference lunar radiance model for each pixel

Thank you for your attention.



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Reference Lunar Irradiance

Lunar reflectance (A_k) provided by ROLO model

$$\ln A_k = \sum_{i=0}^{3} a_{ik} g^i + \sum_{j=0}^{3} b_{jk} \Phi^{2j-1} + c_1\theta + c_2\phi + c_3\Phi\theta + c_4\Phi\phi + d_{1k} e^{-\frac{g}{p_1}} + d_{2k} e^{-\frac{g}{p_2}} + d_{3k} \cos\left[\frac{(g - p_3)}{p_4}\right]$$

where:

A_k	: disk-equivalent reflectance for each band k
g	: absolute phase angle
θ	: selenographic latitude of GOCI-II
ϕ	: selenographic longitude of GOCI-II
Φ	: selenographic longitude of the Sun

- Calculated ROLO model(version 311g) coefficients for GOCI-II

Band	Band Center (nm)	a0	a1 (rad^{-1})	a2 (rad^{-2})	a3 (rad^{-3})	b1 (rad^{-1})	b2 (rad^{-3})	b3 (rad^{-5})	d1	d2	d3
B1	380	-2.53875	-1.73218	0.424342	-0.22212	0.034985	0.010926	-0.00362	0.345536	-0.01098	-0.00502
B2	412	-2.34249	-1.74246	0.420812	-0.21495	0.03156	0.013508	-0.00467	0.365353	-0.05816	0.000765
B3	443	-2.32145	-1.71791	0.375473	-0.19491	0.037671	0.015208	-0.00552	0.376755	-0.09156	0.008859
B4	490	-2.22836	-1.68141	0.371029	-0.1969	0.038784	0.015455	-0.00546	0.366226	-0.09036	0.007187
B5	510	-2.19513	-1.65353	0.336892	-0.18481	0.038616	0.014135	-0.00488	0.368327	-0.09626	0.009814
B6	555	-2.1225	-1.65885	0.383235	-0.20625	0.040559	0.010087	-0.00388	0.372053	-0.10775	0.003567
B7	620	-1.98473	-1.61287	0.336911	-0.19021	0.042679	0.009935	-0.00389	0.371673	-0.12392	0.008829
B8	660	-1.89995	-1.58457	0.308405	-0.18034	0.043984	0.009842	-0.00389	0.37144	-0.13387	0.012067
B9	680	-1.89178	-1.58316	0.292015	-0.1712	0.044225	0.009463	-0.00369	0.381883	-0.15395	0.015173
B10	709	-1.91429	-1.59811	0.365081	-0.20418	0.044258	0.010299	-0.00396	0.371204	-0.14098	0.004827
B11	745	-1.86933	-1.57541	0.337351	-0.19423	0.039708	0.013156	-0.00463	0.368899	-0.14822	0.009541
B12	865	-1.7458	-1.58485	0.350134	-0.19572	0.041439	0.016106	-0.0055	0.391924	-0.18828	0.009775

Technical Issue

Earth Shine Straylight

- ✓ For the effective lunar calibration, leakage of the Earth shine (i.e. Earth straylight) at Moon imaging of GOCI-II is expected to be analyzed as part of GOCI-II straylight analysis.
- ✓ In a next step, minimum distance between the Earth and the Moon to avoid the Earth straylight on the Moon will be provided based on the result of the straylight analysis.

Lunar Radiance Model for each pixel

- ✓ Because the ROLO model can only provide the integrated lunar irradiance at this moment, lunar radiance for each pixel can't be retrieved.
- ✓ In order to overcome this technical limitation, a lunar radiance model for each pixel is required.
- ✓ The expected accuracy of the lunar radiance model is about 0.5% for long-term monitoring and about 5% for single lunar image.

GOCI-II Lunar Calibration Module - Verification

Input Image

- MI/ COMS Moon Image (L1A)
  - W_KR-KMA-NMSC,VISNIR+SUBSET+MOON, COMS1+Imager_C_RKSL_20130420225822_01.nc
    - Bands > dc_obs_imgt
  - Image size : 699 X 699 (Unsigned Integer)