Celebrate Our Centennial at the Annual Meeting

AMS 100

ADVANCING SCIENCE SERVING SOCIETY

- **Centennial Sessions and Presentations**
  - Flagged in the mobile app and in the online program
- **Historical Instruments Display**
  - In the Exhibit Hall
- **Birthday Card**
  - All are welcome to sign
  - In the Exhibit Hall
- **Meteorology/Atmospheric Science Family Tree**
  - Check it out and add yourself
  - In the Poster Hall
- **AMS Oral History Project**
  - Share your story in a fifteen-minute interview to become part of the AMS archives
  - Email amsoralhistoryproject@ametsoc.org or stop by Elm I&II in the Westin
- **Centennial Celebration**
  - Wednesday, 6:30-9pm in the Grand Ballroom




Advanced Meteorological Imager (AMI) On-Orbit Performance

Paul Griffith[1], Koon-Ho Yang[2], Dave Odle[1], Redgie Lancaster[1]

[1]L3Harris, [2]KARI

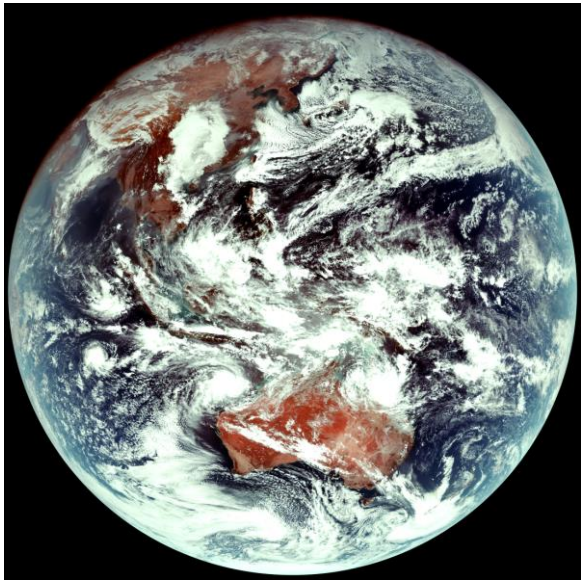
AMS 16NGOESS Presentation 13A.1

AMS Annual Meeting, 16th New Generation Operational Environmental Satellite Systems, Boston, Massachusetts, 16 January 2020

GEO-KOMPSAT-2A AMI is South Korea's newest geostationary weather and environmental imager

- Replacement for COMS Meteorological Imager (MI)
- Better spectral (3x), spatial (4x), and temporal (4x) resolution yields improved quality and quantity of critical data products
- Improved calibration targets yields more accurate images
- Interleaved scene collection provides operational flexibility

AMI (photo by L3Harris)



True color (RGB) image, collected 1/26/2019 03:10 UTC (KARI and KMA)

Agenda

- Payload design
- Scenes and timelines
- Thermal performance
- Signal-to-Noise Ratio (SNR)
- Noise Equivalent Delta Temperature (NEdT)
- Visible and IR calibration stability
- Navigation accuracy

AMI has more bands than COMS MI, providing significantly more data products

COMS MI

Band #	Wavelength
1	0.68 µm
2	3.75 µm
3	6.75 µm
4	10.8 µm
5	12.0 µm

AMI

Band #	Band Name	Wavelength	FPM
1	VIS0.4	0.47 µm	VNIR
2	VIS0.5	0.51 µm	
3	VIS0.6	0.64 µm	
4	VIS0.8	0.86 µm	
5	NIR1.3	1.37 µm	
6	NIR1.6	1.61 µm	
7	IR3.8	3.83 µm	MWIR
8	IR6.3	6.21 µm	
9	IR6.9	6.94 µm	
10	IR7.3	7.33 µm	
11	IR8.7	8.59 µm	
12	IR9.6	9.62 µm	LWIR
13	IR10.5	10.35 µm	
14	IR11.2	11.23 µm	
15	IR12.3	12.37 µm	
16	IR13.3	13.29 µm	

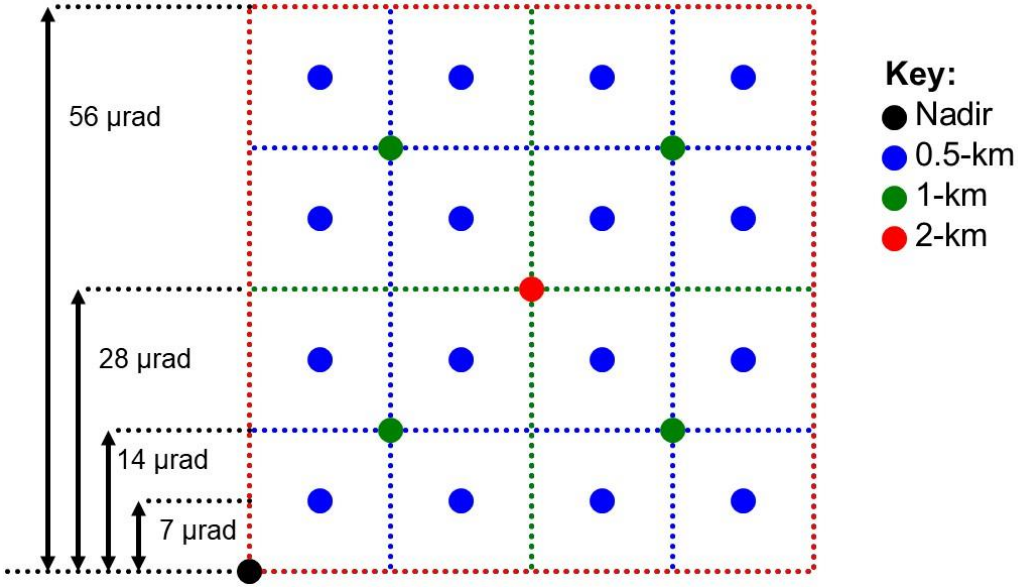
FPM = Focal Plane Module
VNIR = Visible and Near Infrared
MWIR = Mid-Wave Infrared
LWIR = Longwave Infrared

Instantaneous field of view (IFOV) and spatial sampling distance (SSD) provide improved resolution

Bands	Resolution (km at nadir)†	IFOV (μrad)		SSD (μrad)		Rows
		NS	EW	NS	EW	
VIS06	0.5	10.5	12.4	10.5	11	1460
VIS04, VIS05	1	22.9	22.9	22.9	22	676
VIS08	1	22.9	22.9	22.9	22	676
NIR13, NIR16	2	42.0	51.5	42	44	372
IR38, IR63, IR69, IR73, IR87, IR96	2	47.7	51.5	47.7	44	332
IR105, IR112, IR123, IR133	2	38.1	34.3	38.1	44	408

†After resampling (1 km = 28 μrad)

- Final image pixel grid staggered to facilitate combining bands with different resolutions for multi-spectral products



AMI unique interleaved scene collection delivers Full Disk, Extended Local Area, and Local Area

- AMI Observation Timeline
  - Full Disk: every 10 minutes
  - ELA: every 2 minutes
    - Korean peninsula and surrounding area
  - LA: every 2 minutes
    - Typhoons, calibration, etc.
- Blackbody, spacelooks, and stars included in all timelines
  - For radiometric calibration and navigation

Scene	NS	EW	Swaths
Full Disk	17.8° diameter		23
ELA	2400 km	3800 km	5
LA	1000 km	1000 km	3

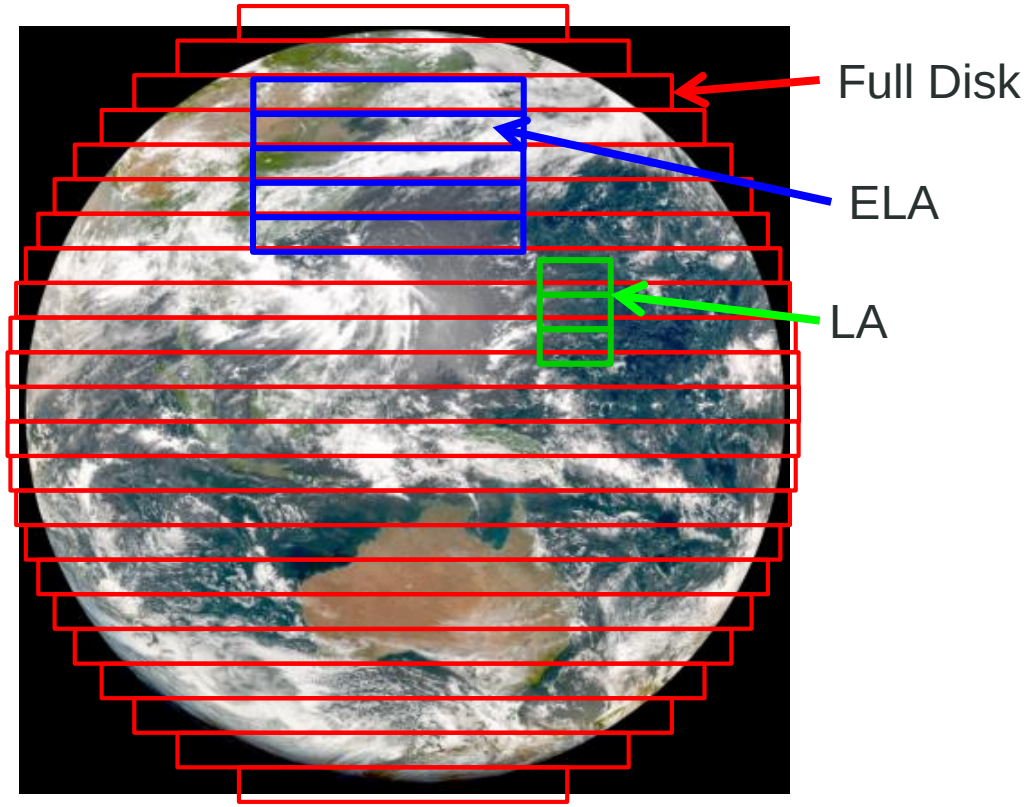
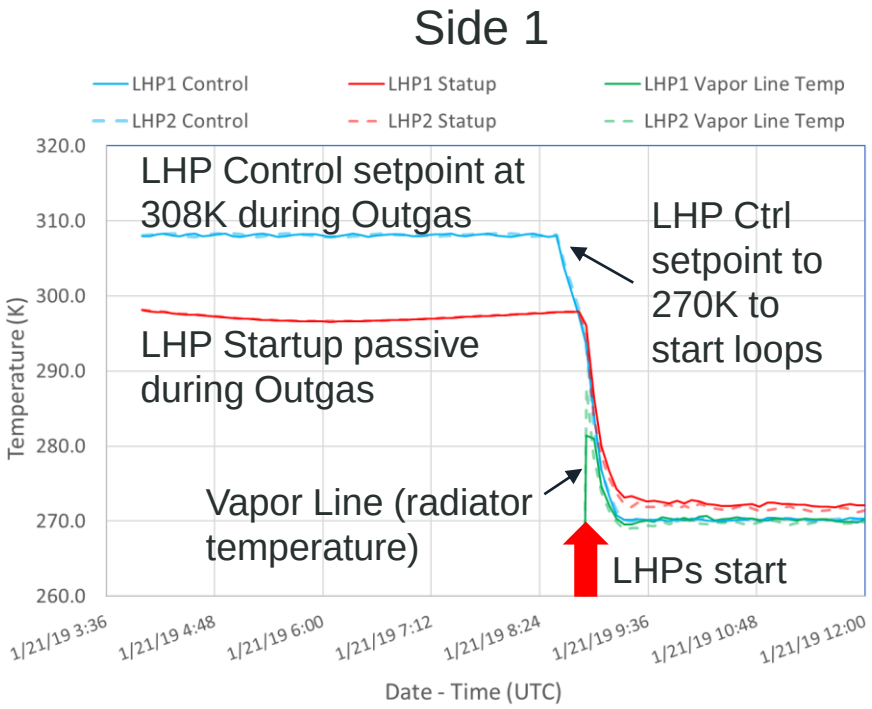


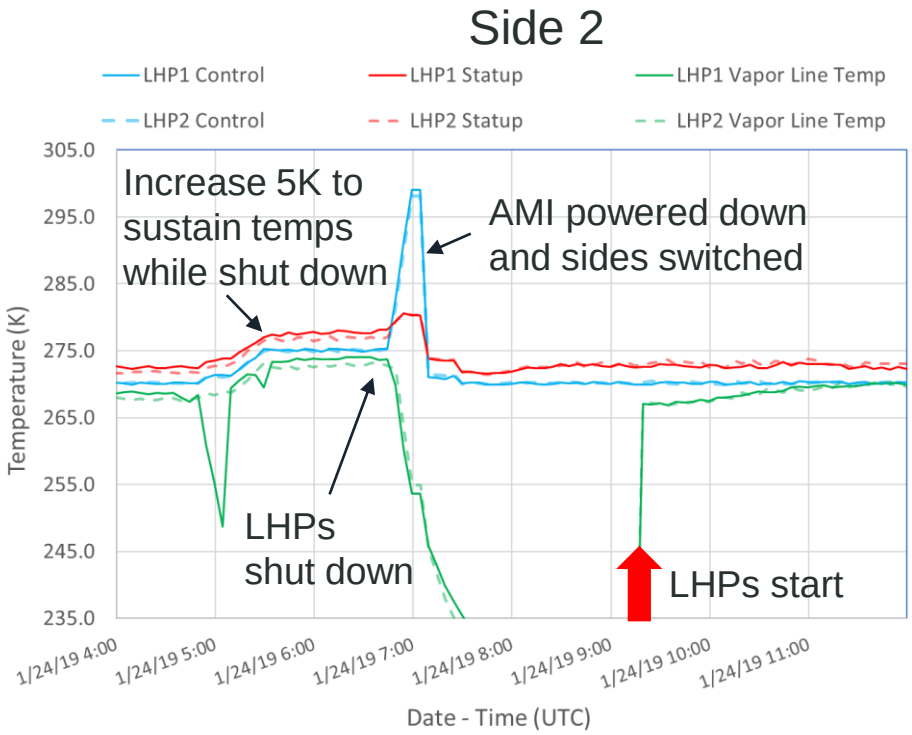
Image courtesy of KMA

ELA = Extended Local Area
LA = Local Area

User can design and load any desired scenario, even on orbit

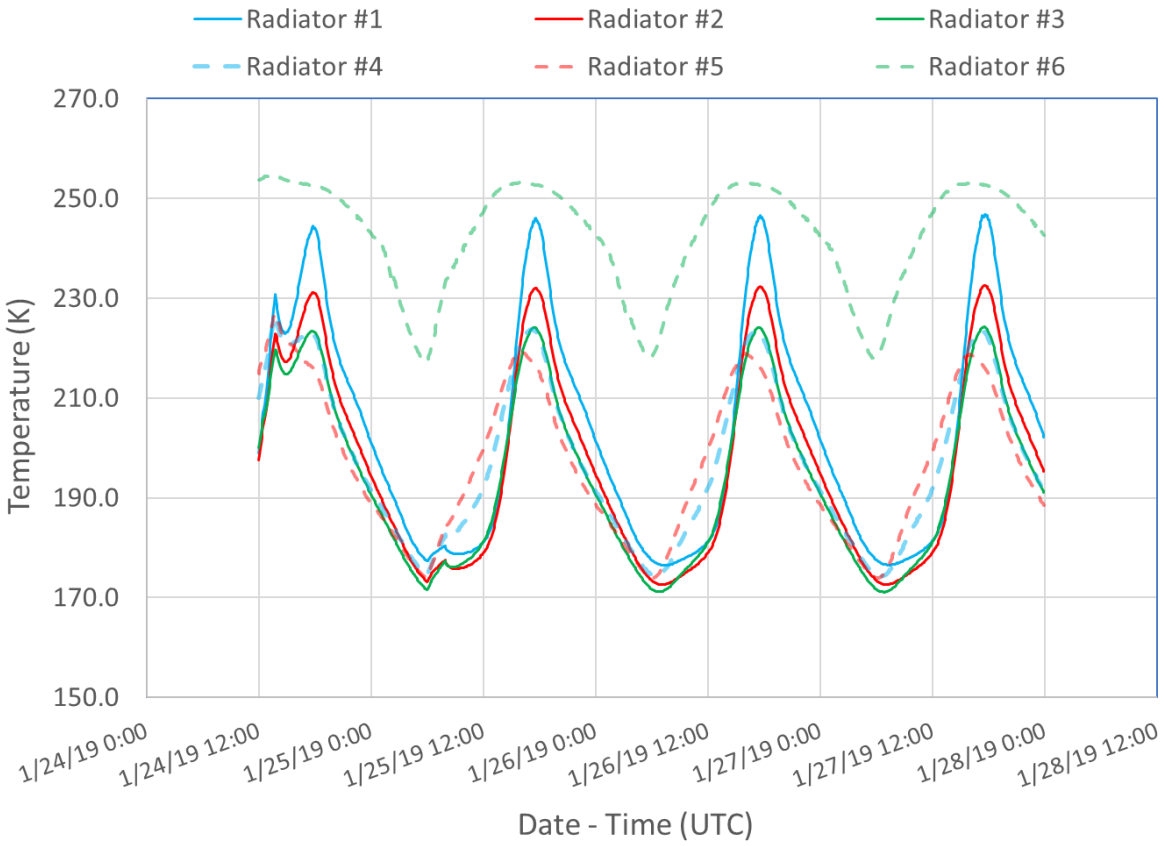
AMI loop heat pipes (LHPs) started on first attempt (Side 1 and Side 2)





- Side 1 and Side 2 defined by whether primary or redundant electronics are powered (one side used at a time)
- LHPs are fully redundant – both sets used simultaneously
  - Side 1 start-up: LHP1/LHP2 load sharing ~60/40
  - Side 2 start-up: LHP1/LHP2 load sharing ~50/50

All five radiator condenser legs working



- Radiator temperatures 1 thru 5 are all similar and tracking diurnal cycle
  - Indicates no blockage in the five condenser legs
- Side 1 and Side 2 show similar performance

VNIR bands deliver SNR margin (Side 1 and Side 2)

SNR - Side 1:		PSR (EOL)			IOT (BOL)		
Channel	Specification	Min	Mean	Max	Min	Mean	Max
VIS0.4_A047	261	553	720	760	804	**912**	1040
VIS0.5_A086	299	439	611	653	644	**761**	857
VIS0.6_A064	130	178	444	479	266	**470**	562
VIS0.8_A161	300	461	494	519	395	**563**	639
NIR1.3_A138	300	565	668	720	705	**791**	878
NIR1.6_A225	300	1166	1239	1338	1217	**1369**	1551

SNR - Side 2:		PSR (EOL)			IOT (BOL)		
Channel	Specification	Min	Mean	Max	Min	Mean	Max
VIS0.4_A047	261	586	713	752	791	**910**	1033
VIS0.5_A086	299	417	607	643	671	**758**	887
VIS0.6_A064	130	272	436	468	395	**488**	567
VIS0.8_A161	300	461	495	517	331	**562**	631
NIR1.3_A138	300	615	672	718	515	**790**	944
NIR1.6_A225	300	1165	1233	1299	1128	**1369**	1593

- PSR = Pre-Ship Review end-of-life (EOL) predicted performance based on pre-launch testing
- IOT = In-Orbit Test beginning-of-life (BOL) measured performance

MWIR and LWIR bands deliver NEdT margin (Side 1)

240K Scene

Side 1 NEdT @ 240K		PSR (EOL)	IOT (BOL)		
Channel	Spec	Max	Max	Mean	Min
IR3.8_A390	2.7K	1.4K	1.5K	**1.3K**	1.1K
IR6.3_A618	0.40K	0.053K	0.078K	**0.049K**	0.045K
IR6.9_A695	0.37K	0.046K	0.061K	**0.053K**	0.050K
IR7.3_A734	0.32K	0.077K	0.094K	**0.074K**	0.068K
IR8.7_A850	0.27K	0.055K	0.107K	**0.051K**	0.044K
IR9.6_A961	0.22K	0.044K	0.061K	**0.045K**	0.042K
IR10.5_A1035	0.21K	0.043K	0.064K	**0.042K**	0.039K
IR11.2_A1120	0.19K	0.043K	0.043K	**0.039K**	0.034K
IR12.3_A1230	0.26K	0.038K	0.148K	**0.034K**	0.031K
IR13.3_A1333	0.48K	0.091K	0.326K	**0.066K**	0.056K

300K Scene

Side 1 NEdT @ 300K		PSR (EOL)	IOT (BOL)		
Channel	Spec	Max	Max	Mean	Min
IR3.8_A390	0.18K	0.11K	0.10K	**0.09K**	0.08K
IR6.3_A618	0.10K	0.015K	0.018K	**0.011K**	0.010K
IR6.9_A695	0.10K	0.018K	0.017K	**0.015K**	0.014K
IR7.3_A734	0.10K	0.029K	0.028K	**0.023K**	0.021K
IR8.7_A850	0.10K	0.025K	0.041K	**0.019K**	0.017K
IR9.6_A961	0.10K	0.024K	0.027K	**0.020K**	0.019K
IR10.5_A1035	0.10K	0.029K	0.031K	**0.020K**	0.019K
IR11.2_A1120	0.10K	0.025K	0.023K	**0.021K**	0.018K
IR12.3_A1230	0.12K	0.025K	0.085K	**0.020K**	0.018K
IR13.3_A1333	0.30K	0.056K	0.200K	**0.041K**	0.034K

MWIR and LWIR bands deliver NEdT margin (Side 2)

240K Scene

Side 2 NEdT @ 240K		PSR (EOL)	IOT (BOL)		
Channel	Spec	Max	Max	Mean	Min
IR3.8_A390	2.7K	1.5K	2.51K	**1.34K**	1.23K
IR6.3_A618	0.40K	0.058K	0.074K	**0.051K**	0.047K
IR6.9_A695	0.37K	0.046K	0.075K	**0.054K**	0.049K
IR7.3_A734	0.32K	0.069K	0.097K	**0.076K**	0.069K
IR8.7_A850	0.27K	0.054K	0.061K	**0.050K**	0.045K
IR9.6_A961	0.22K	0.047K	0.051K	**0.044K**	0.040K
IR10.5_A1035	0.21K	0.046K	0.077K	**0.043K**	0.040K
IR11.2_A1120	0.19K	0.047K	0.147K	**0.038K**	0.034K
IR12.3_A1230	0.26K	0.072K	0.038K	**0.034K**	0.030K
IR13.3_A1333	0.48K	0.096K	0.130K	**0.065K**	0.058K

300K Scene

Side 2 NEdT @ 300K		PSR (EOL)	IOT (BOL)		
Channel	Spec	Max	Max	Mean	Min
IR3.8_A390	0.18K	0.14K	0.17K	**0.09K**	0.08K
IR6.3_A618	0.10K	0.016K	0.017K	**0.012K**	0.011K
IR6.9_A695	0.10K	0.018K	0.021K	**0.015K**	0.014K
IR7.3_A734	0.10K	0.028K	0.029K	**0.023K**	0.021K
IR8.7_A850	0.10K	0.024K	0.024K	**0.019K**	0.017K
IR9.6_A961	0.10K	0.024K	0.023K	**0.020K**	0.018K
IR10.5_A1035	0.10K	0.025K	0.037K	**0.021K**	0.019K
IR11.2_A1120	0.10K	0.029K	0.078K	**0.020K**	0.018K
IR12.3_A1230	0.12K	0.044K	0.022K	**0.020K**	0.017K
IR13.3_A1333	0.30K	0.062K	0.079K	**0.040K**	0.036K

VNIR dynamic range L_{max} meets requirements with margin (Side 1 and Side 2)

Dynamic Range - Side 1		PSR (BOL)	IOT (BOL)		
Channel	Specification	Min	Min	Mean	Max
VIS0.4_A047	720	745	894	**906**	927
VIS0.5_A086	710	1001	1073	**1094**	1119
VIS0.6_A064	620	857	1216	**1245**	1308
VIS0.8_A161	320	360	766	**776**	799
NIR1.3_A138	114	632	345	**353**	363
NIR1.6_A225	77	78	94	**95**	97

Dynamic Range - Side 2		PSR (BOL)	IOT (BOL)		
Channel	Specification	Min	Min	Mean	Max
VIS0.4_A047	720	756	897	**907**	922
VIS0.5_A086	710	996	1075	**1096**	1124
VIS0.6_A064	620	857	1215	**1245**	1302
VIS0.8_A161	320	357	753	**770**	796
NIR1.3_A138	114	623	343	**354**	366
NIR1.6_A225	77	77	94	**95**	96

L_{max} in $W/m^2/sr/\mu m$

BOL represents worst case over mission life for dynamic range

MWIR and LWIR dynamic range T_{max} meets requirements with margin (Side 1 and Side 2)

Side 1

Dynamic Range - Side 1		PSR (BOL)	IOT (BOL)		
Channel	Spec	Min	Min	Mean	Max
IR3.8_A390	400K	>410K*	435K	**436K**	439K
IR6.3_A618	300K	332K	332K	**334K**	335K
IR6.9_A695	300K	336K	336K	**338K**	340K
IR7.3_A734	320K	365K	368K	**370K**	377K
IR8.7_A850	330K	393K	398K	**404K**	410K
IR9.6_A961	300K	361K	333K	**369K**	375K
IR10.5_A1035	330K	380K	359K	**382K**	385K
IR11.2_A1120	330K	399K	385K	**403K**	407K
IR12.3_A1230	330K	406K	356K	**410K**	415K
IR13.3_A1333	305K	>410K*	561K	**618K**	626K

Side 2

Dynamic Range – Side 2		PSR (BOL)	IOT (BOL)		
Channel	Spec	Min	Min	Mean	Max
IR3.8_A390	400K	>410K*	435K	**436K**	439K
IR6.3_A618	300K	328K	332K	**333K**	335K
IR6.9_A695	300K	331K	335K	**337K**	339K
IR7.3_A734	320K	363K	366K	**370K**	373K
IR8.7_A850	330K	390K	398K	**404K**	409K
IR9.6_A961	300K	356K	359K	**365K**	371K
IR10.5_A1035	330K	375K	378K	**380K**	383K
IR11.2_A1120	330K	395K	397K	**401K**	403K
IR12.3_A1230	330K	402K	379K	**410K**	414K
IR13.3_A1333	305K	>410K*	508K	**615K**	627K

*410K is the Max value reported by analysis software used during ground system test

BOL represents worst case over mission life for dynamic range

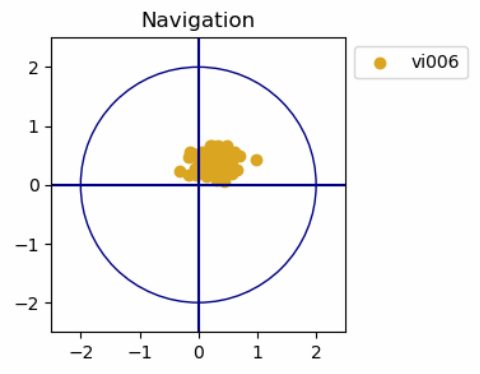
Calibration repeatability has large margin against requirements

Calibration Repeatability		% Gain Change Back-to-Back		% Gain Change 24-hrs	
Channel	Spec	Side 1 AVG	Side 2 AVG	Side 1 AVG	Side 2 AVG
VIS04_A047	0.5%	-0.0128%	0.062%	See Note	0.0639%
VIS05_A086	0.5%	-0.0101%	0.070%	See Note	0.0628%
VIS06_A064	0.5%	-0.0141%	0.062%	See Note	0.0611%
VIS08_A161	0.5%	0.00368%	0.073%	See Note	0.0650%
NIR13_A138	0.5%	0.00272%	0.052%	See Note	0.0460%
NIR16_A225	0.5%	Saturated	0.069%	See Note	0.0454%
IR3.8_A390	0.5%	0.000090%	-0.000454%	0.0091%	-0.0923%
IR6.3_A618	0.5%	0.000018%	-0.000448%	0.0024%	-0.0858%
IR6.9_A695	0.5%	0.000079%	-0.000378%	0.0112%	-0.0724%
IR7.3_A734	0.5%	-0.000170%	-0.000452%	-0.0246%	-0.0866%
IR8.7_A850	0.5%	-0.000309%	-0.000468%	-0.0447%	-0.0895%
IR9.6_A961	0.5%	-0.000607%	-0.000329%	-0.0875%	-0.0630%
IR10.5_A1035	0.5%	0.000019%	-0.000350%	0.0025%	-0.0670%
IR11.2_A1120	0.5%	-0.000865%	-0.000647%	-0.1246%	-0.1237%
IR12.3_A1230	0.5%	-0.000680%	-0.000913%	-0.0908%	-0.1744%
IR13.3_A1333	0.5%	-0.000781%	-0.001680%	-0.1129%	-0.3214%

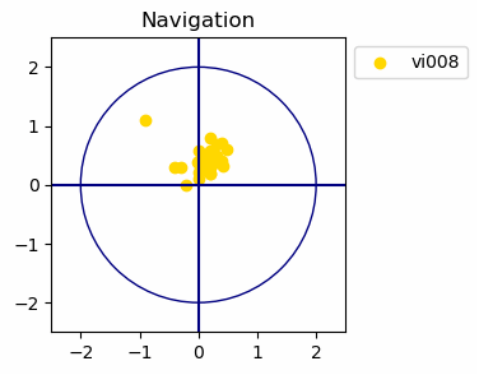
Note: Due to NIR16 saturation on first day's Solar Cal (Side 1), integration factor changed from 10 to 9 for second day's Solar Cal (Side 1). Hence, cannot compute day-to-day comparison for Side 1.

Image Navigation and Registration (INR)
IOT results show accuracy and stability

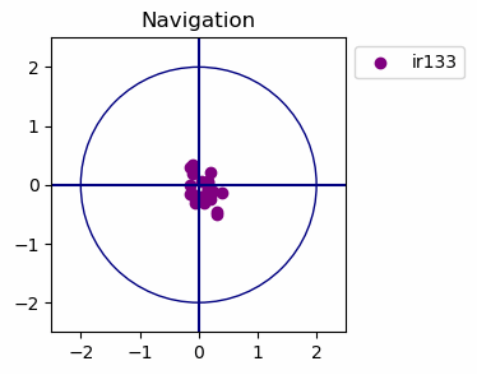
VIS0.6 (0.5 km)



VIS0.8 (1 km)



IR13.3 (2 km)



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INR results provided by Dr. Ki-Lyeok Yong of KARI

INR performance meets requirements with margin

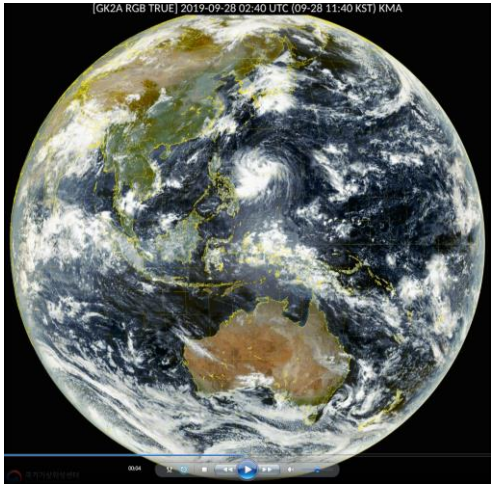
Requirement Items	Resolution (km)	Requirement		Spec /pixel	Performance: abs(mean)+3σ [pixel]	Ref. channels at 20190607~09
		(km,3σ)	(μrad,3σ)			
Absolute Navigation	0.50	0.75	21	1.5	**< 0.9 pixel**	VIS06
	1.00	1.50	42	1.5	**< 1.0 pixel**	VIS04,05,08 avg.
	2.00	3.00	82	1.5	**< 1.1 pixel**	All IR.
Frame-to-Frame Registration	0.50	1.35	37	2.7	**< 0.4 pixel**	VIS06
	1.00	1.35	37	1.3	**< 0.3 pixel**	VIS04,05,08 avg.
	2.00	1.35	37	0.7	**< 0.3 pixel**	All IR avg.
Within Frame Registration	0.50	1.35	37	2.7	**< 0.4 Pixel**	VIS06
		0.90	25	1.8	**< 0.7 pixel**	VIS06
	1.00	2.10	58	2.1	**< 0.7 Pixel**	VIS04,05,08 avg.
		1.78	49	1.8	**< 0.9 pixel**	VIS04,05,08 avg.
	2.00	4.17	115	2.1	**< 0.9 pixel**	All IR avg.
		3.57	98	1.8	**< 0.9 pixel**	All IR avg.
Swath-to-Swath Registration	0.50	0.38	10	0.8	**< 0.6 pixel**	VIS06
	1.00	0.75	21	0.8	**< 0.8 pixel**	VIS04,05,08 avg.
	2.00	1.50	41	0.8	**< 0.7 pixel**	All IR avg.
Channel-to-Channel Registration	0.50	3.00	82	6.0	**< 1.1 pixel**	VIS06 – All others avg.
	1.00	3.00	82	3.0	**< 1.1 pixel**	VIS06 – VIS04,05,08 avg.
	2.00	3.00	82	1.5	**< 1.1 pixel**	VIS06 – All IR avg.

INR results provided by Dr. Ki-Lyeok Yong of KARI

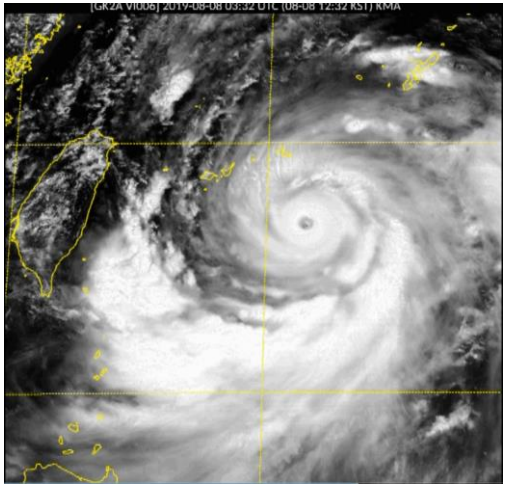
AMI delivering expected high quality imagery for weather and environmental monitoring

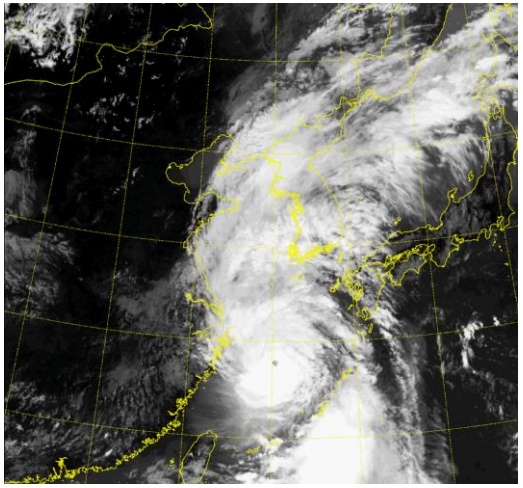
- Loop heat pipes started up first time and entire thermal subsystem operating as designed
- Collecting Full Disk, Extended Local Area, and Local Area scenes
- Delivering significant margin against SNR and NEdT requirements
- Meeting required dynamic range with margin
- Stable calibration
- Precise navigation

AMI images courtesy of KMA



True color RGB


Typhoon Lekima


Typhoon Lingling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