HARRIS®

7.1 Advanced Himawari Imager (AHI) Design and Operational Flexibility

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AHI – Paradigm Shift in Geostationary Weather Imaging

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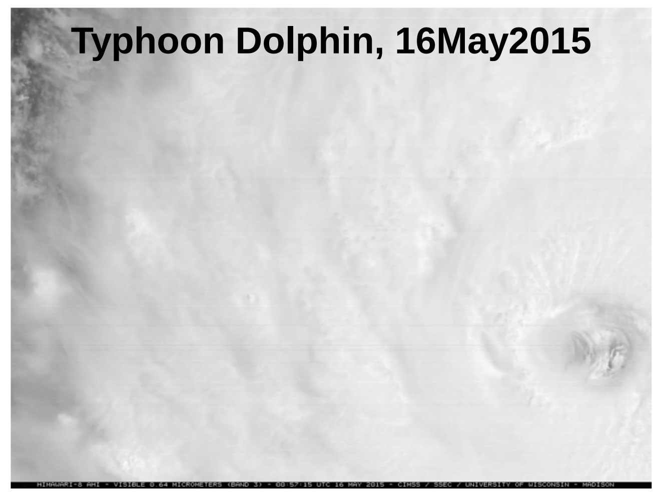
Better spectral, spatial, and temporal resolution improves quality and number of critical data products

Improved calibration targets yields more accurate images

Interleaved scene collection provides operational flexibility

- Himawari-8: Full Disk, Japan, and rapid scan interleaved
- Himawari-7 (MTSAT-2): interrupt Full Disk for rapid scan of storms
- **One instrument** – multiple scenes of different sizes, locations, and repetitions seamlessly interleaved

AHI-8 lunar image courtesy of JMA



Data from JMA, Video courtesy of UW/SSEC, CIMSS

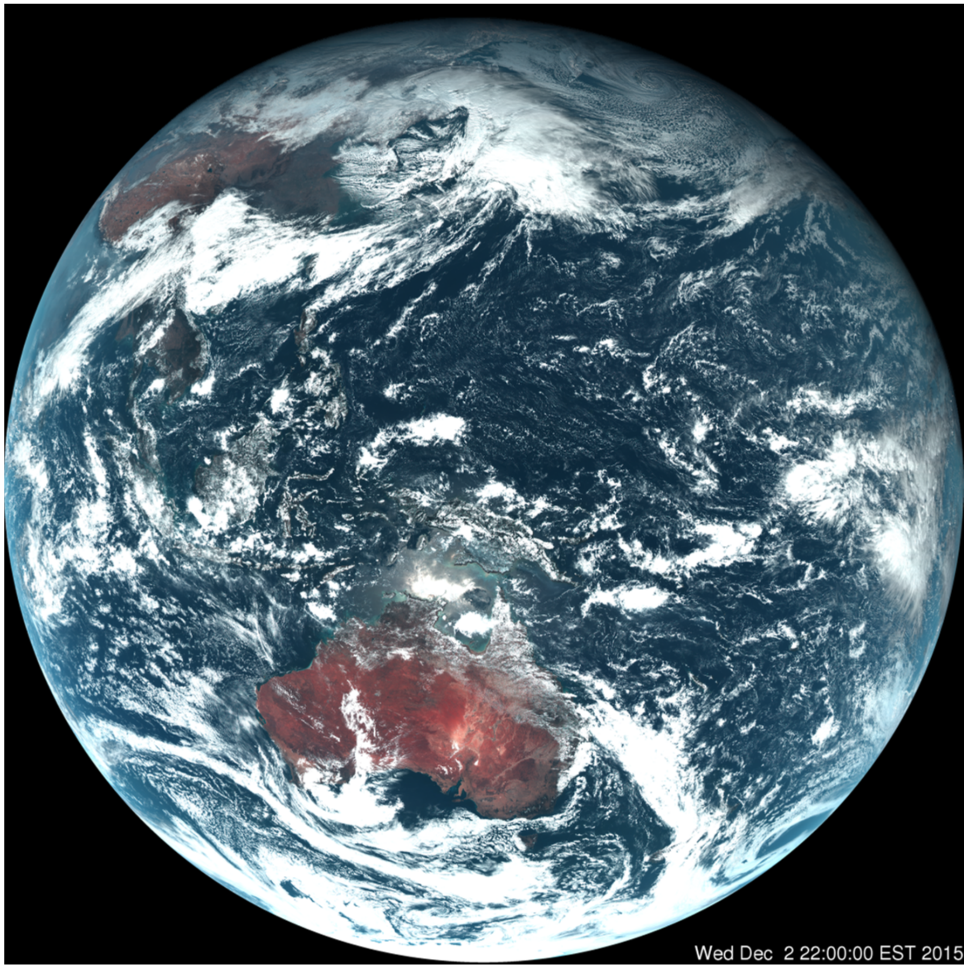
AHI Design

Calibration Targets

Operational Flexibility

Summary

AHI-8 (photo by Harris)



AHI-8 True Color (RGB) Image 3Dec2015 12:00 JST
(Data from JMA, Processing by Harris)

AHI-8: First Next Generation Geostationary Imager On Orbit

ABI imagers supporting three missions:

- GOES-R (ABI), Himawari (AHI), GEO-KOMPSAT-2A (AMI)

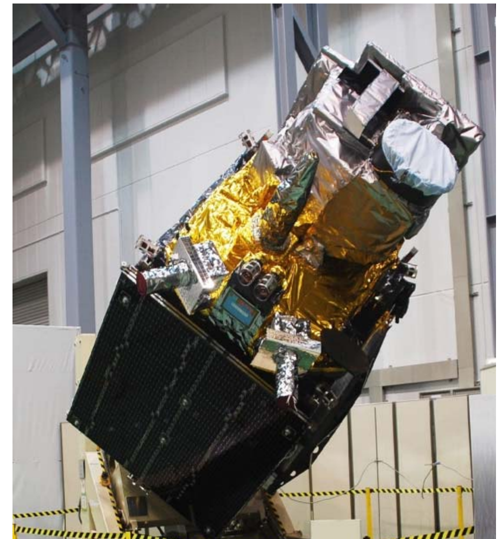
Four flight models delivered

- ABI PFM: Integrated on GOES-R spacecraft
- **AHI-8: Operating on orbit (Himawari-8)**
- ABI FM2: Delivered
- AHI-9: Integrated on Himawari-9 spacecraft

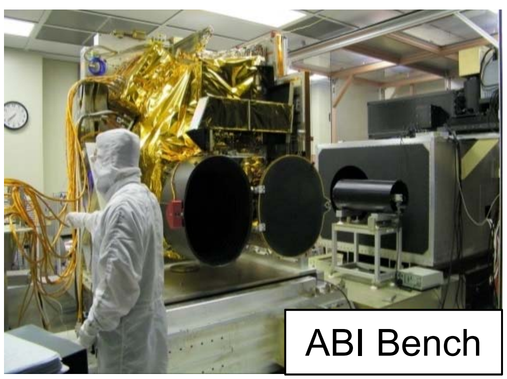
Three more in production at Harris

- ABI FM3, ABI FM4, AMI

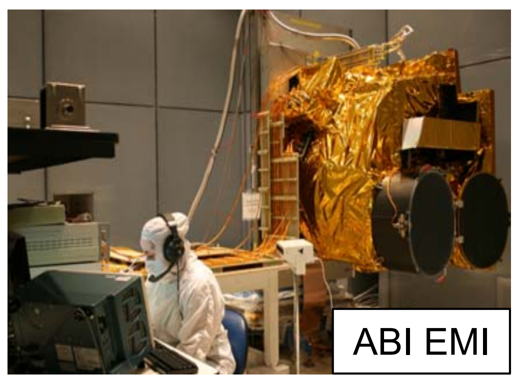
Himawari 8



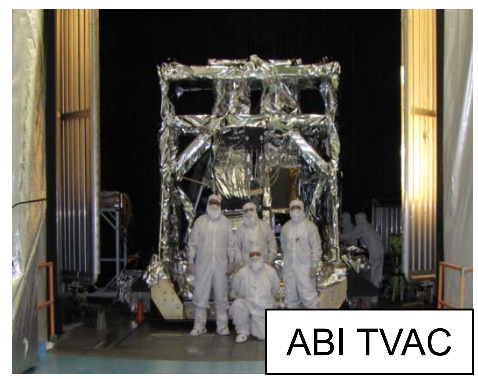
Courtesy of Mitsubishi Electric Corporation



ABI Bench



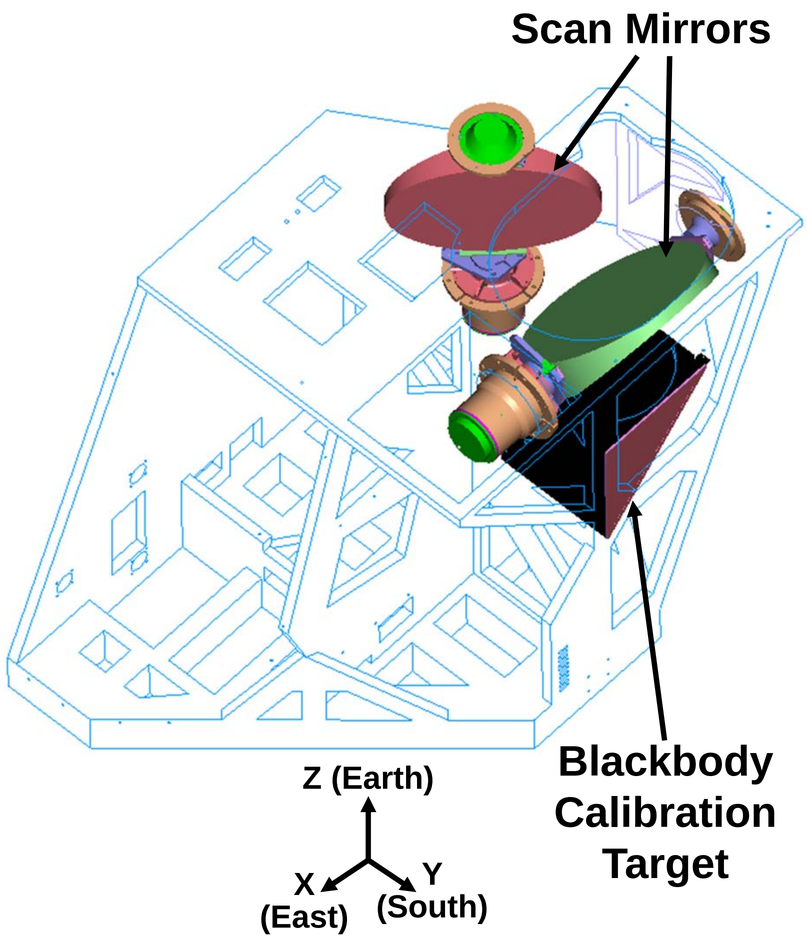
ABI EMI



ABI TVAC

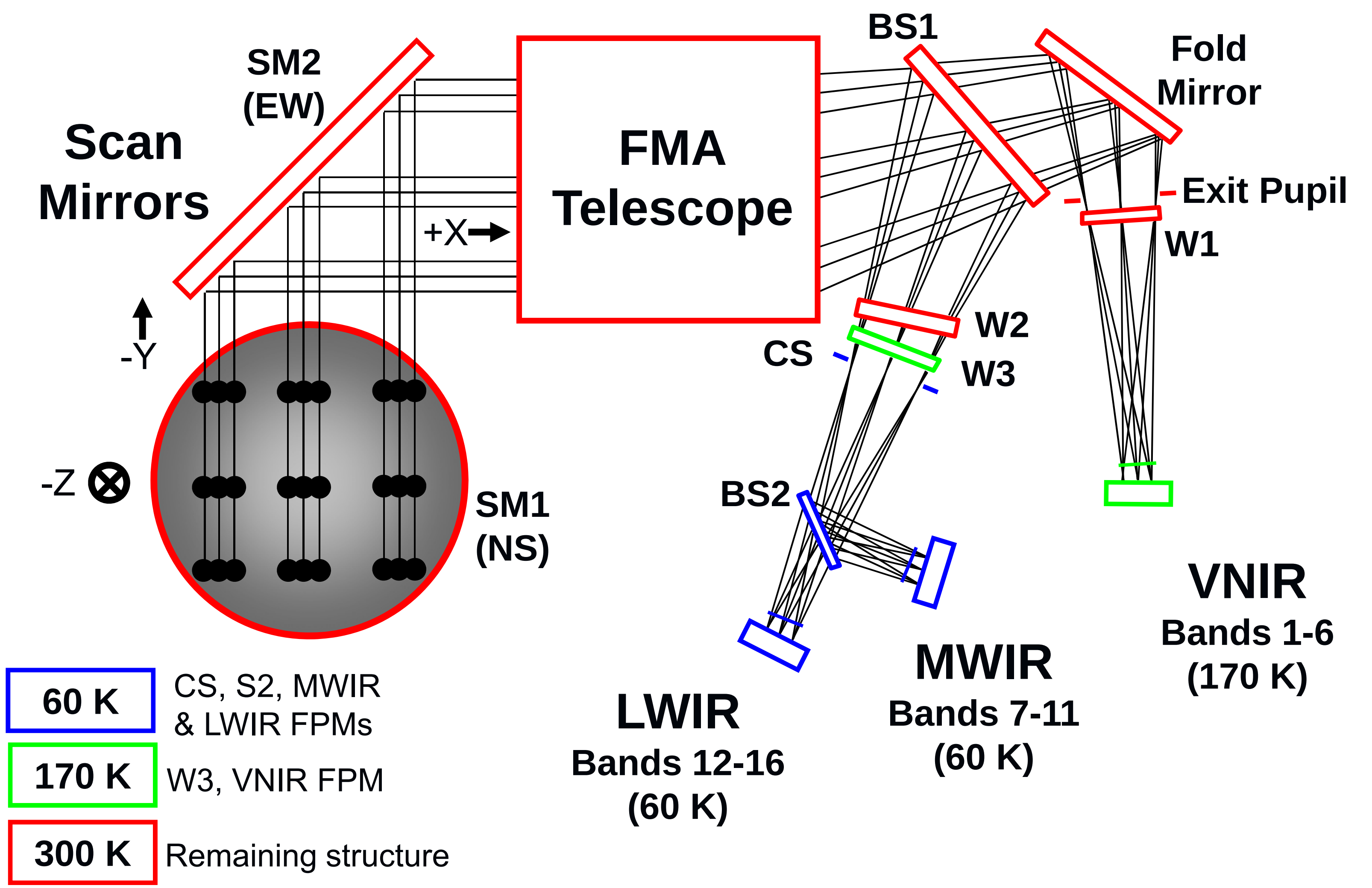
AHI's 2-Mirror Scanner Key to Operational Flexibility

- Scans parallel to equator without rotating image
  - 100% scan coverage efficiency
- Lowest inertia and power
- 2x EW <u>and</u> NS mechanical-to-optical motion
- Inherently polarization compensating
  - At nadir, polarization introduced by reflection off NS scanner is canceled by reflection off of EW scanner
  - Blackbody located anti-nadir, so same observing geometry applies



Delivers fast slews and accurate slow scans with minimal disturbance

AHI Optical Architecture: Simple Solution to Mission Needs



AHI Channels Optimized for JMA's Mission

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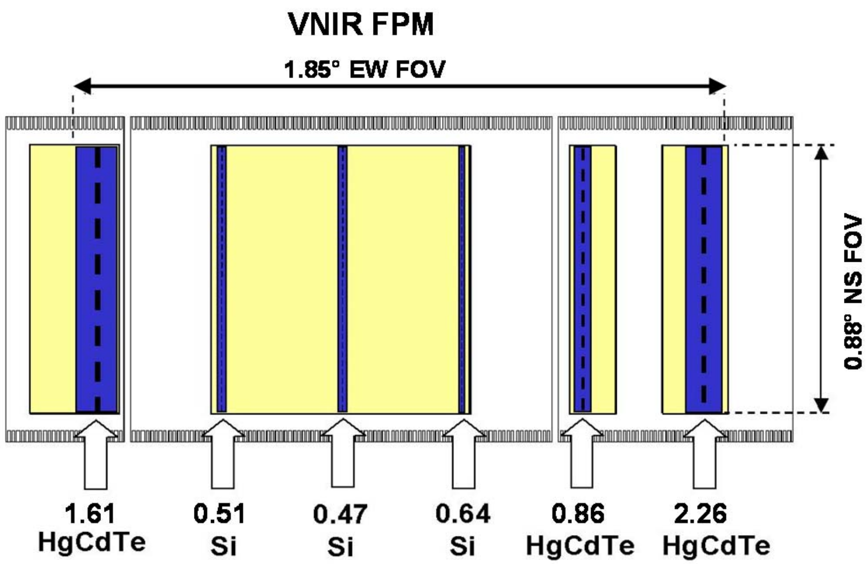
FPM	FPA	Resolution (km)	AHI Band #	Nominal Wavelength (μm)		
				ABI	AHI	AMI
VNIR	A047	1	1	0.47	0.47	0.47
	A086	1	2	0.86	0.51	0.51
	A064	0.5	3	0.64	0.64	0.64
	A161	1	4	1.61	0.86	0.86
	A138	2	5	1.38	1.61	1.38
	A225	2	6	2.25	2.26	1.61
MWIR	A390	2	7	3.9	3.9	3.9
	A618	2	8	6.185	6.185	6.185
	A695	2	9	6.95	6.95	6.95
	A734	2	10	7.34	7.34	7.34
	A850	2	11	8.5	8.5	8.5
LWIR	A961	2	12	9.61	9.61	9.61
	A1035	2	13	10.35	10.35	10.35
	A1120	2	14	11.2	11.2	11.2
	A1230	2	15	12.3	12.3	12.3
	A1330	2	16	13.3	13.3	13.3

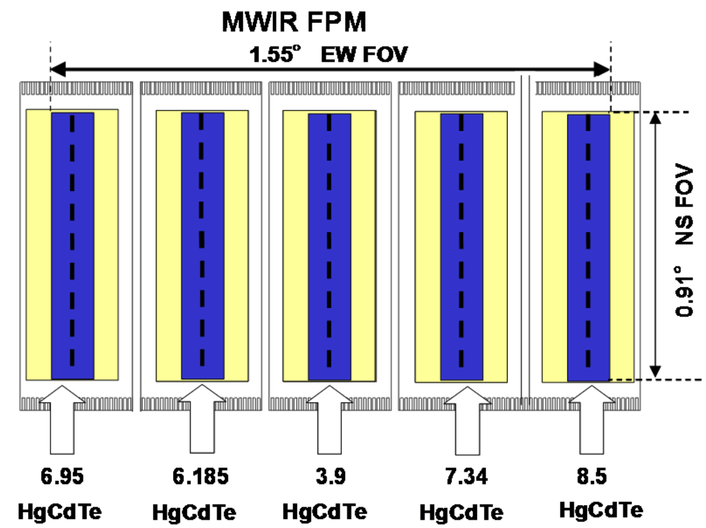
- AHI & AMI added 1-km 0.51 μm channel (green)
  - True 3-color visible images
  - Improved ocean images
- Retained 1-km 0.865 μm channel
  - Shifted to HgCdTe detector array
- Changed 1.61 μm channel to 2-km
- Eliminated one NIR channel
  - AHI: 1.378 μm
  - AMI: 2.25 μm

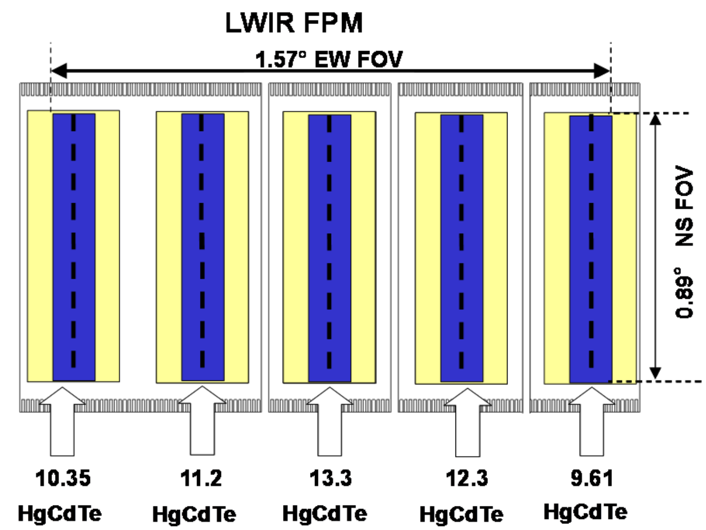
Color Key:

Not in ABI
Different FPA

Focal Plane Modules Spatially Separate Channels in Scan Direction



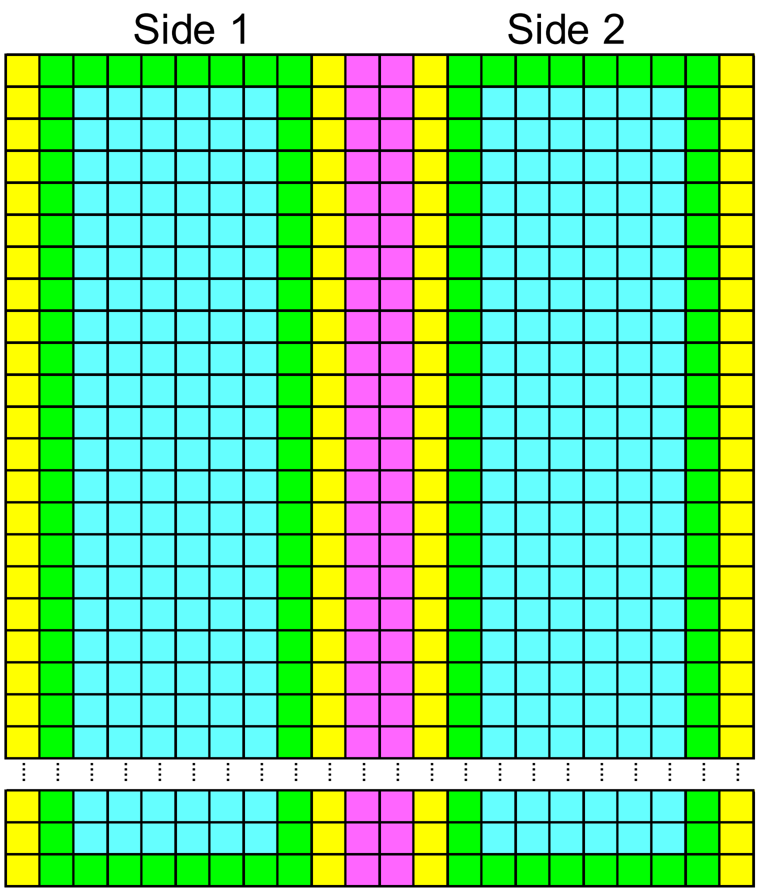




Acronyms:

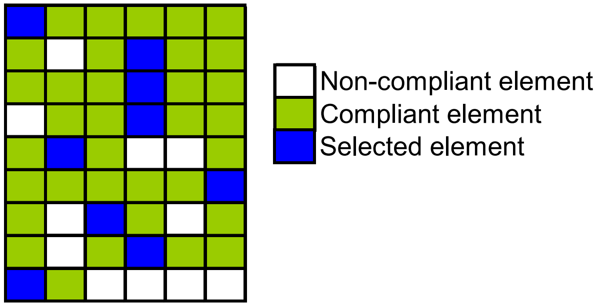
- FPM = Focal Plane Module
  - VNIR = Visible and Near-Infrared
  - MWIR = Midwave Infrared
  - LWIR = Longwave Infrared
- FPA = Focal Plane Array
- FOV = Field of View

Detector Selection Capability Provides Operational Redundancy and Optimization



Externally: Line array
Internally: 2D array

Select best element in each row



Color Key:
- Ground
- Guard
- Active Detector Element
- Separation

Requirement: one operational element per downlinked row per side

Best Detector Select (BDS) Map Can Be Updated In Orbit

All detector elements characterized using on-board targets, spacelooks, and/or stable vicarious calibration targets

- Zero radiance and "typical" radiance scenes
- Performed for all detector elements in each column

"Best" detector element in each row selected

- Operable – i.e. responds to light
- Median quantum efficiency
- Low noise – but not unrealistically low
- No popcorn noise
- Minimal long term drift

Updated BDS map uploaded to instrument

Detector Elements: IFOV, Rows, Columns

Channels (wavelengths in μm)	Resolution (km)	IFOV (μrad)		Rows	Columns
		NS	EW		
0.64	0.5	10.5	12.4	1460	3
0.47, 0.51	1	22.9	22.9	676	3
0.86	1	22.9	22.9	676	6
1.61, 2.26	2	42.0	51.5	372	6
3.9, 6.18, 6.95, 7.34, 8.5, 9.61	2	47.7	51.5	332	6
10.35, 11.2, 12.3, 13.3	2	38.1	34.3	408	6

Resolution = pixel spacing of final image after resampling

- 1 km = 28 μrad

77,400 detector elements total; 7,856 downlinked

Agenda

AHI Design

Calibration Targets

Operational Flexibility

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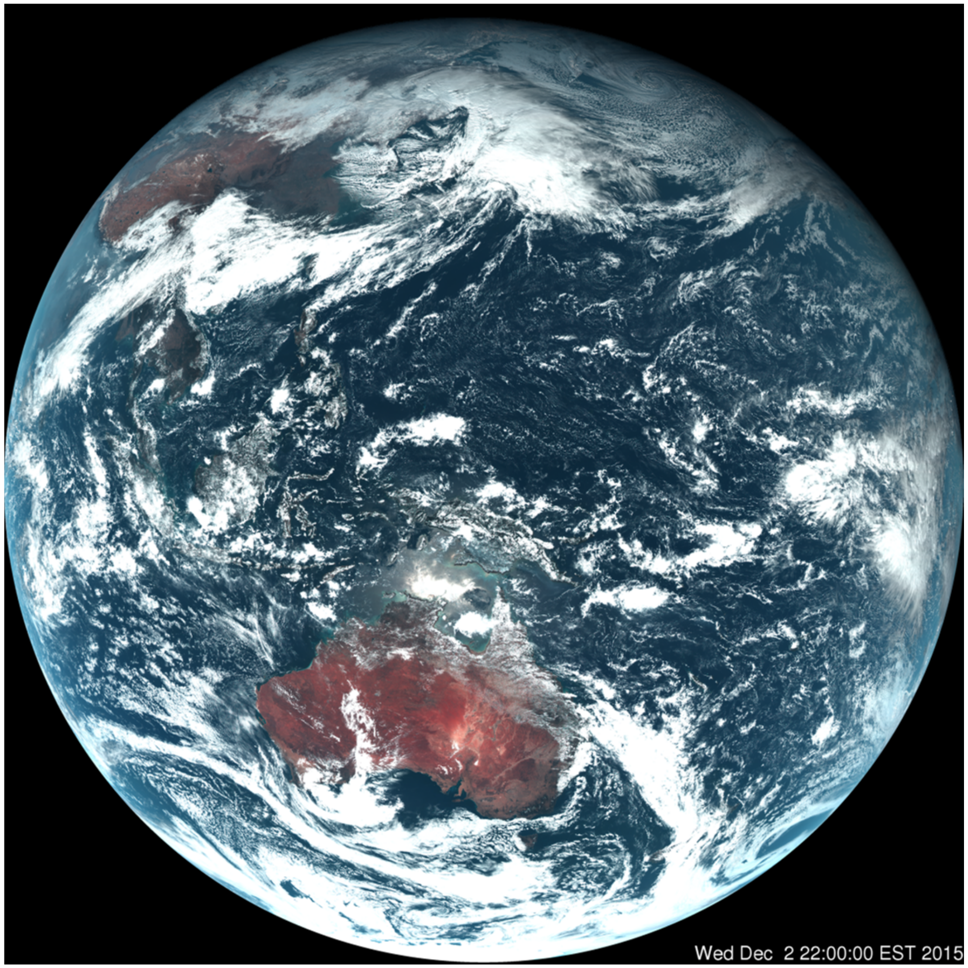
AHI-8 (photo by Harris)



AHI-8 True Color (RGB) Image 3Dec2015 12:00 JST
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Advanced Imagers Pose Calibration Challenges

Large number of detector elements

- Much more to be calibrated
- Increased risk of striping

Large FOV

- Much larger than traditional vicarious calibration scenes

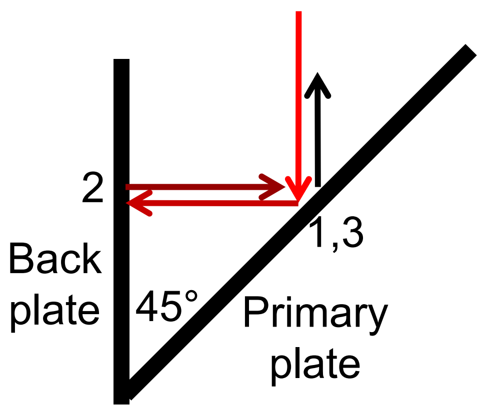
Greater calibration accuracy expectations

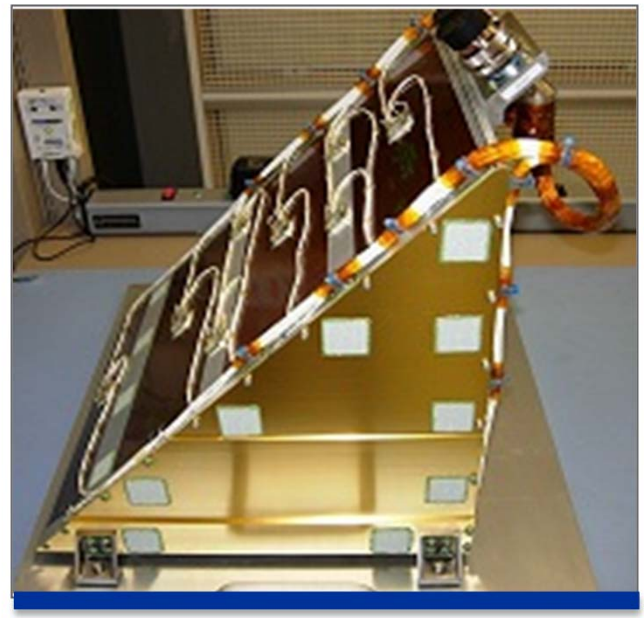
Parameter	Units	Himawari-7	AHI	Ratio
Channels		5	16	3.2
Detector Elements: total		24	77,400	3225
Detector Elements: downlinked		16	7,856	491
NS FOV: max channel	µrad	274	16,311	60
EW FOV: max FPM	µrad	140	33,203	237

Harris' ABI-class imager provides calibration solutions

Internal Calibration Target (ICT) Accurately Calibrates Emissive Channels On-orbit

- 3-bounce blackbody based on patented 5-bounce Harris design
  - Trap configuration and specular black paint guarantees very high emissivity (>0.995)
  - Robust against stray light and contamination
  - NIST-traceable
- Built, tested, and demonstrated



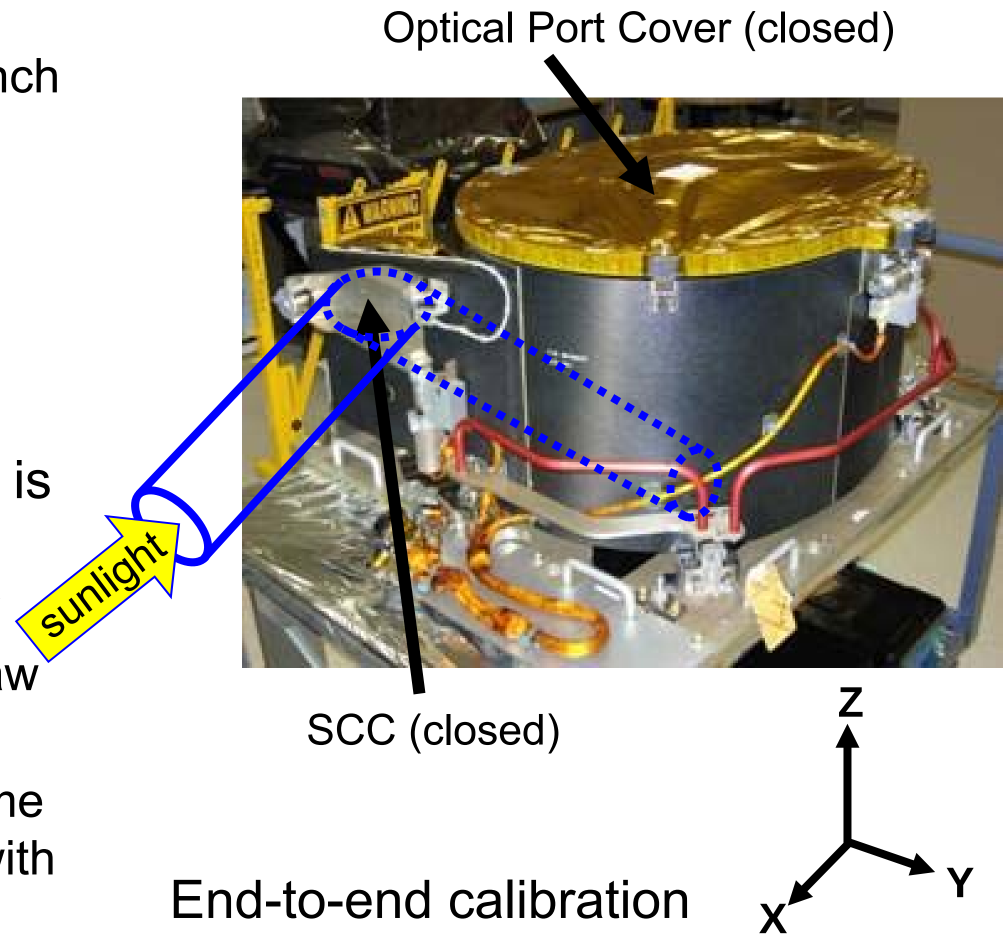


ABI PFM 3-bounce blackbody

Full aperture,
end-to-end calibration

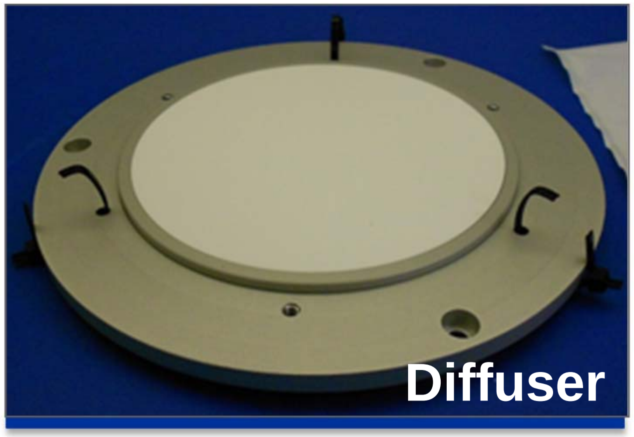
Solar Calibration Assembly Delivers On-Orbit Calibration Over Mission Life

- Optical Port Cover:
  - One time deployable
  - Keeps payload clean during launch and outgassing
- Solar Cal Cover (SCC):
  - Open only when calibrating
  - Closed rest of time to preserve cleanliness
- Solar Calibration Target (SCT) is Spectralon™ diffuser
  - Calibration can occur any day of year at 6:00 a.m. (6:00 p.m. if yaw flipped)
  - Collected with 10x integration time to obtain ~100% albedo signal with sub-aperture target



End-to-end calibration

Solar Calibration Subsystem Built, Tested, and Qualified for ABI



Design optimized
for minimum
calibration uncertainty

Optical Port Sunshield Assembly
Stray Light Baffles

Solar Calibration Port

Electronic Calibration (ECAL) Verifies Linearity Throughout Mission

End-to-end test collects radiance from on-board targets (ICT & SCT) while varying integration time multiplicative factor

- 0.5x to 16.5x in 33 steps of 0.5x
- 0.0625x to 2x in 32 steps of 0.0625x (1/16th)
- 1x to 22x in 22 steps of 1x

Integration time proportional to integrated photons

- More easily controlled than injected voltage levels and tests much more of analog-to-digital signal processing chain

All integration times collected with all targets and all channels

- First set typically used for λ < 3 μm (bands 1-6) when viewing SCT
  - Nominal SCT observation performed with integration factor of 10x
- Second set typically used for λ > 5 μm (bands 8-16) when viewing ICT
- Third set typically used for λ = 3.9 μm (band 7) when viewing ICT

ECAL can also be used when observing space or any other external scene

Operational Calibration Routinely Performed

Spacelook collected at least every 30 s

- First data collected in every operational timeline
- Automatically collected as part of every Full Disk swath
  - Either at start or end, depending upon scan direction and location of sun
  - Can be autonomously collected on side opposite the sun
- Explicitly scheduled in timeline as needed

Blackbody (ICT) observed at start of each timeline

- Hence, collected every 10 minutes
- Ensures all imagery collected during timeline can be radiometrically calibrated

Solar calibration scheduled when needed

- Primary cause of VNIR calibration drift is throughput loss due to molecular contamination and radiation

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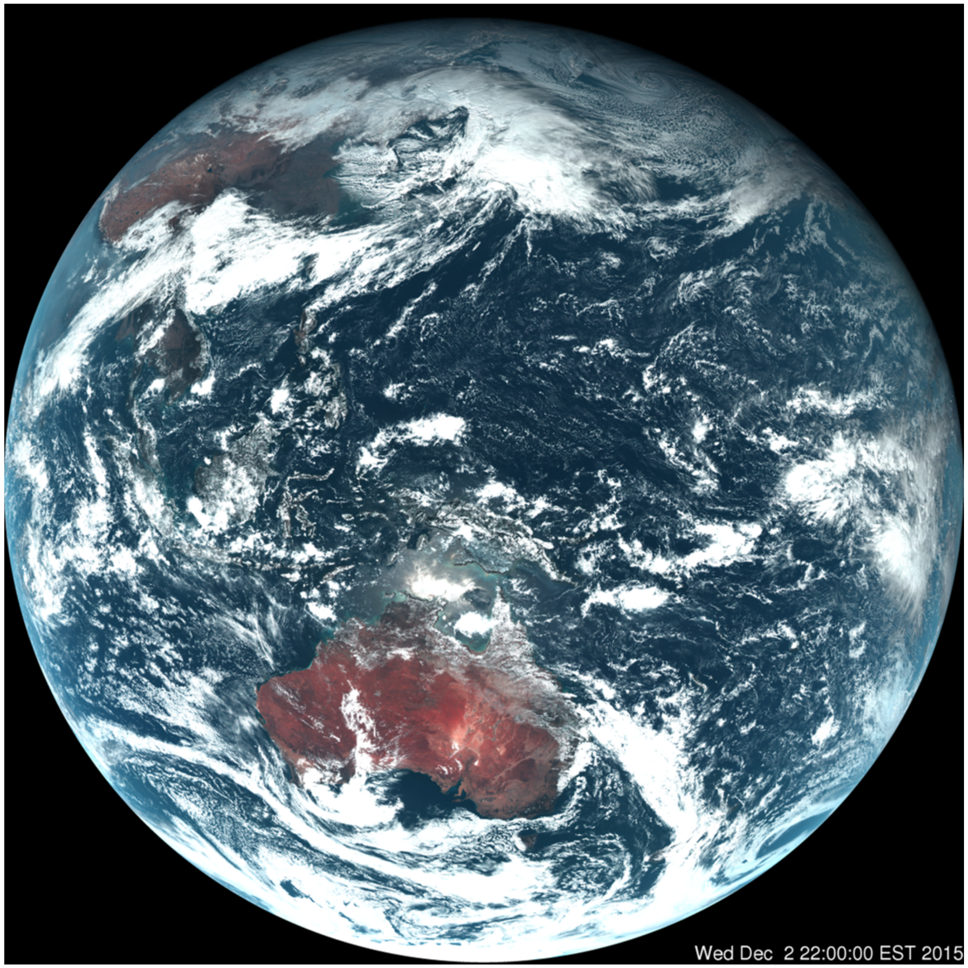

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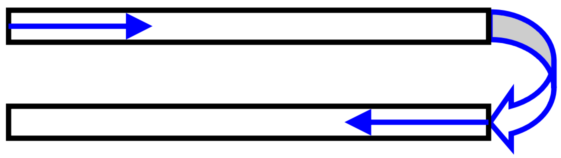
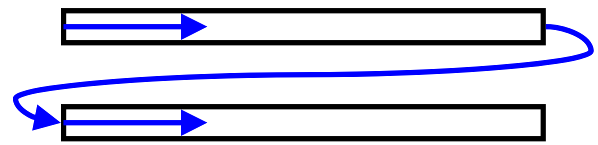
(Data from JMA, Processing by Harris)

On-Orbit Operations: Raster Scan vs. Boustrophedonic

Himawari-7 Imager	AHI
Boustrophedonic	Default = Raster Scan
("as the ox plows")	Capable of boustrophedonic





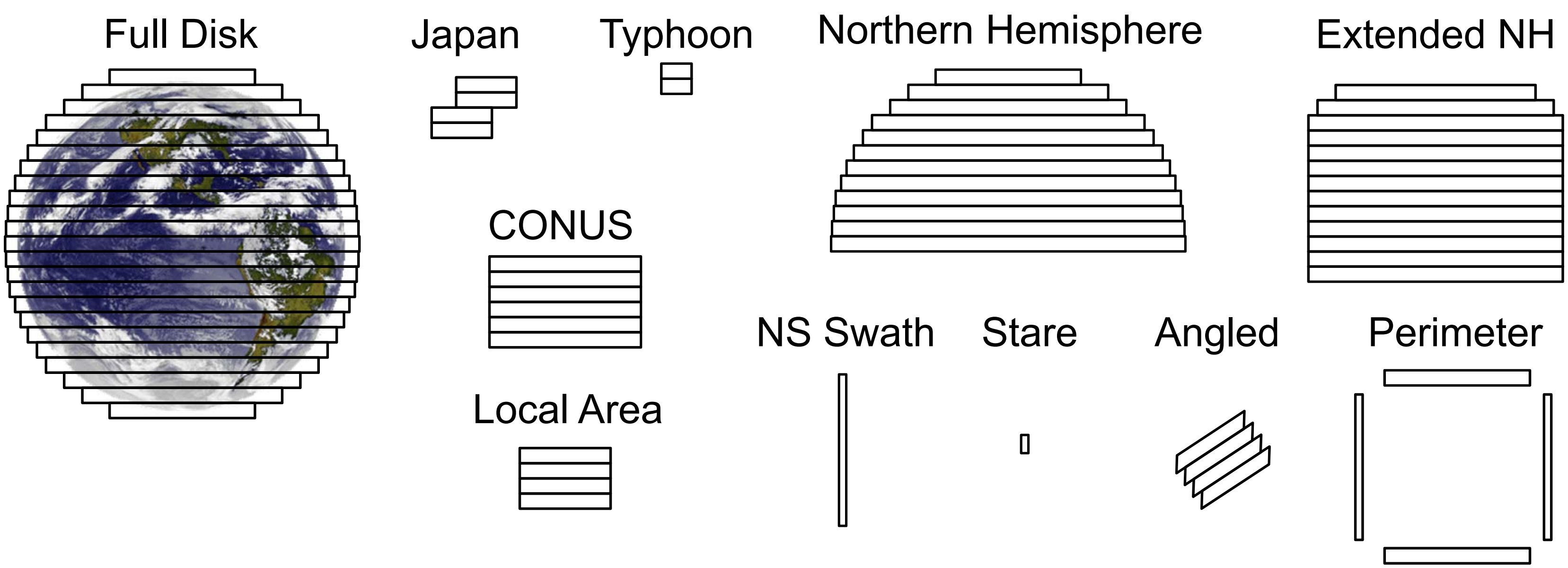
Raster scan results in higher quality images

- Constant time interval across swath boundary

Only possible because of Harris' advanced scanner

- Smooth, fast slews at low power with little spacecraft disturbance

Harris' ABI-Class Imagers Offer Unique Scan Flexibility



NS swath & stare support vicarious calibration for GSICS

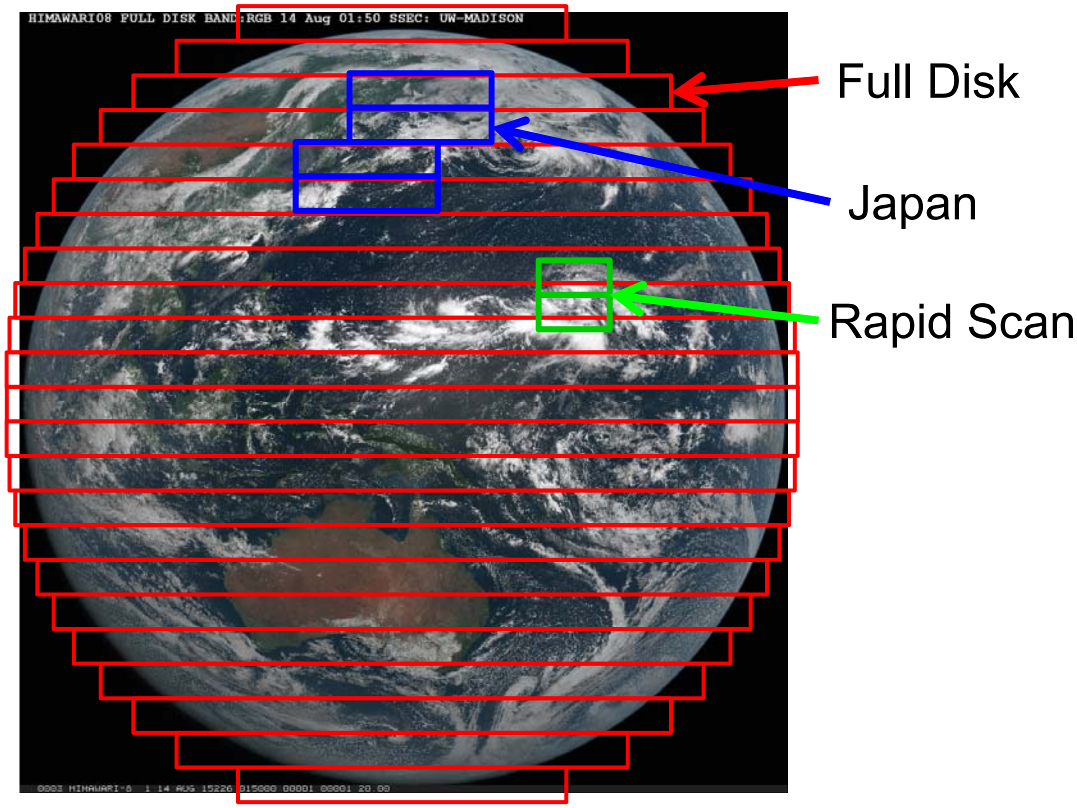
Angled swaths can compensate for spacecraft yaw

- FPM is not rotated; hence coverage decreases as tilt increases

All scenes and timelines can be updated in orbit

AHI Unique Interleaved Scene Collection Delivers Full Disk and Regional Scenes

- Himawari Observation Timeline
  - Full Disk: every 10 minutes
  - Japan: every 2.5 minutes
  - Rapid Scan (RO3): every 2.5 minutes
    - Typhoons, calibration, etc.
- Himawari Housekeeping with Solar Calibration Timeline
  - Solar Calibration
  - Japan: every 2.5 minutes
  - Rapid Scan: every 2.5 minutes
- Blackbody, spacelooks, & landmarks included in all timelines for radiometric calibration and navigation



AHI-8 data from JMA, Image courtesy of UW/SSEC CIMSS

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

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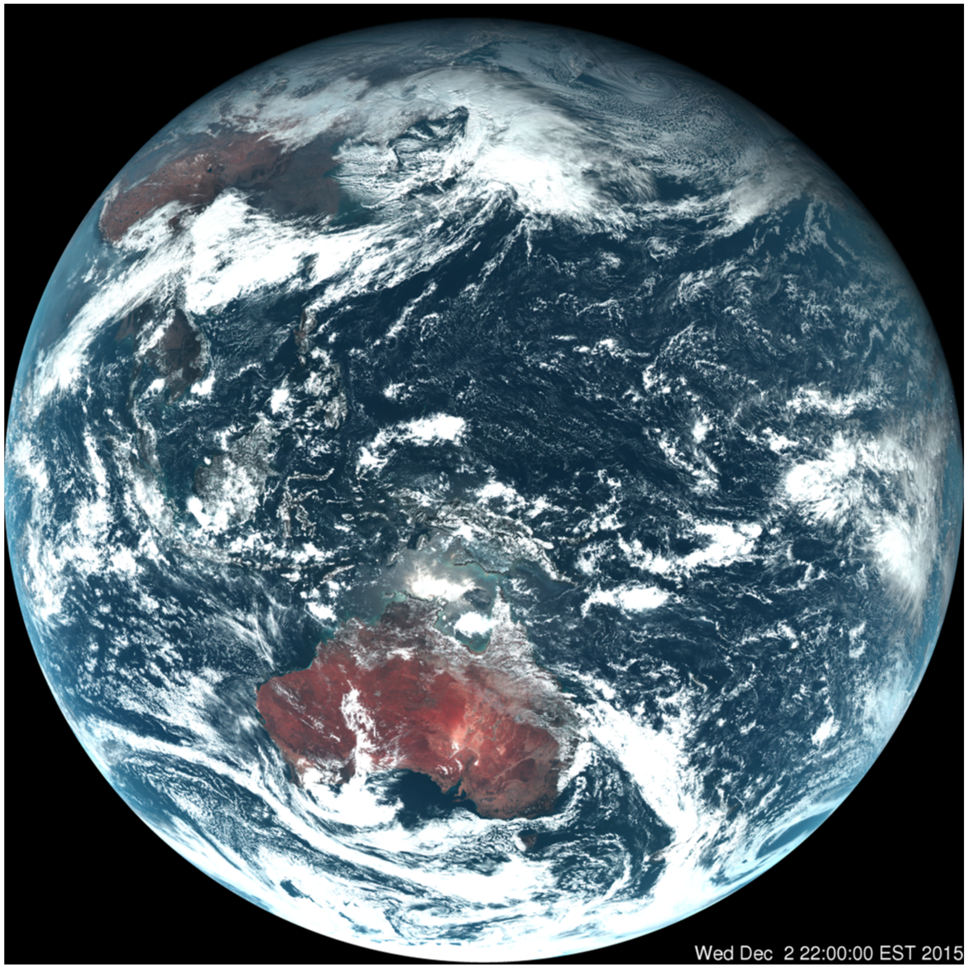

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Summary

AHI-8 is the first of the next generation geostationary weather imagers in operation

Provides improved spectral, spatial and temporal resolution

New on-board targets improve radiometric calibration

Paradigm shift in image collection delivers regional and rapid scan images without impacting Full Disk cadence

- Due to scanner performance and innovative scan algorithm

Operational flexibility provides unique vicarious calibration capability

AHI-8: The Future is Now!

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Appreciation to NOAA, JMA, MELCO, and UW/SSEC CIMSS