Development status of the Second-generation Global Imager (SGLI) on GCOM-C1

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GCOM PI Workshop

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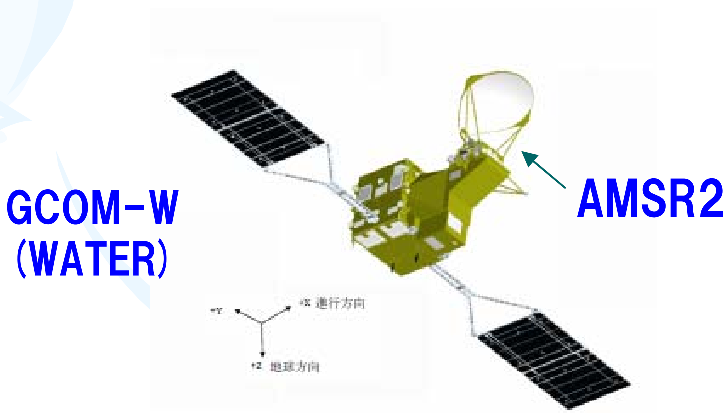
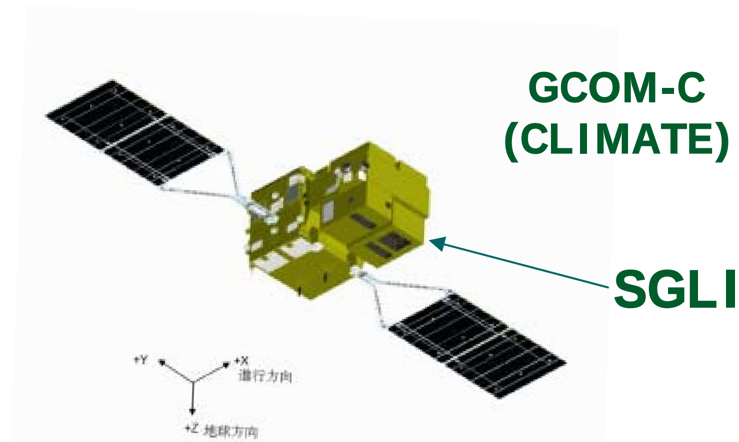
2. SGLI OVERVIEW
3. SGLI Observation Mechanism
4. BBM Test Results
5. Current Phase (EM Phase) Activity
6. Conclusion

Global Change Observation Mission (GCOM)

- Global observation satellite system as JAXA's GEOSS contribution.
- 2 satellite series for 5 years, total 13 years observation.
  - ✓ **GCOM-W** Microwave radiometer observation for **WATER CYCLE** using AMSR2 (AMSR-E follow on)
  - ✓ **GCOM-C** Optical multi-channel observation for **RADIATION BUDGET** and **CARBON CYCLE** using SGLI (GLI follow on)





Sensor	**Advanced Microwave Radiometer 2 (AMSR2)** Passive Microwave Observation Water vapor, soil moisture etc

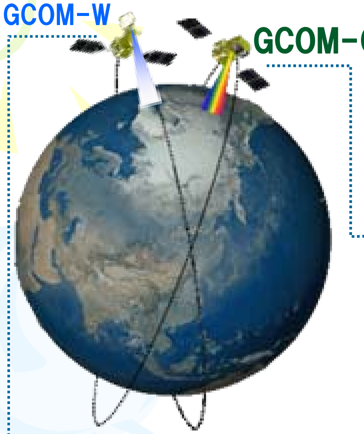
Sensor	**Second Generation Global Imager (SGLI)** Optical Observation 380nm – 12 micron Cloud, Aerosol, Vegetation, Chrolophl etc

GCOM Contribution

GCOM observation

GCOM-W

GCOM-C



Frequent and long term (>10yer) global observation system

GCOM observation

Radiation budget
- Surface albedo
- Snow ice
- Cloud/ aerosol
- SST/ LST

Carbon cycle
- Vegetation cover
- Primary production
- Coastal environment

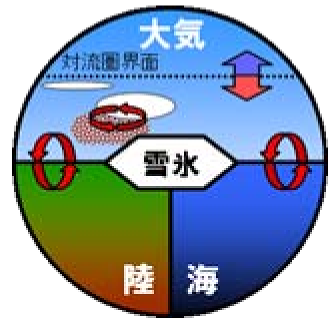
Water cycle
- Water vapor, cloud, precipitation
- Soil moisture
- Sea ice, snow
- SST, wind

Input

Comparison

Model prediction

Climate system model



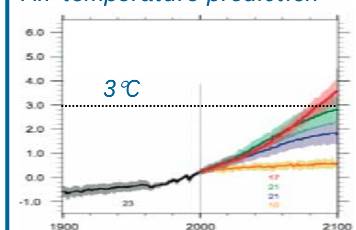
Improve accuracy

- Improvement of parameterization about **radiation budget** and **carbon cycle**, etc. in climate prediction model.
- Verification and improvement of prediction of the earth environment change including the water cycle by comparison with the satellite observation.

Prediction results

- Surface temperature
- Sea level
- Snow and sea ice area
- Environmental change
- Rain/drought distribution
- Extreme weather frequency
- Land cover

Air temperature prediction



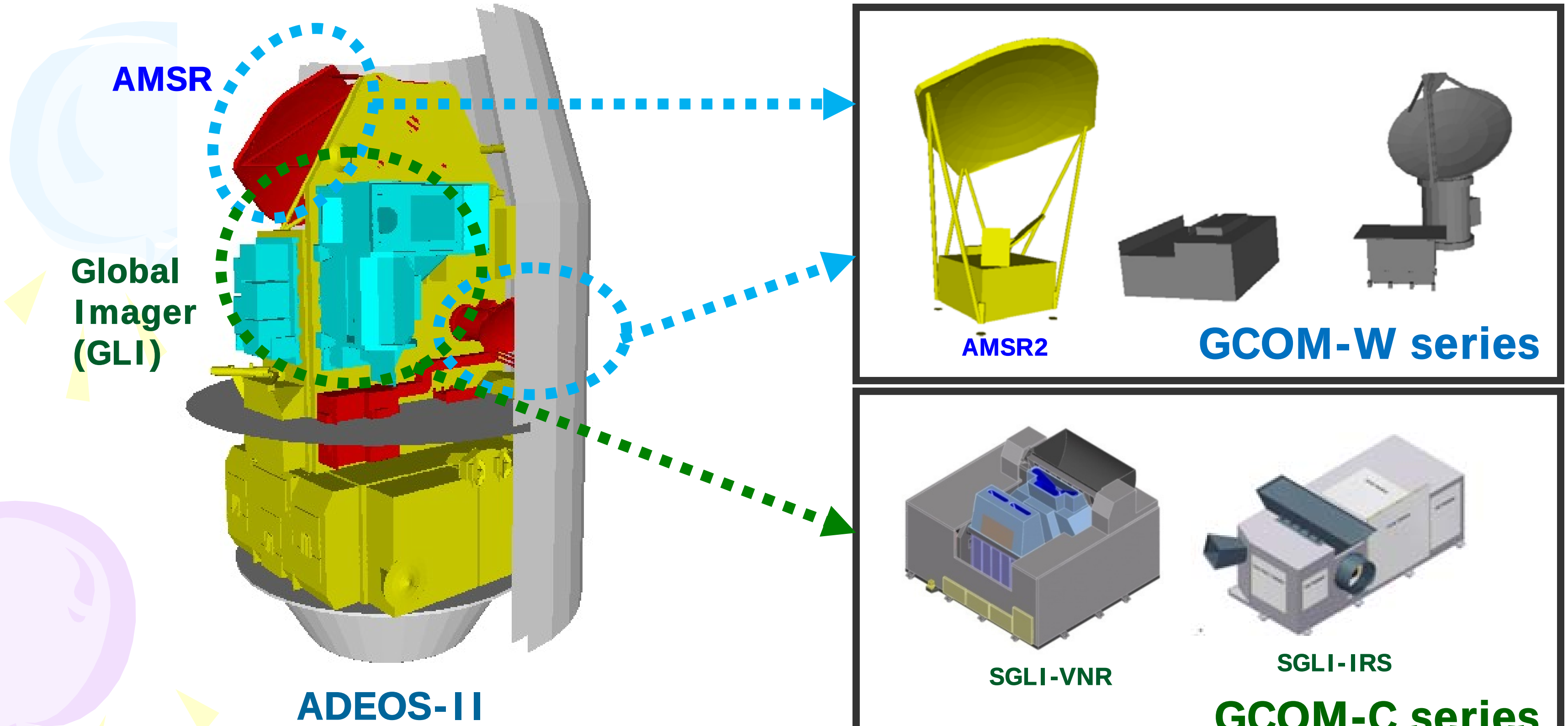
Data application → **Operational use for fishery, sea route, weather forecast, etc.**

Knowledge → **monitoring and understanding of the earth environment change**

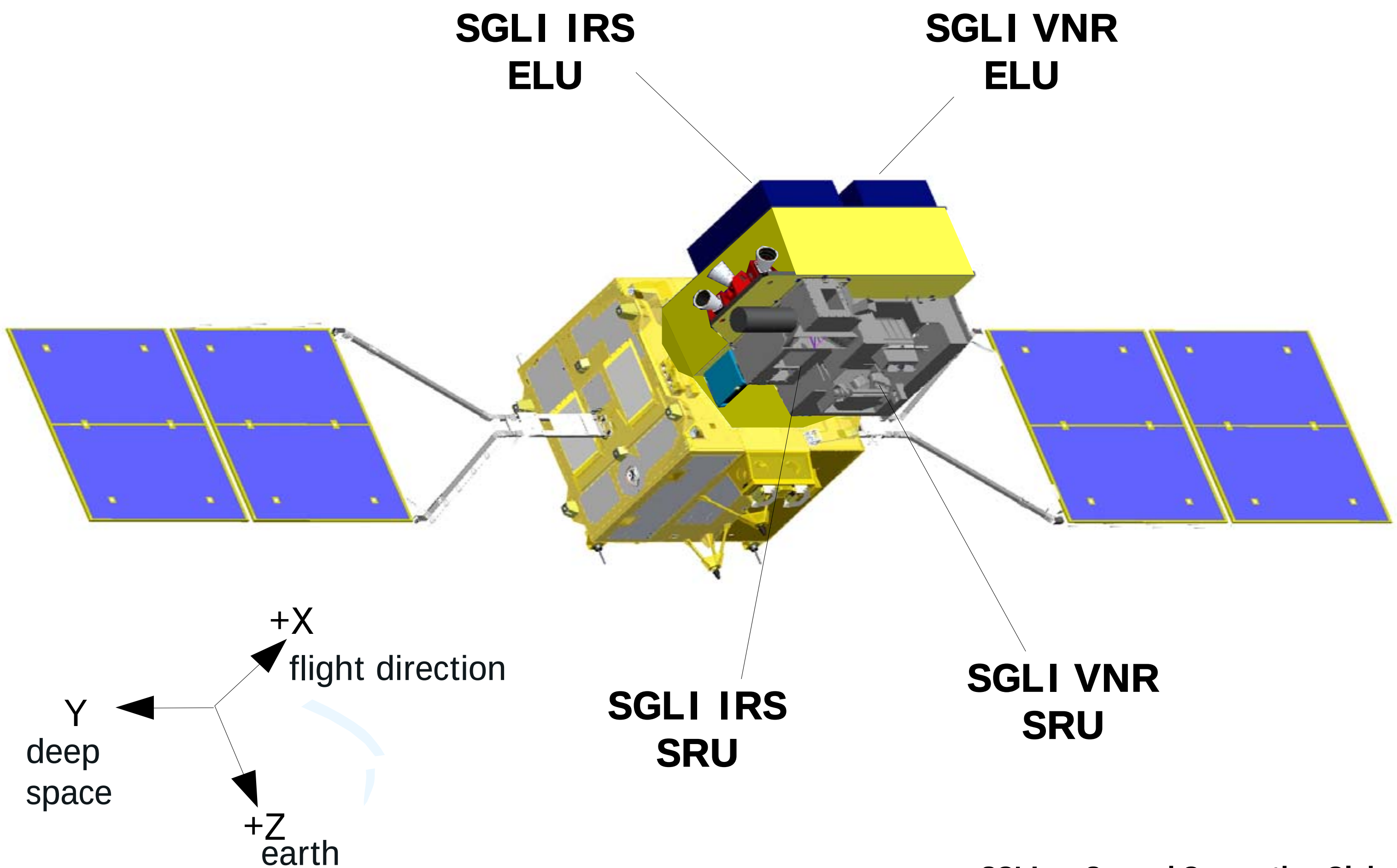
Future prediction → **Policy design through prediction improvement**

GCOM Background
(ADEOS, ADEOS-II)

- GCOM is follow on program of ADEOS and ADEOS-II.
- Based on ADEOS-II operational anomaly, satellite development policy was discussed at Space Activity Committee (SAC) of Japanese government.
- GCOM mission as a successor of ADEOS-II was re-evaluated.
  → **SGLI on GCOM-C1 satellite (SINGLE MISSION).**



SGLI on GCOM-C1 satellite



SGLI	**Second Generation Global Imager**
VNR	**Visible and Near Infrared Radiometer**
IRS	**Infrared Scanning Radiometer**
SRU	**Scanning Radiometer Unit**
ELU	**Electronic Unit**

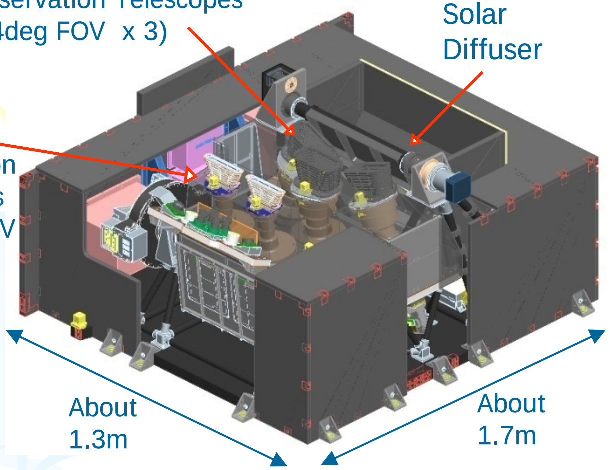
1. GCOM MISSION and BACKGROUND

2. <u>SGLI OVERVIEW</u>
   - ✓ Second Generation Global Imager (SGLI)
   - ✓ Technology background of SGLI
   - ✓ SGLI Specification
   - ✓ Observation Intervals

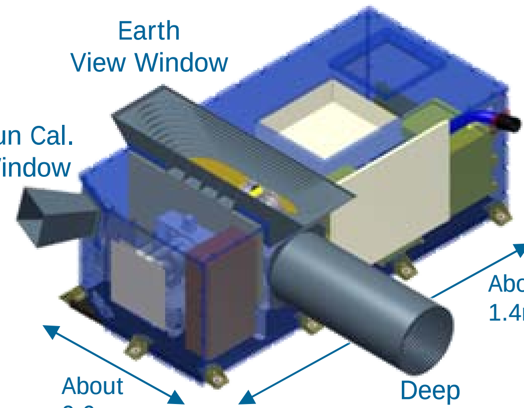
3. SGLI Observation Mechanism
4. BBM Test Results
5. Current Phase (EM Phase) Activity
6. Conclusion

SGLI

Second Generation Global Imager

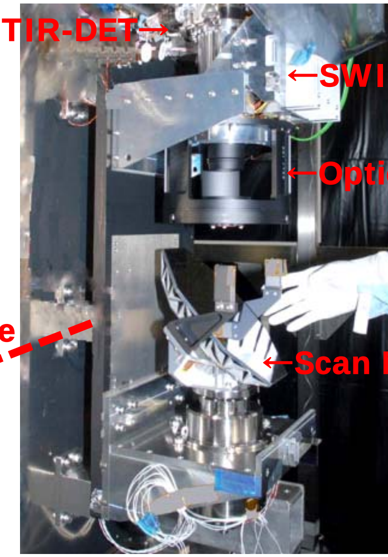


Visible and Near Infrared Radiometer
(SGLI-VNR)



Infrared Scanning Radiometer
(SGLI-IRS)

Inside



SGLI IRS
Bread Board Model

Sensor Unit	features
SGLI VNR	Non Polarized Observation (11ch), IFOV 250m, Swath 1150km Polarized Observation(2ch), IFOV 1km, Swath 1150km
SGLI IRS	Shortwave Infrared (SWI 4ch), IFOV 250m/1km, Swath 1400km Thermal Infrared (TIR:2ch), IFOV 500m, Swath 1400km

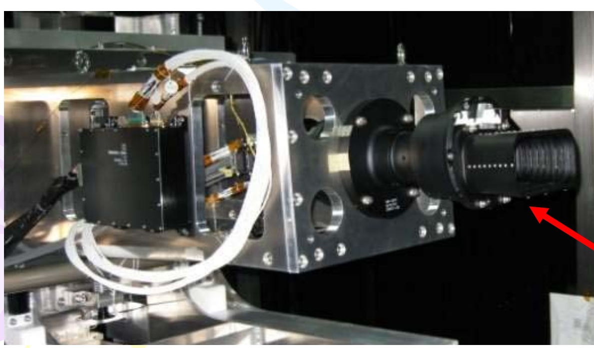
Visible and Near infrared radiometer SGLI-VNR

VNR non Polarized Obs. (NP)

- 3 telescopes with 24deg FOV realize the total 70 deg FOV Observation (1,150km)
- Wide wavelength range Observation from 380nm to 868.5nm.

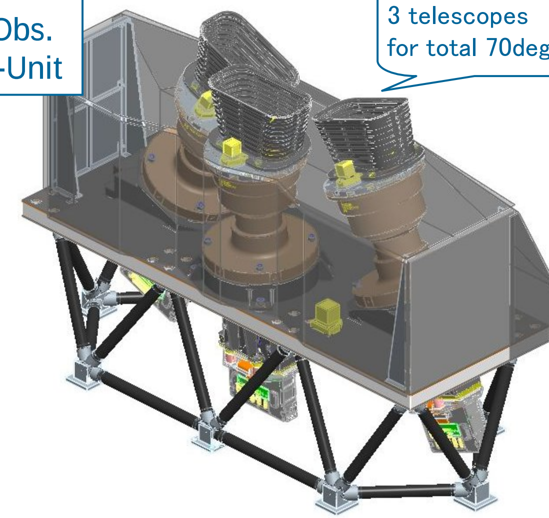
VNR Polarized Obs. (PL)

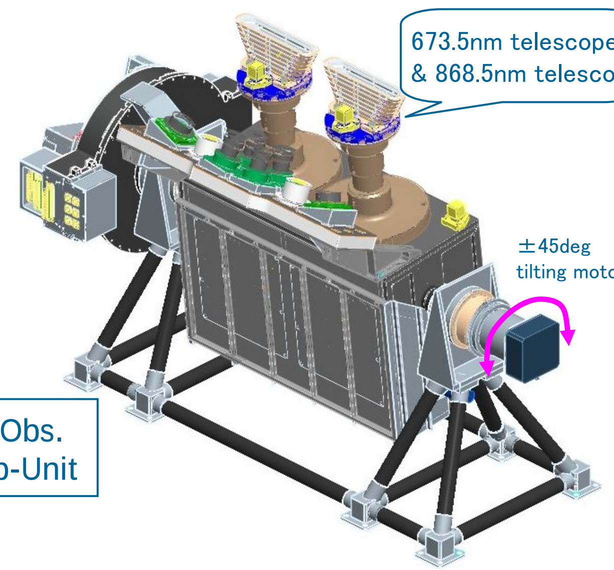
- 2 telescopes with 55deg FOV each for 673.5nm and 868.5nm Observation.
- AT tilting mechanism for +/-45deg
- 55deg FOV with 45deg tilting corresponds to 1,150km swath.



BBM
NP telescope

NP Obs.
Sub-Unit

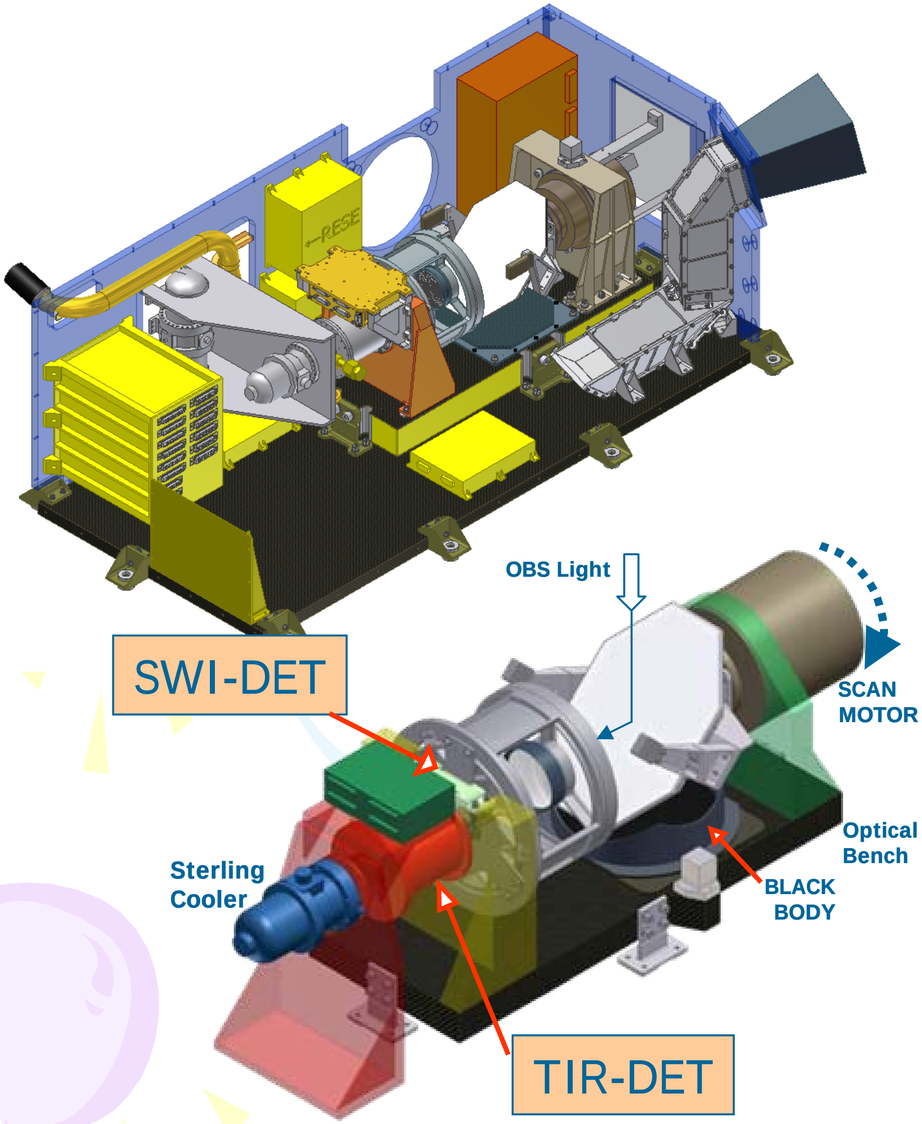




PL Obs.
Sub-Unit

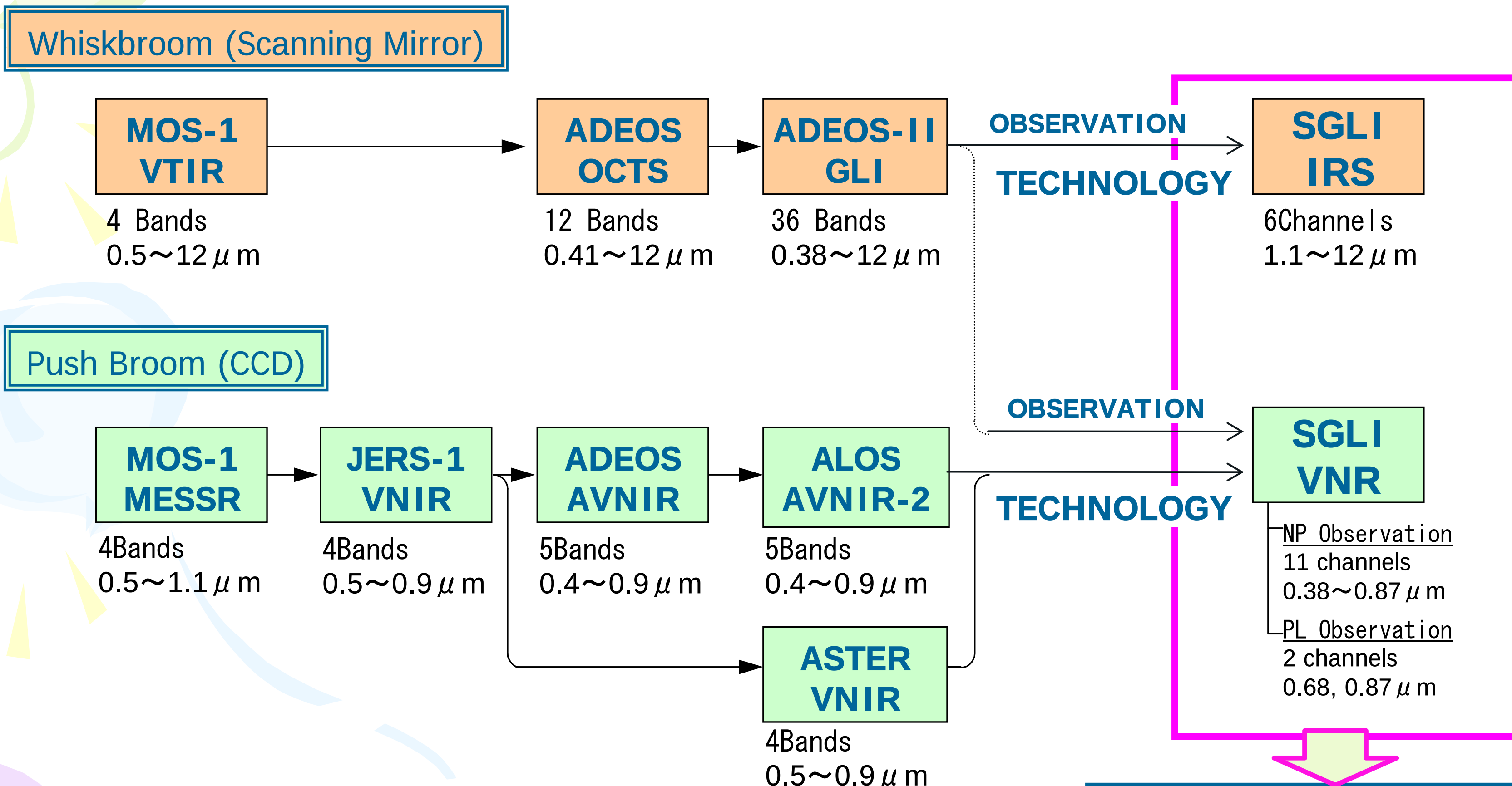
AT : Along Track Direction
CT : Cross Track Direction

Infrared Scanning Radiometer SGLI-IRS



- 45deg folding mirror rotates continuously at 81rpm (740msec/rev) to observe “Earth – Solar Diffuser – Black Body – LED lamps – Deep Space”.
- Observation light through Ritchey Chretien type telescope is divided for two wavelength region.
  - ✓ Shortwave Infrared detector (SWI-DET)
  - ✓ Thermal Infrared detector (TIR-DET).
- SWI-DET uses InGaAs type detectors at -30deg C using peltier cooler.
- TIR-DET uses PV-MCT type detectors at 55K using mechanical stirling cooler.

Technology background of SGLI



SGLI uses both Whisk Broom and Push Broom type Sensor Heritage

JAXA
NEC/TOSHIBA
NEC東芝スペースシステム

SGLI Specification

GCOM Global Change Observation Mission

- The SGLI features are **250m (VNR-NP & SW3) and 500m (TIR) spatial resolution** and **polarization/along-track slant view** channels (VNR-PL), which will improve land, coastal, and aerosol observations.

250m over the Land or coastal area, and 1km over offshore

GCOM-C SGLI characteristics	
Orbit	Sun-synchronous (descending local time: 10:30) Altitude 798km, Inclination 98.6deg
Mission Life	5 years (3 satellites; total 13 years)
Scan	Push-broom electric scan (VNR) Wisk-broom mechanical scan (IRS)
Scan width	1150km cross track (VNR: VN & P) 1400km cross track (IRS: SW & T)
Digitalization	12bit
Polarization	3 polarization angles for P
Along track direction	Nadir for VN, SW and T, +45 deg and -45 deg for P
On-board calibration	VN: Solar diffuser, LED, Lunar cal maneuvers, and dark current by masked pixels and nighttime obs. SW: Solar diffuser, LED, Lunar, and dark current by deep space window T: Black body and dark current by deep space window

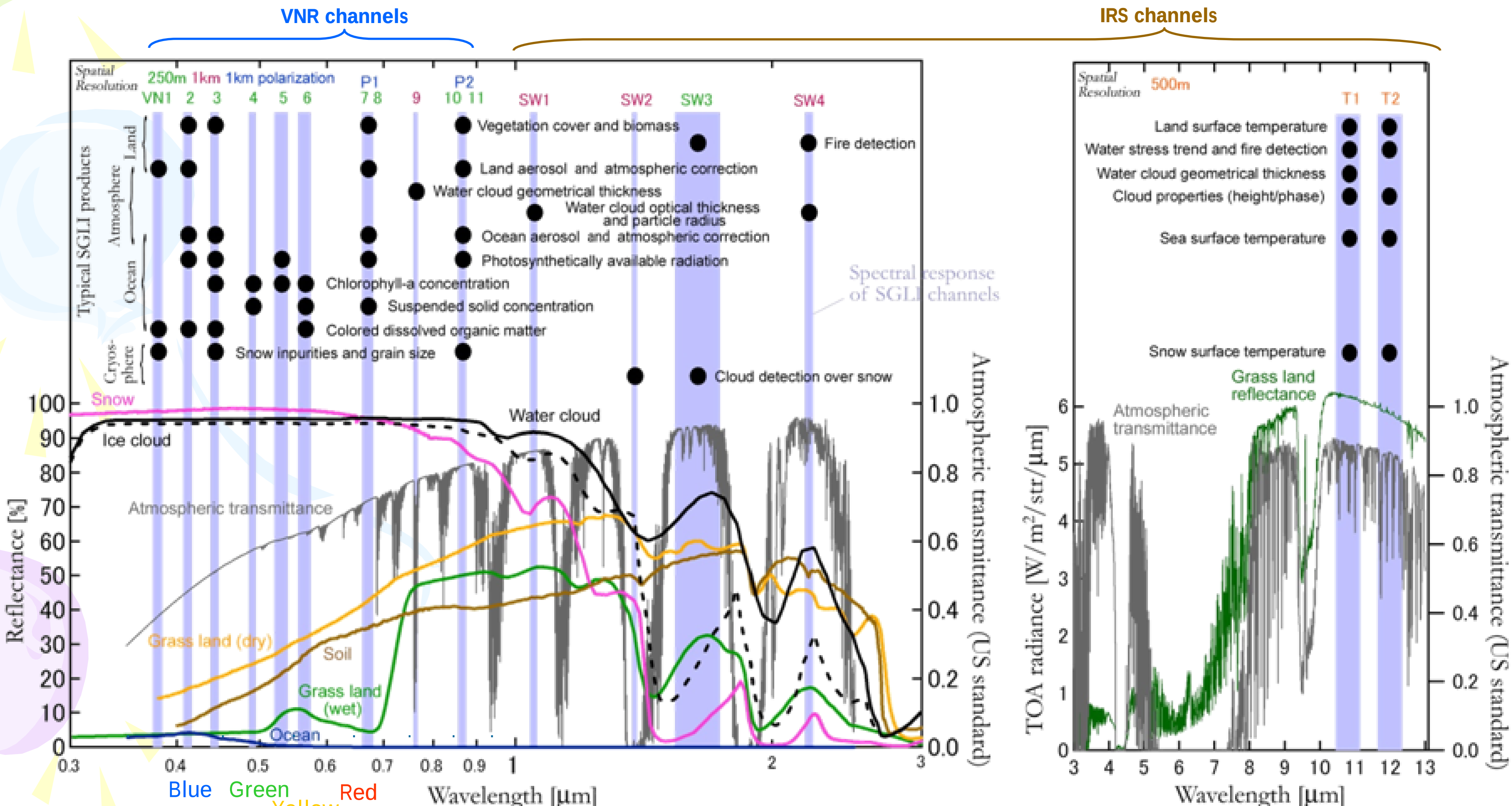
Multi-angle obs. for 674nm and 869nm

SGLI channels						
CH	λ	$\Delta\lambda$	L_{std}	L_{max}	SNR at Lstd	IFOV
	VN, P, SW: nm T: μm		VN, P: W/m^2/sr/μm T: Kelvin		VN, P, SW: SNR T: NEΔT	m
VN1	380	10	60	210	250	250
VN2	412	10	75	250	400	250
VN3	443	10	64	400	300	250
VN4	490	10	53	120	400	250
VN5	530	20	41	350	250	250
VN6	565	20	33	90	400	250
VN7	*673.5*	*20*	23	62	400	250
VN8	*673.5*	20	25	210	250	250
VN9	763	12	40	350	1200	250/1000
VN10	*868.5*	20	8	30	400	250
VN11	*868.5*	20	30	300	200	250
P1	*673.5*	20	25	250	250	1000
P2	*868.5*	20	30	300	250	1000
SW1	1050	20	57	248	500	1000
SW2	1380	20	8	103	150	1000
SW3	*1630*	200	3	50	57	250
SW4	2210	50	1.9	20	211	1000
T1	10.8	0.7	300	340	0.2	250/500
T2	12.0	0.7	300	340	0.2	250/500

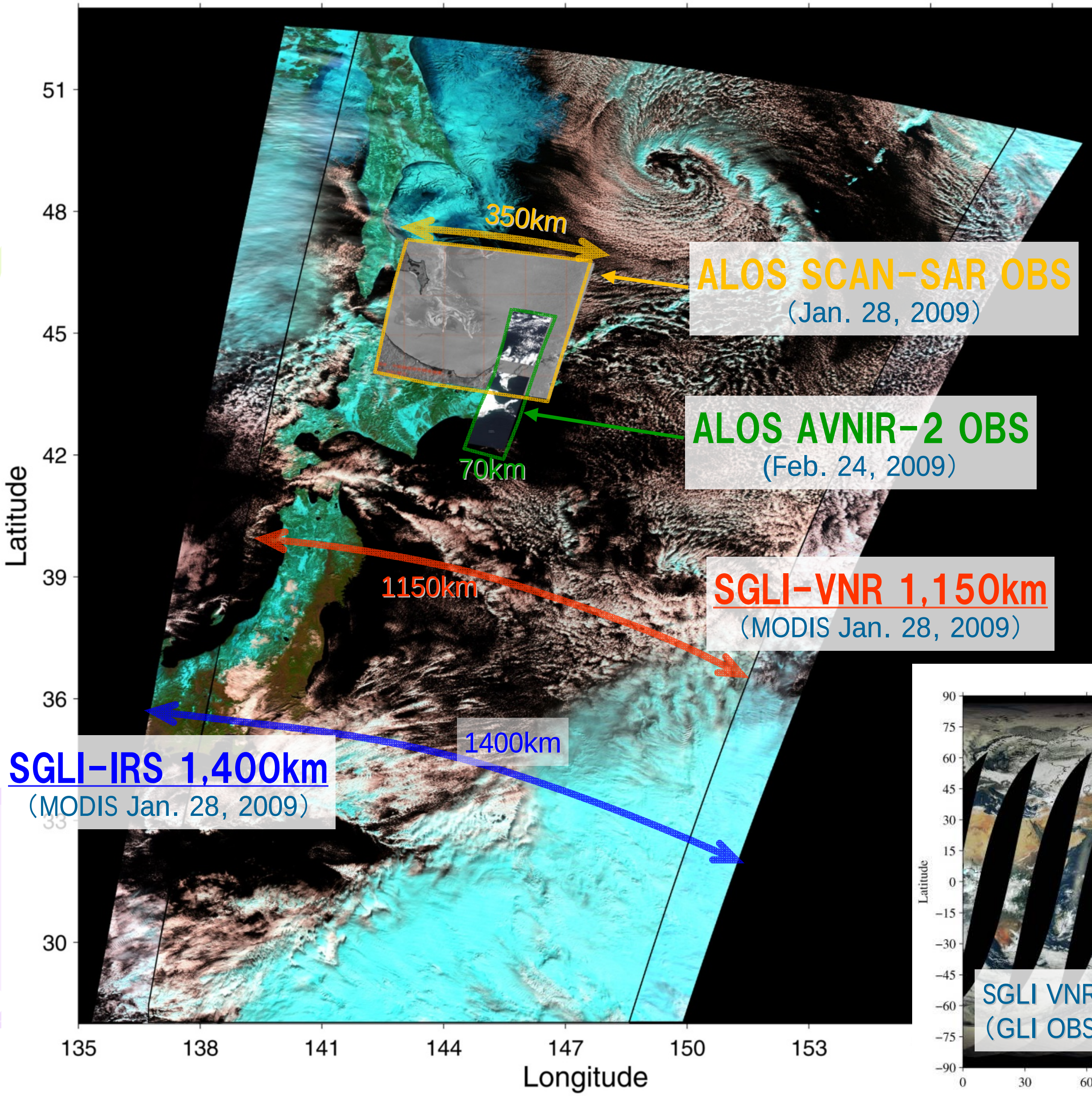
option

SGLI Spectral Channels

- Specifications of SGLI, such as center wavelengths, band width, SNR, and dynamic range, are **designed in consideration of retrieval algorithms of the observation targets**.



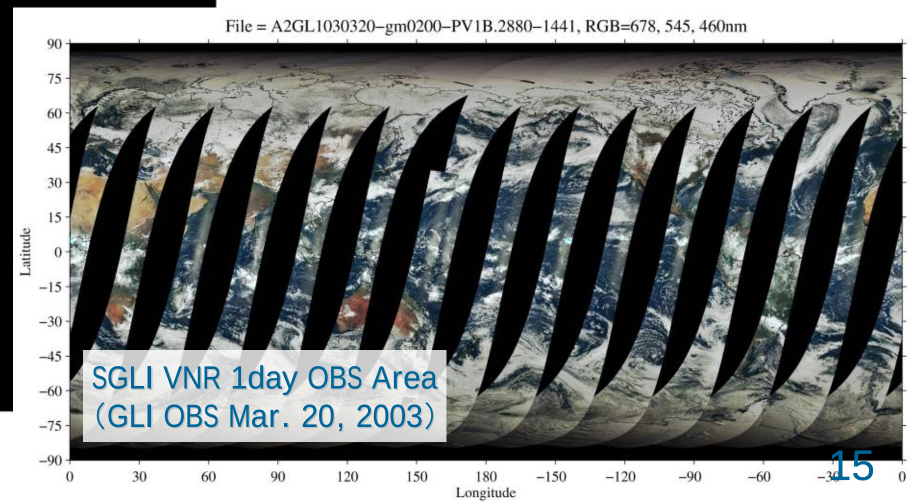
Observation Frequency



- GCOM-C1 orbit is "**34days repeat orbit**" with "**3.8days quasi repeat cycle**".

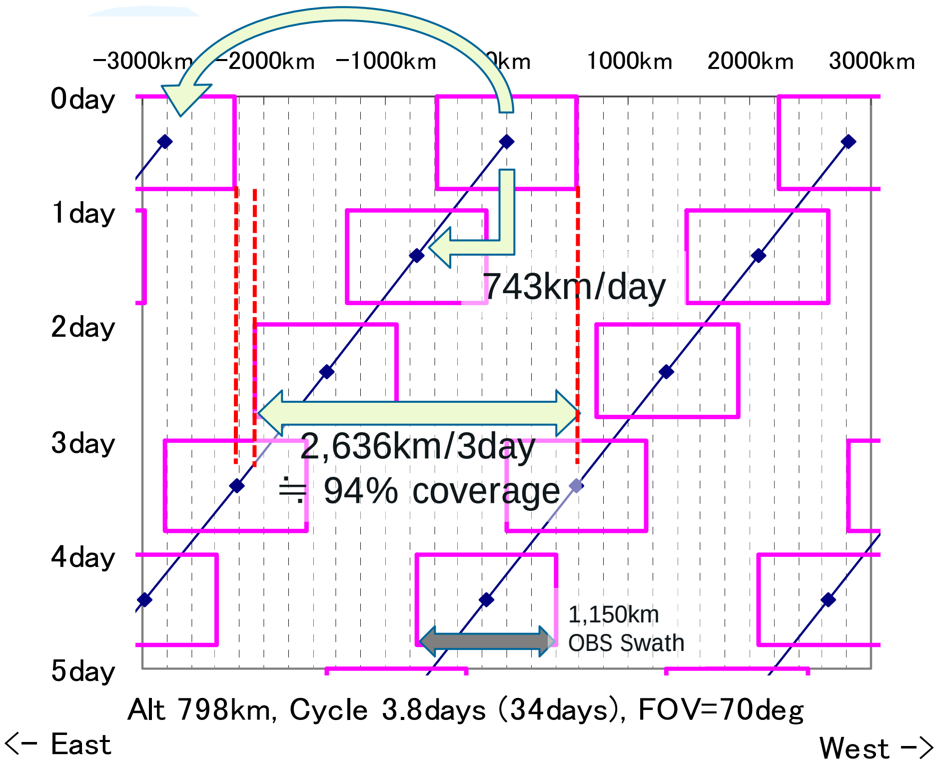
→ Any point on the equator can be observed at average **2.4 days frequency**.

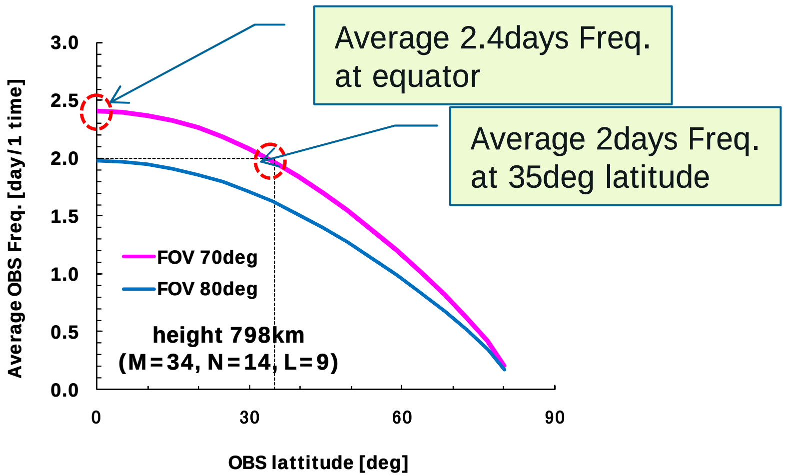
→ Average **2 days frequency observation** is possible for middle latitude. (35deg)

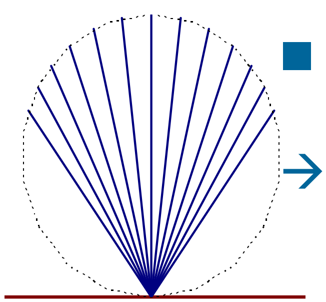


Observation Frequency

- GCOM-C1 ground trace distance at equator is 2,809km/rev and 743 km/day.
  → SGLI-VNR with 1,150km swath (70deg FOV) realizes 94% global coverage for 3 days at equator.
  → **<u>Average 100％ coverage per 2 days at middle latitude</u>**.







- GCOM-C1 orbit is 34 day recurrent orbit.
  → **<u>13 Cross Track directional observation per 34 days</u>** is possible.

1. GCOM MISSION and BACKGROUND
2. SGLI OVERVIEW

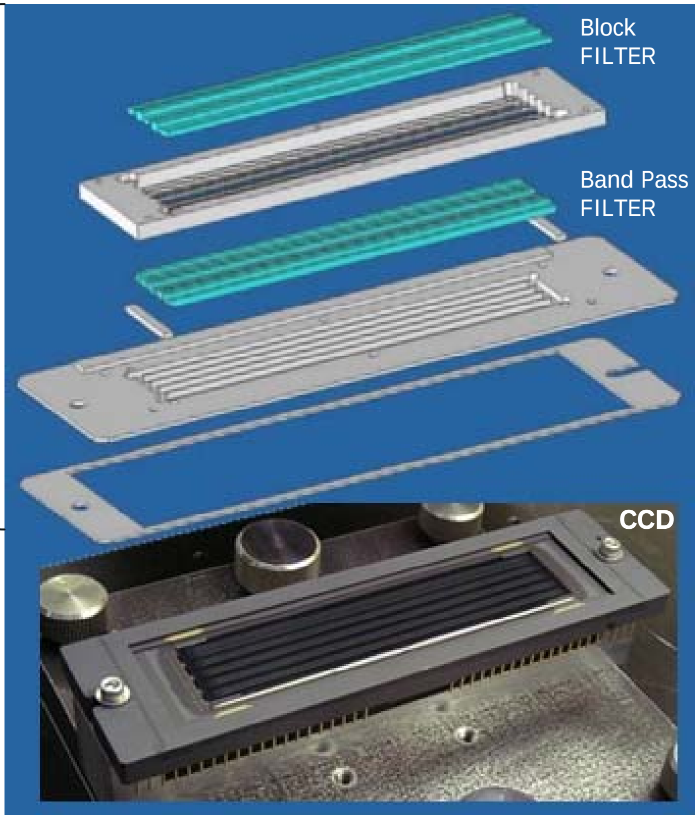
3. **SGLI Observation Mechanism**
   - ✓ VNR Non Polarized Observation Focal Plane Assembly
   - ✓ VNR Polarization Observation
   - ✓ TDI mode observation of TIR detectors
   - ✓ Data Acquisition Scenario
   - ✓ Onboard calibration

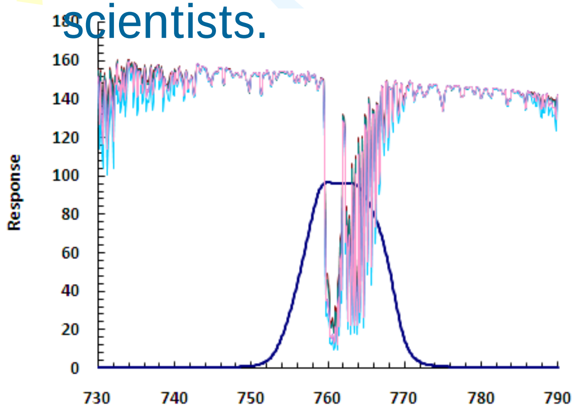
4. BBM Test Results
5. Current Phase (EM Phase) Activity
6. Conclusion

VNR Non Polarized Obs. Focal Plane Assembly

- Each NP telescope is equipped with independent Focal Plane Assembly.
- To realize 11ch observations of VNR-NP telescope, 11 lines long Band Pass Filter (BPF) is mounted on 11 line CCD.
- Channel location and spectral non uniformity requirement is set based on detailed mission analysis such as O2A band observation by EORC scientists.

11 Chs Filter Assy.





Channel Location

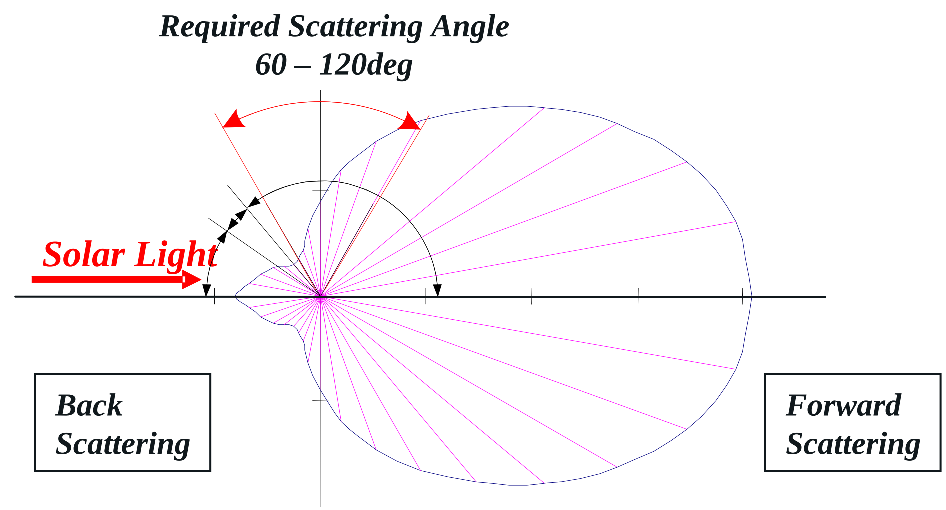
ocean gain channels / **land gain channels**

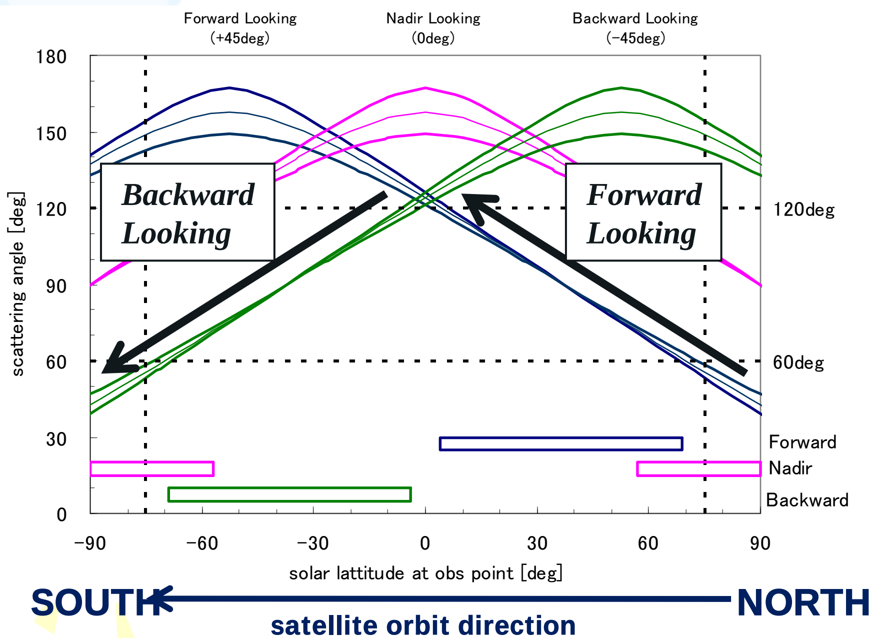
865H	670H	565H	490H	412	380	443	530	670	865	763
(VN10	VN7)	(VN6	VN4)	(VN2	VN1)	(VN3	VN5)	(VN8	VN11	VN9)

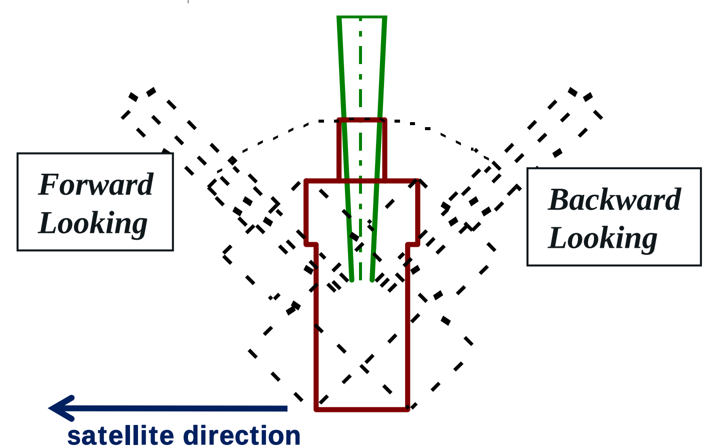
satellite flight direction →

VNR Polarization Observation

- Intermediate scattering direction (60-120deg) should be observed for aerosol retrieval with +/- 45deg tilting radiometer. Tilt angle will be switched by command depending on this scattering angle requirement.
  - ✓ Backward Looking
  - ✓ Forward Looking
  - ✓ Nadir Looking (optional)
- 3 directional linear polarizer on FPA realize Stokes parameter observation (I, Q, U components)

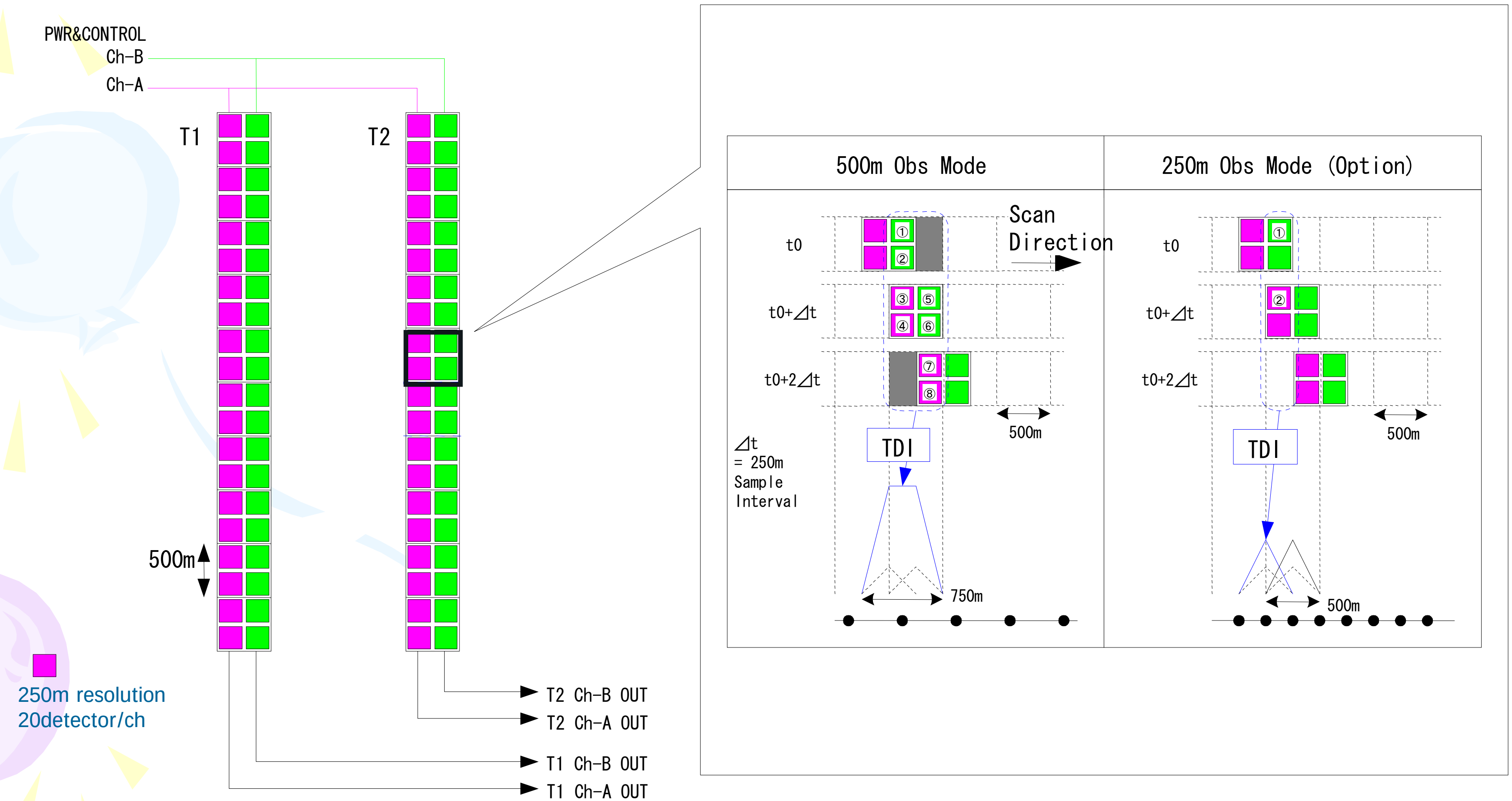






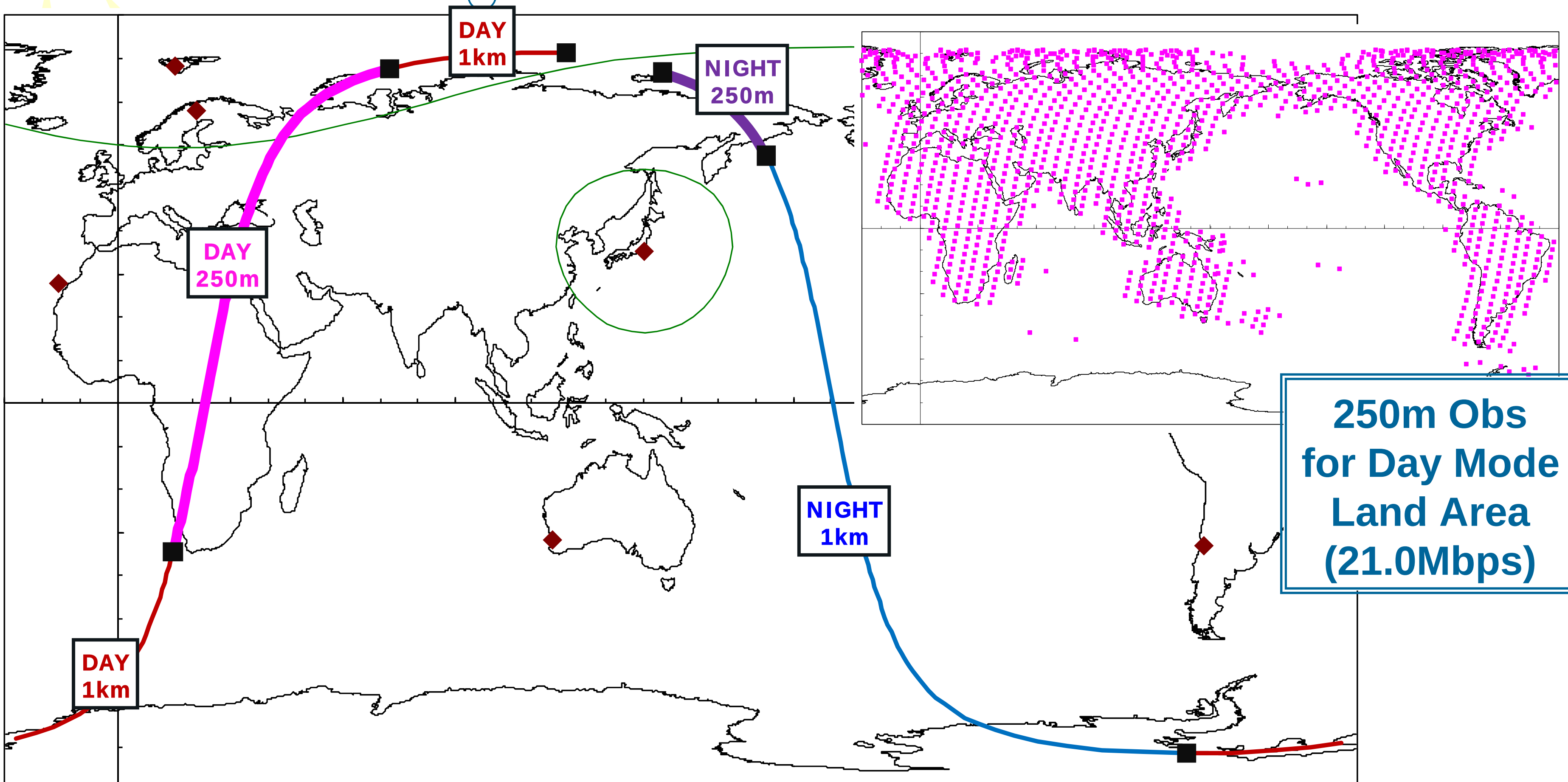
TDI mode observation of TIR detectors

- TIR-DET works with Time Delayed Integration (TDI) mode.
  - → Each 500m Observation channels consists of 250m Ch-A and Ch-B.
  - → Optional 250m Observation is possible.

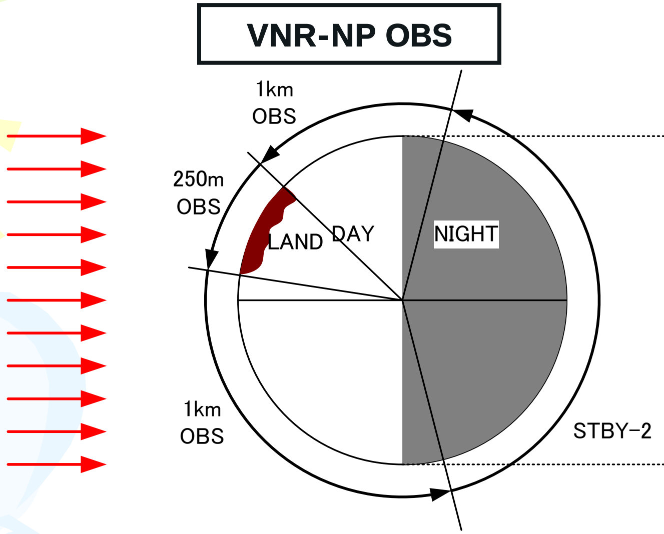


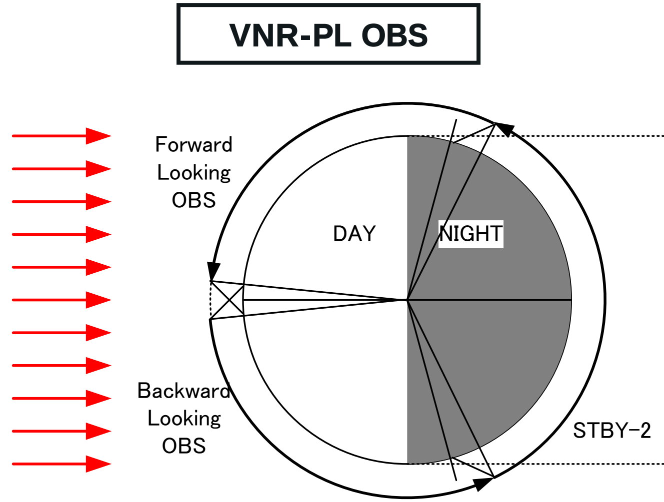
Data Acquisition Scenario

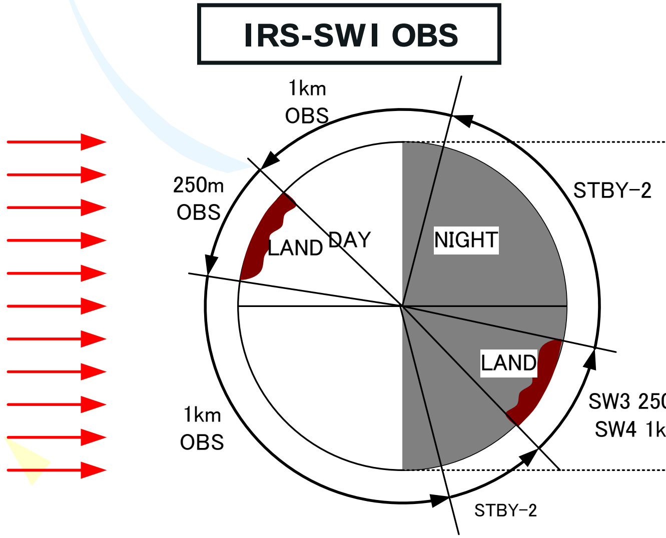
- BASIC Observation Concept →
  - ALL 19 Channels observation for Day Mode
  - 250m/500m resolution data for Land, 1km for Ocean
  - TIR & SW（1.6 & 2.2 micron ; Land）for Night Mode.

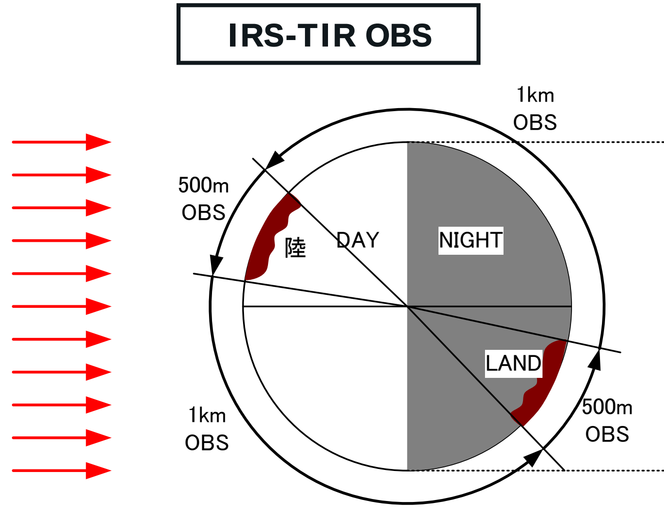


Data Acquisition Scenario



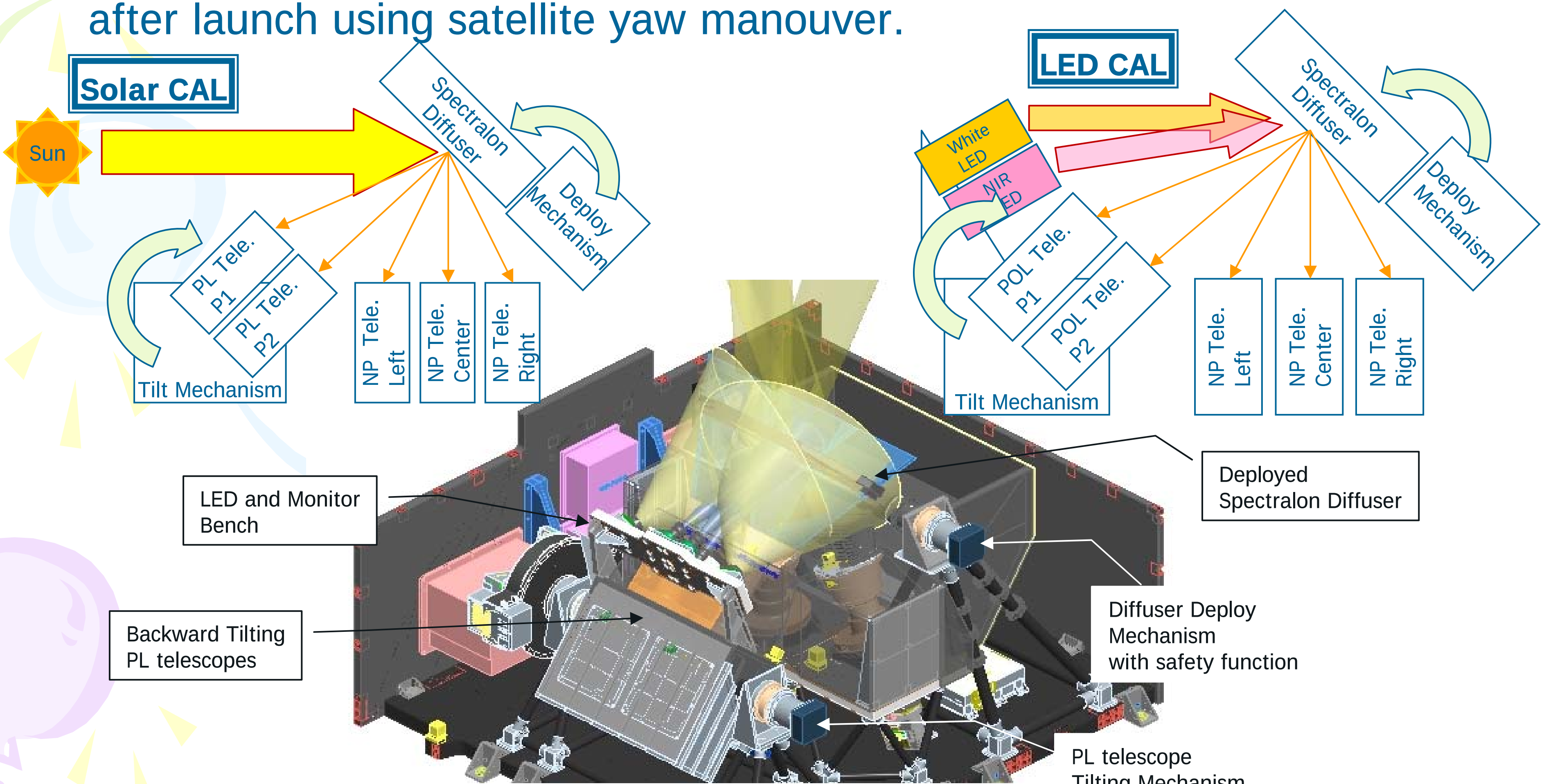






SGLI-VNR Onboard calibration

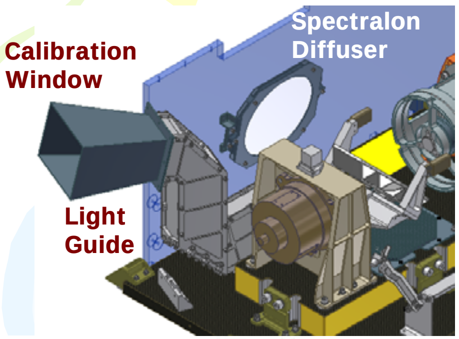
- Deployable Spectralon diffuser is used for both Solar and LED calibration. Calibration coefficient will be traced using this solar calibration data.
- β angle dependency for solar calibration will be characterized shortly after launch using satellite yaw manouver.

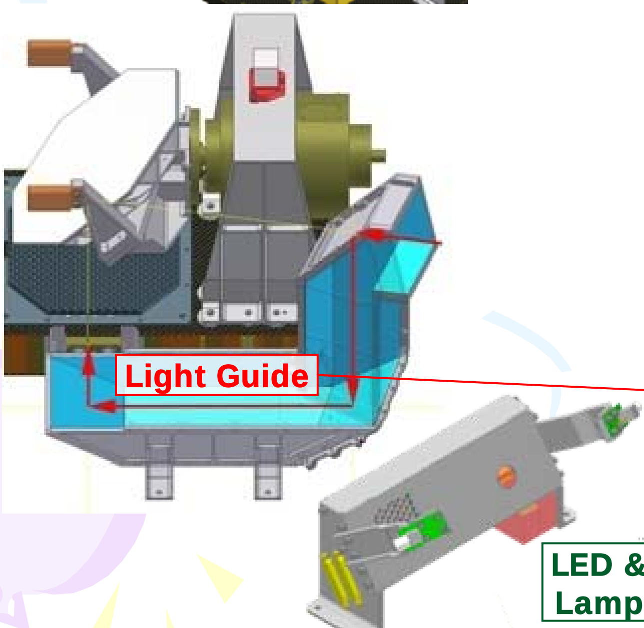


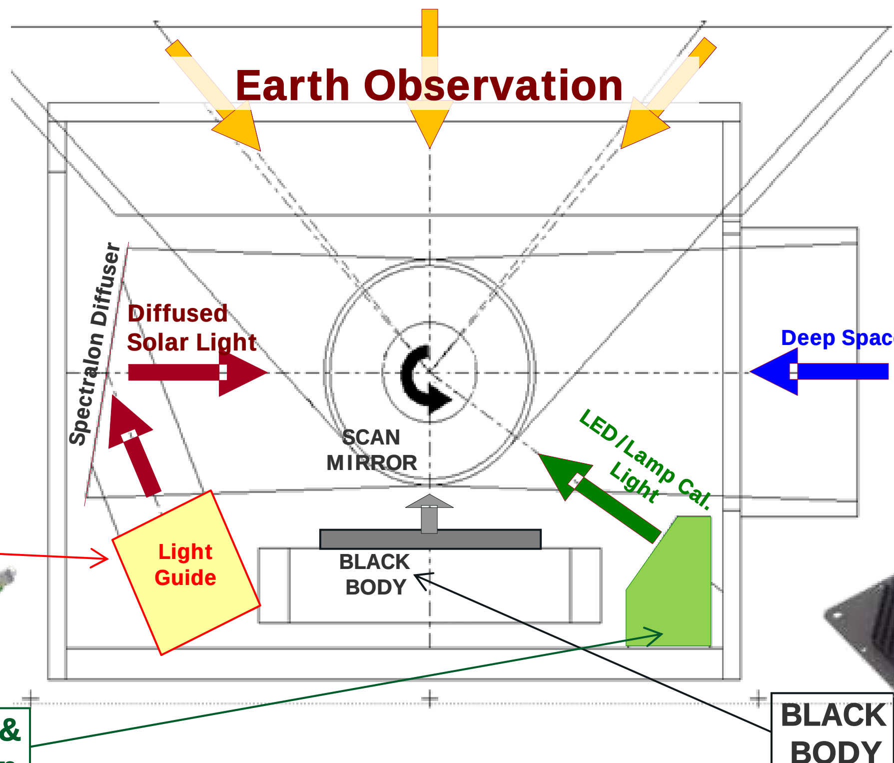
SGLI-IRS
Onboard calibration

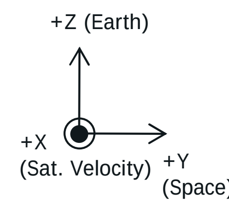
- IRS 81rpm rotating for both "**Earth Observation**" and "**Calibration**".

TIR Calibration : "**BLACK BODY**" and "**Deep Space**"
SWI Calibration : "**Diffused Solar Light**", "**LED/Lamp**"
and "**Deep Space**"









1. GCOM MISSION and BACKGROUND
2. SGLI OVERVIEW
3. SGLI Observation Mechanism

4. **BBM Test Results**
   - ✓ **Breadboard Model (BBM) activity**
   - ✓ **BBM test results of VNR**
   - ✓ **BBM test results of IRS**

5. Current Phase (EM Phase) Activity
6. Conclusion

Bread Board Model (BBM) Activity
Visible and Near infrared radiometer (VNR)

Critical Technologies

- To Validate feasibility of the critical components

・Bandpass filters

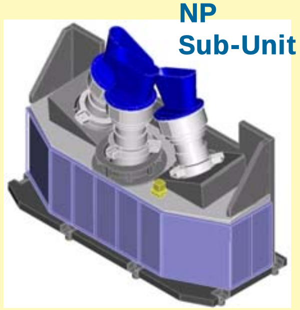
・CCD

Complete

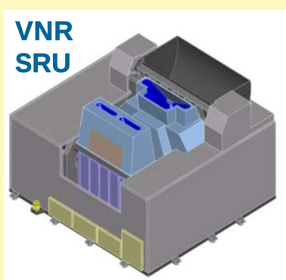
BBM System Design

-To establish SGLI system design to achieve observation requirement

NP Sub-Unit



VNR SRU



Complete

BBM Component Tests

- To assess and demonstrate the observation performances by component level

<Major BBM component>

・11line CCD

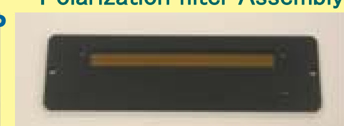
・Bandpass filter Assembly

・Optics

VNR-NP

VNR-PL

・Polarization filter Assembly



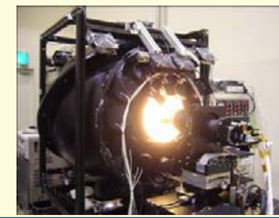
・Readout Circuit

Complete

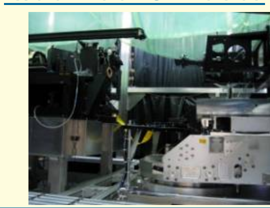
BBM System Tests

- To assess and demonstrate the observation performances by system level

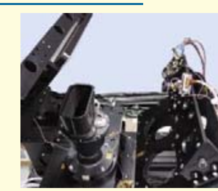
Radiometric Tests



Geometric Tests



Tests with onboard calibrators

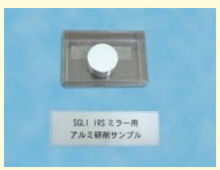


Complete

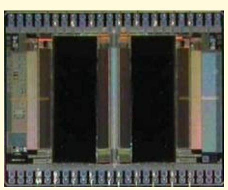
Bread Board Model (BBM) Activity
Infrared Scanning radiometer (IRS)

Critical Technologies

- To Validate feasibility of the critical components



・Mirror Sample

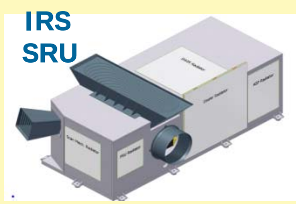


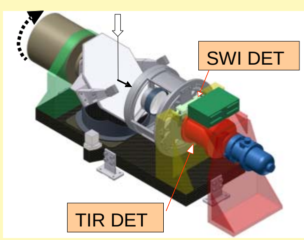
・TIR detector

Complete

BBM System Design

-To establish SGLI system design to achieve observation requirement





IRS Optical Bench

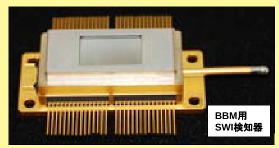
Complete

BBM Component Tests

- To assess and demonstrate the observation performances by component level

〈Major BBM component〉

・SWIR Detector

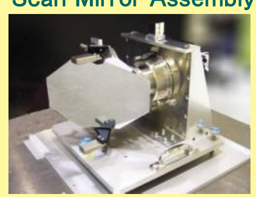


・TIR Detector

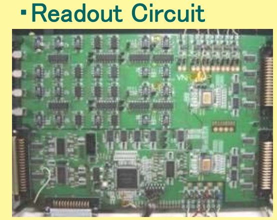
・Optics

・Mechanical Cooler

・Scan Mirror Assembly



・Readout Circuit



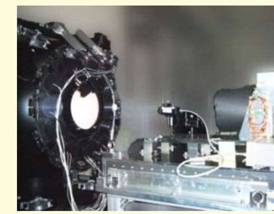
・Blackbody

Complete

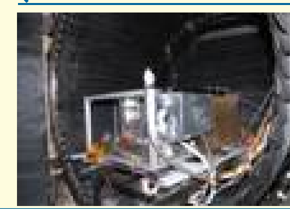
BBM System Tests

- To assess and demonstrate the observation performances by system level

SWIR Radiometric Tests



TIR Radiometric Tests (Vacuum condition)



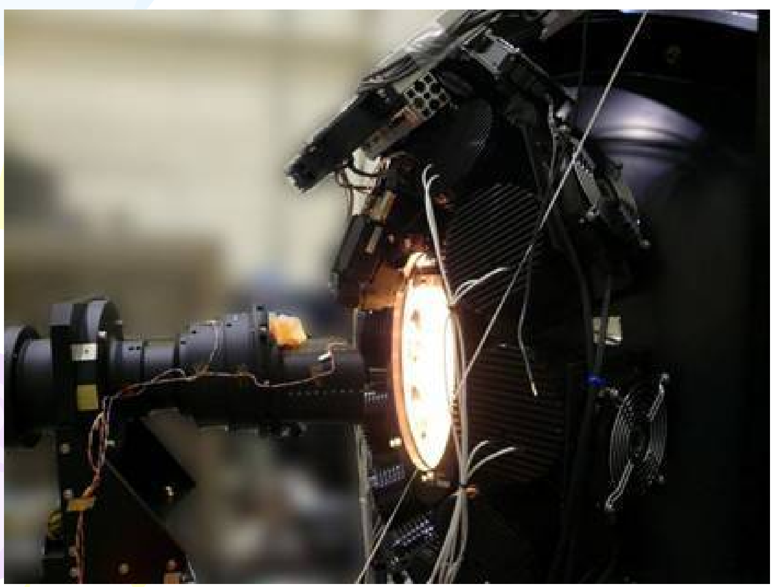
Geometric Tests

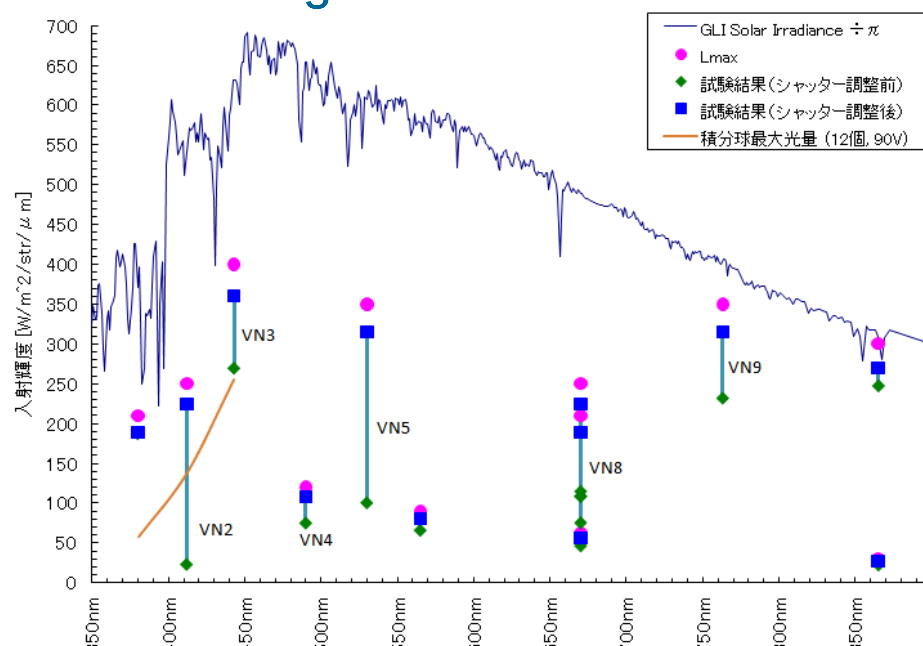
Tests with onboard calibrators

Complete

BBM test results of VNR Dynamic Range

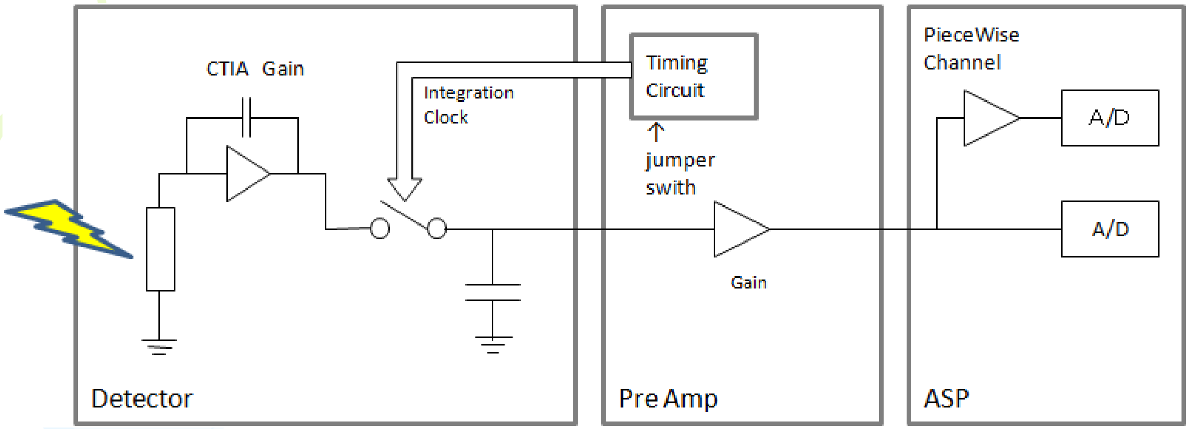
- VNR dynamic range requirement is set based on careful study of target characteristics.
- VNR uses CCD. Integration time can be easily changed by command.
- This means dynamic range adjustment is possible.
  - ✓ Difference between design and manufacturing results such as transmittance of optics can be adjusted
  - ✓ Dynamic range can be changed by command even after launch
  - ✓ Calibration technique using different integration time.

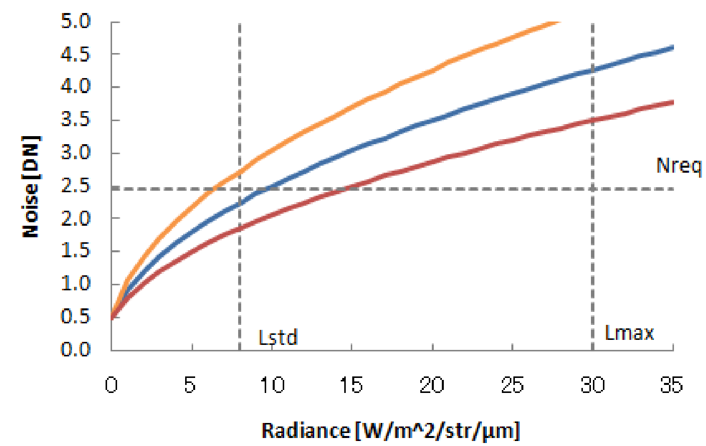




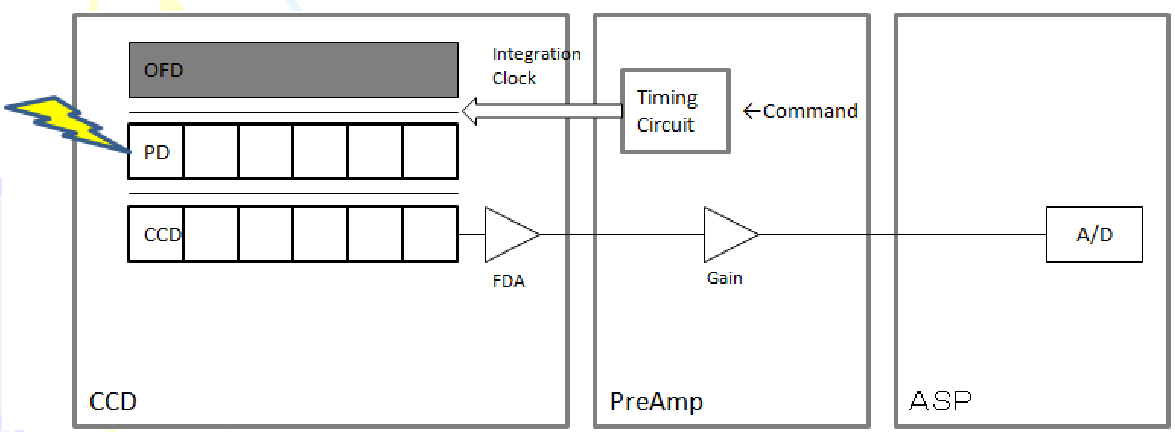
BBM test results of VNR CCD Integration Time

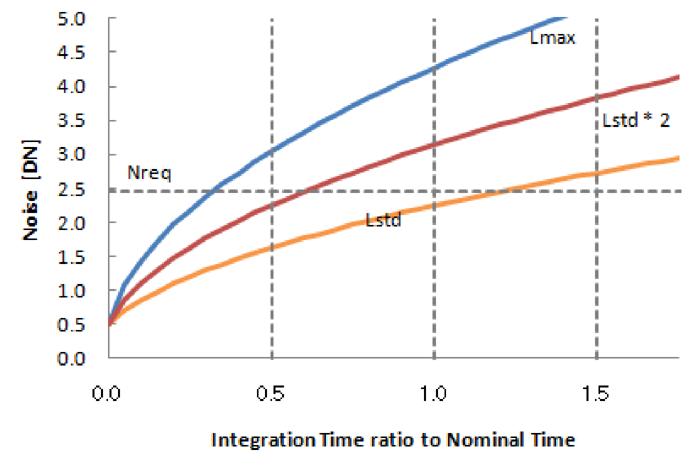
Previous GLI design





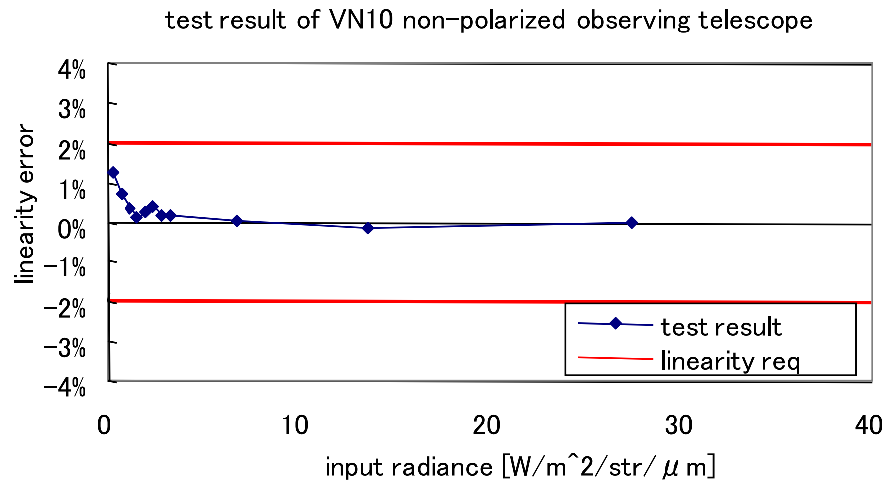
SGLI VNR design

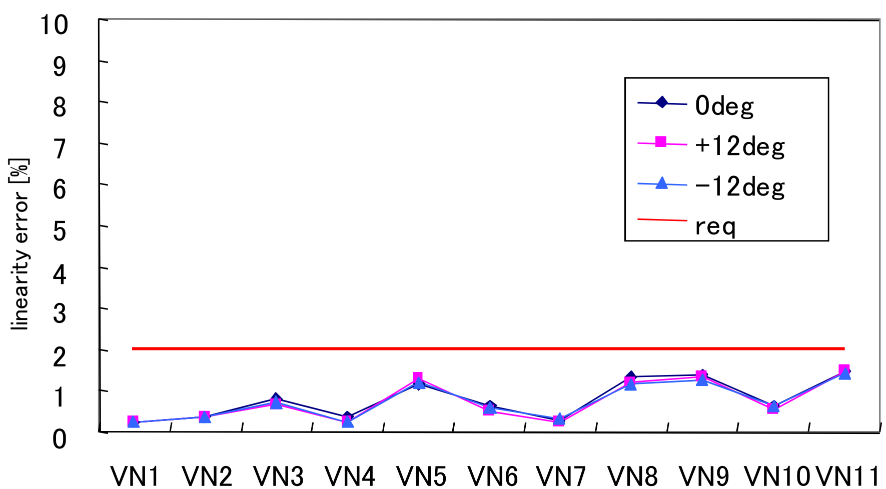




BBM test results of VNR Linearity

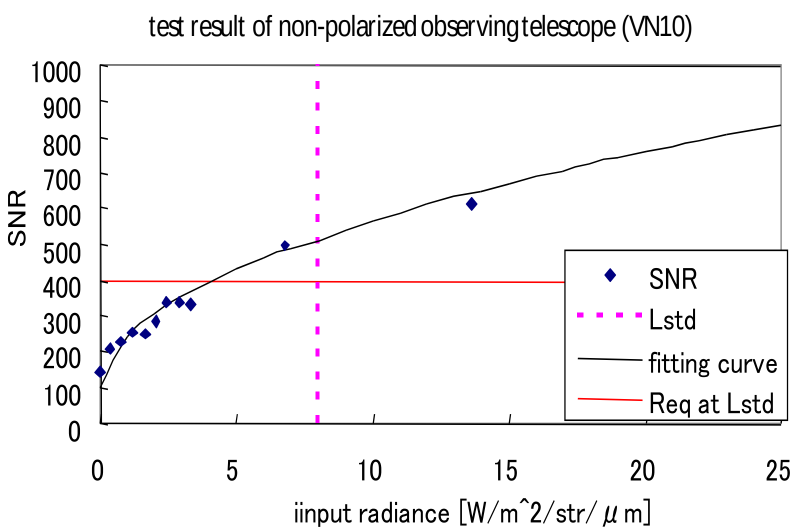
- Linearity is very important for radiometer because it leads to accuracy dependencies to input radiance level.
- Also, the test methodology using integration time above mentioned uses the assumption that sensor is very linear.
- VNR BBM linearity is checked for both input radiance dependencies and integration time dependencies.
- Test result is very good and further detailed analysis is conducted to find the major non-linear element to improve.





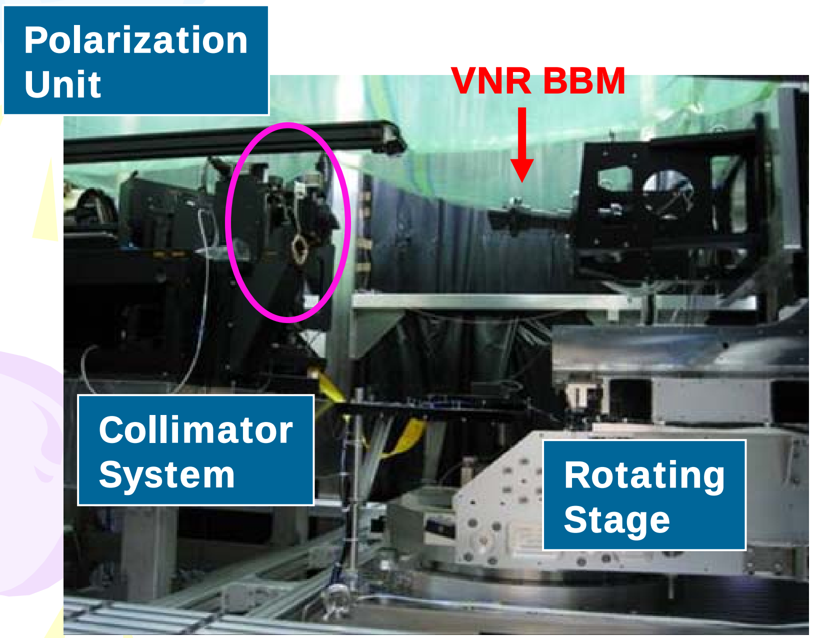
BBM test results of VNR Noise

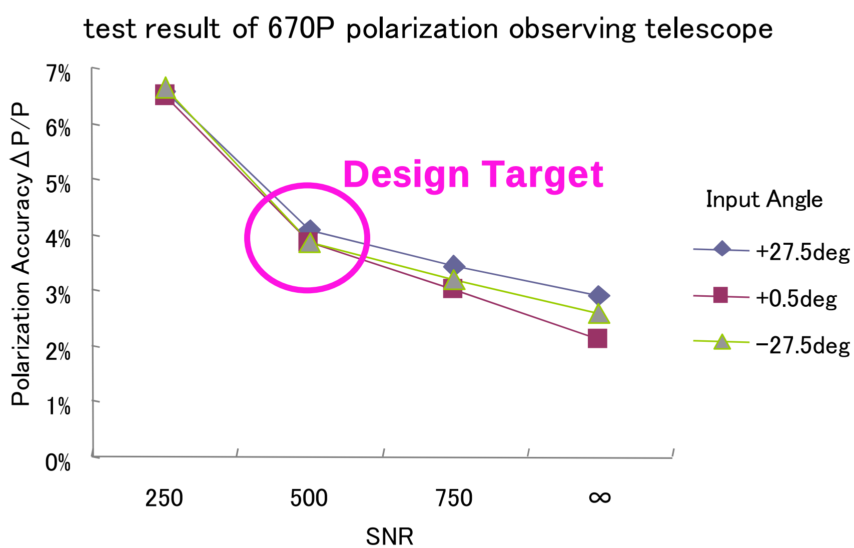
- SGLI noise performance is required as Signal to Noise Ratio (SNR) at standard signal observation radiance (Lstd) for each observation channel.
- Both integration time dependence and input radiance for SNR was checked.
- The all channels noise level met the sensor specification.



BBM test results of VNR Polarized Light Observation

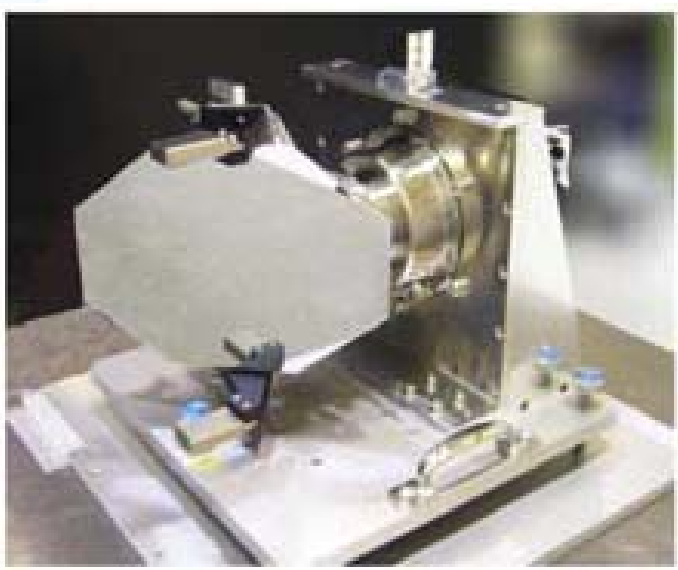
- The special polarization unit is set to the collimator light source. The collimator polarization characteristic is canceled with de-polarizer filter and polarized unit can be rotated around the optical axis to realize the desired polarized direction for both linear and partially polarized light.
- As the result of BBM test, approximately 4% polarization observation accuracy (ΔP/Pstd) and 1.3deg polarization direction error is confirmed for the 670nm polarization observing telescope with standard 5% polarized light (Pstd).

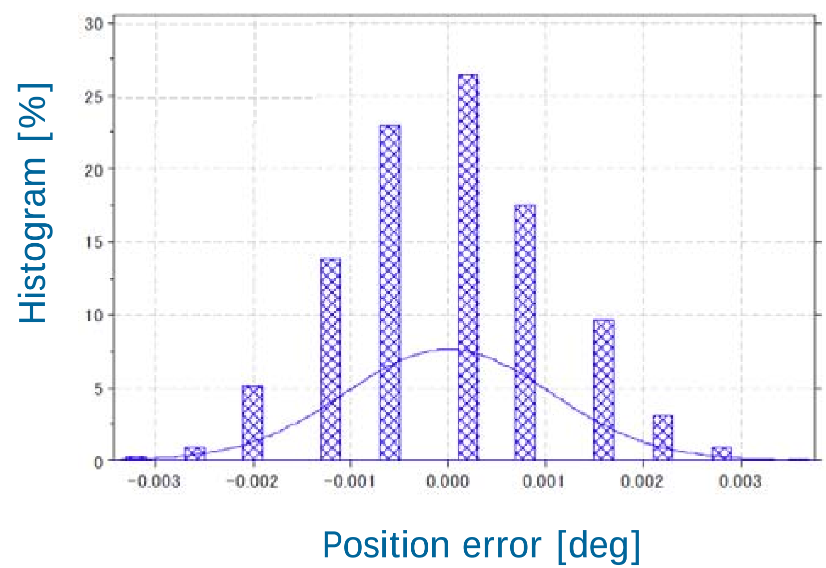




BBM test results of IRS Scanning Performance

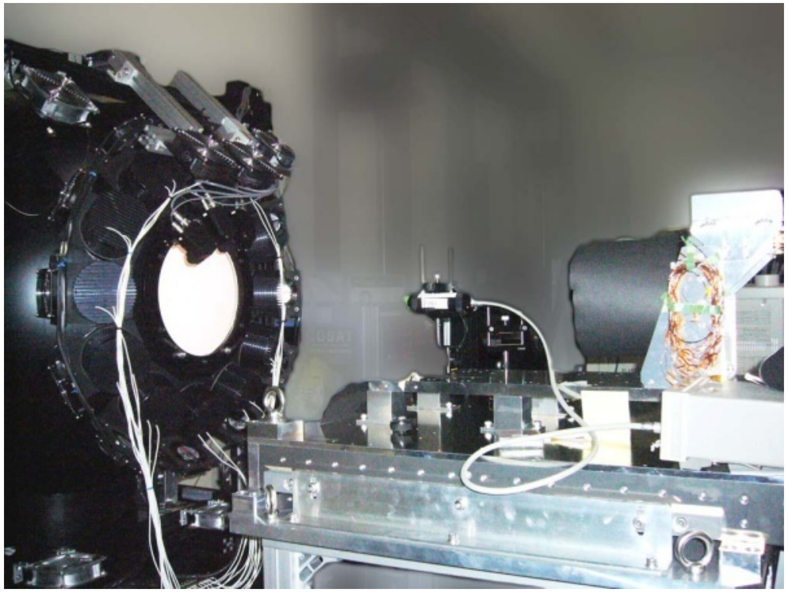
- Because very stable rotating speed is important for sensor observation geometry, the centroid position error and product of inertia should be minimized.
- Manufacturing error and assembly process were carefully studied and confirmed. The friction learning technique in the rotation speed control loop is also applied.
- The selection of the bearing unit is another key issue for the IRS 5years operation requirement. The bearing lifetime test under the vacuum condition was successfully completed for required 2.7 x 10^8 revolution operation and still under the test for the further design margin.

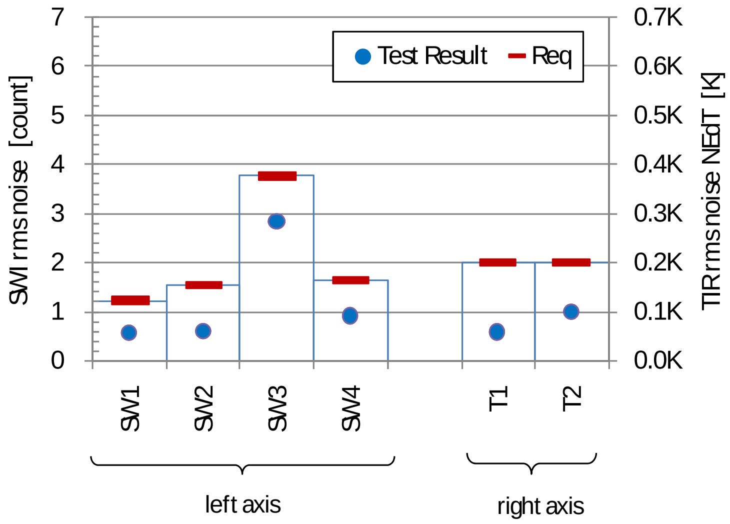




BBM test results of IRS SWI Radiometric Performance

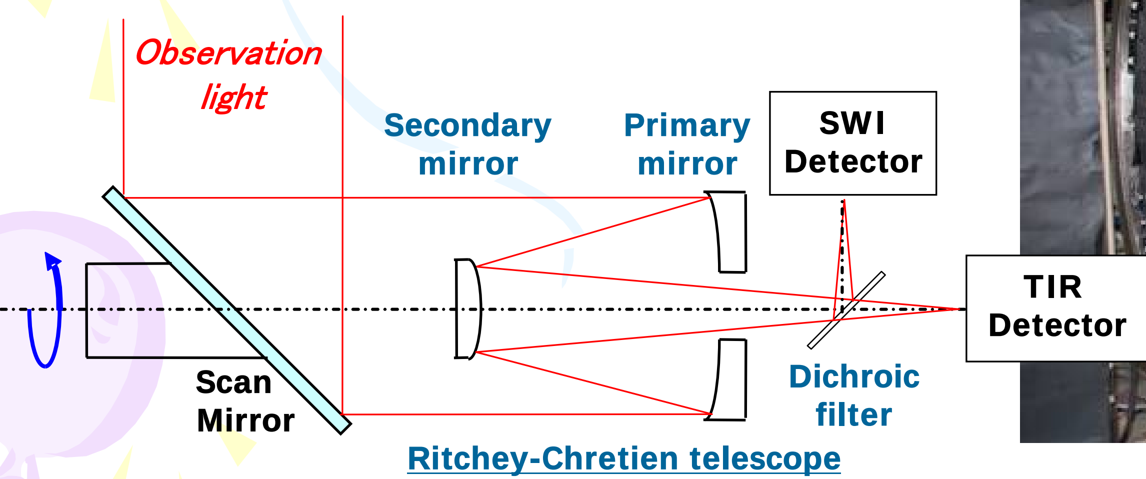
- ■SNR performance
  - ✓ high transmittance of telescope and filters
  - ✓ detector sensitivity
  - ✓ dark current of 2.2μm channel at operating -30deg C
  - ✓ System SNR performance
- ■Dynamic Range
  - ✓ adjustment at analog signal processor (ASP)
- ■EMC allowance limit
  - ✓ Trans Impedance Amplifier (TIA) for detector readout.
  - ✓ EMC test in the shield room for both RF radiation and conductive noise allowance

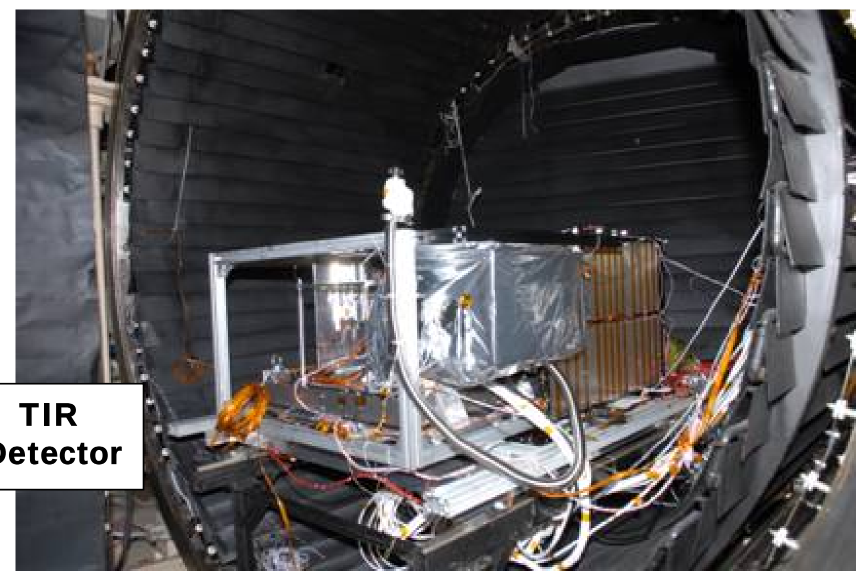




BBM test results of IRS TIR Radiometric Performance

- Detector temperature & performance
  → special dewar for 55K
  → spectral characteristics at 55K
  → detector linearity
- Effects of sensor temperature around optical path
  → dynamic range design considering sensor temperature range
  → Thermal vacuum test to confirm the design.
- Dynamic range adjustment methodology
  → integrating capacity at ROIC
  → integration time
  → post amplifier gain (fixed)
- TIR system level test meets the noise requirement (NEdT). (previous page)





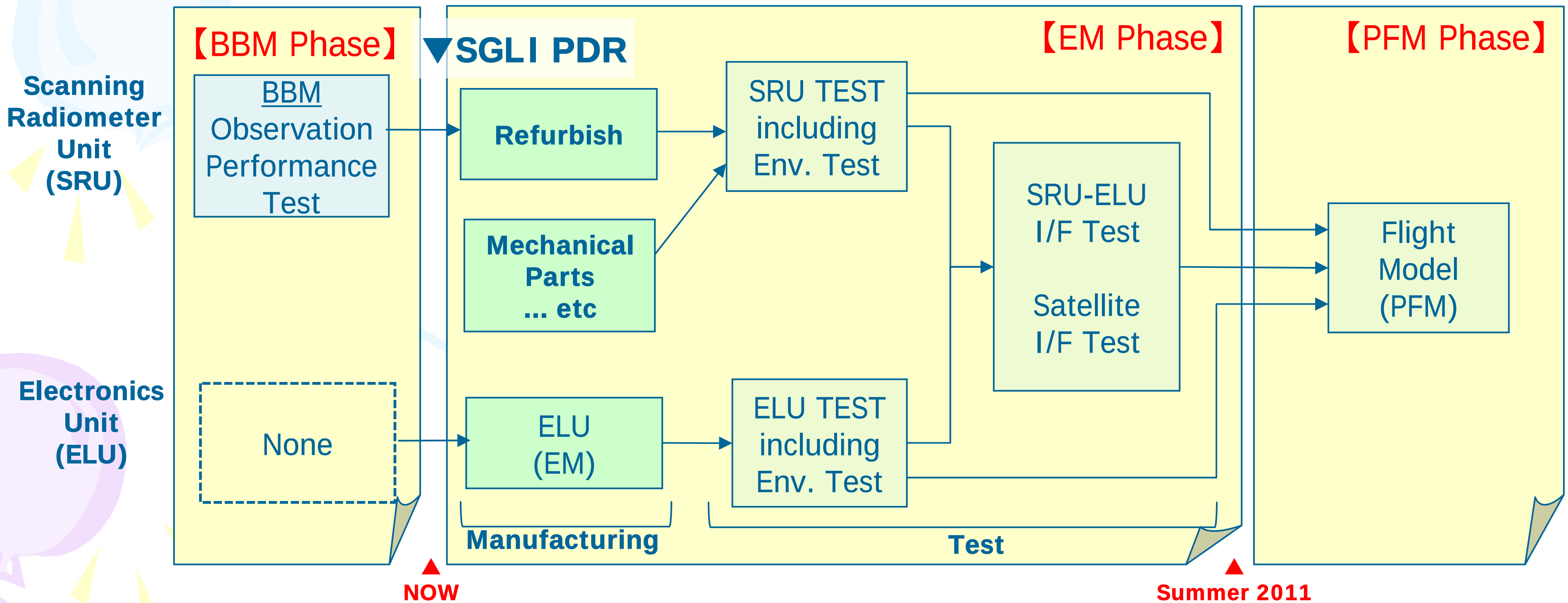
1. GCOM MISSION and BACKGROUND
2. SGLI OVERVIEW
3. SGLI Observation Mechanism
4. BBM Test Results

5. **Current Phase (EM Phase) Activity**
   - ✓ Major issues for EM phase activity
   - ✓ SGLI EM phase activity
   - ✓ GCOM-C1 project status

6. Conclusion

SGLI EM phase activity

- 1st SGLI preliminary design review (PDR-1) was held on Dec. 22, 2009
- 2nd SGLI PDR (PDR-2) for CCD is planned for middle of Feb. 2010.
- Based on these design review SGLI BBM refurbishment and Engineering Model (EM) manufacturing is under way.
- Full EM test is planned including environmental test, such as Vibration, Shock and Thermal Vacuum Test.



Major issues for EM phase activity

- The full EM test and evaluation is planned updated from the BBM test results and items not tested in BBM phase.

  - SGLI VNR + IRS
    - ✓ Contamination Strategy, Design, Analysis, Test and Evaluation
    - ✓ Electrical power consumption. Satellite anomaly case analysis.
    - ✓ SGLI operational design, such as normal TLM/CMD operation, contingency plan and calibration manouver.
    - ✓ SGLI data processing requirement for Level-1 algorithm.
  - SGLI VNR
    - ✓ Spectral non uniformity of Band pass filter for NP observation
    - ✓ Stray Light reduction
    - ✓ CCD blooming and diffusion
  - SGLI IRS
    - ✓ TIR detector stability, cooler disturbance
    - ✓ SWI noise suppression, stray light reduction, polarization sensitivity
    - ✓ Scanning stability

GCOM-C1 Project Status

- GCOM-C1 satellite design is on going. Main design focus is on the difference between GCOM-W1 and GCOM-C1 satellite because of mission difference, such as high data rate handling from SGLI.
- GCOM-C1 satellite system PDR is planned for June 2010.
- The target launch of GCOM-C1 is JFY2014 (TBD).

Japanese Fiscal Year	JFY 2006	JFY 2007	JFY 2008	JFY 2009	JFY 2010	JFY 2011	JFY 2012	JFY 2013	JFY 2014
Milestone		△ *GCOM-W1 Project start*	△ *GCOM-C1 Project start*			*GCOM-W1 Launch* △		*GCOM-C1 Launch (TBD)*	△
GCOM-W1	▲ *SDR*	▲ *PDR*		▲ *CDR*					
	Phase-A	Phase-B	Phase-C	Phase-D	Phase-D	Phase-D			
GCOM-C1		▲ *SDR*			▲ *PDR*	▲ *CDR*			
	Pre-Phase-A	Phase-A	Phase-A	Phase-B	Phase-C	Phase-C / Phase-D	Phase-D	Phase-D	Phase-D

1. GCOM MISSION and BACKGROUND
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6. **Conclusion**

Conclusion

- GCOM is JAXA's GEOSS contribution of global observation for water cycle, radiation budget and carbon cycle.
- SGLI is the optical sensor on GCOM-C1 satellite.
- Bread Board Model (BBM) design and test activity has successfully completed.
- 1st SGLI PDR was held on Dec. 22, 2009. 2nd SGLI PDR is planned for Feb. 2010. Engineering Model (EM) manufacturing is under way.
- The EM testing including environmental test and I/F test with satellite system is planned.