Operation Concept of the Second-generation Global Imager (SGLI)

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SPIE meeting in Incheon

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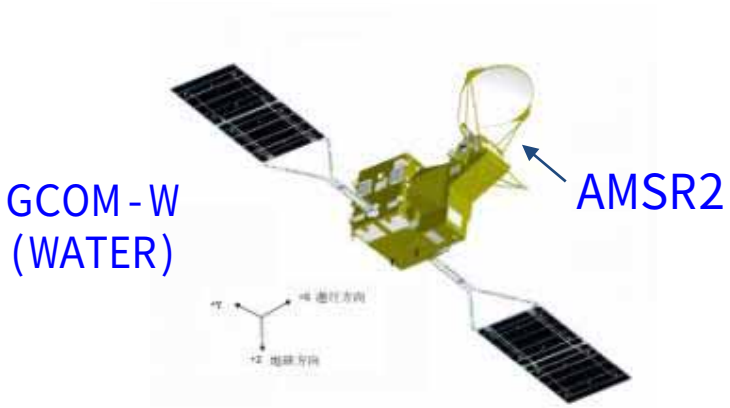
Global Change Observation Mission

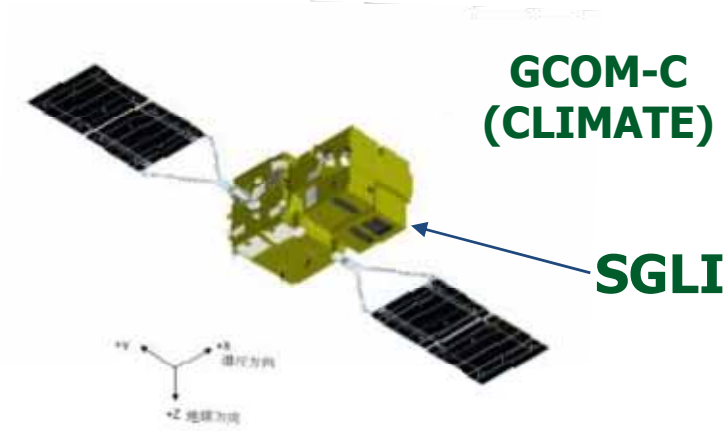
http://suzaku.eorc.jaxa.jp/GCOM_C/index_j.html

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)

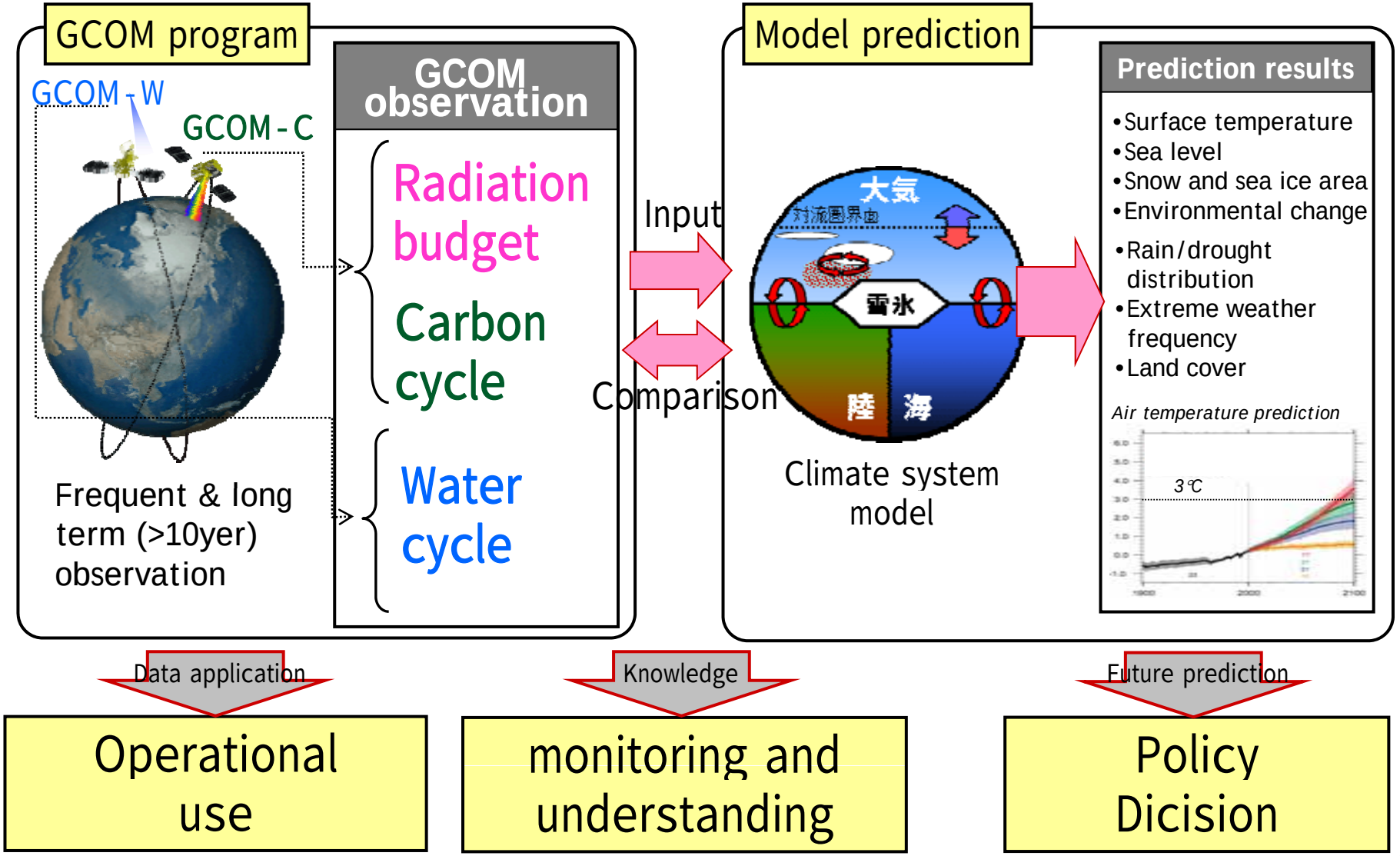


Sensor	Advanced Microwave Radiometer 2 (AMSR2) Passive Microwave Observation Water vapor, soil moisture etc

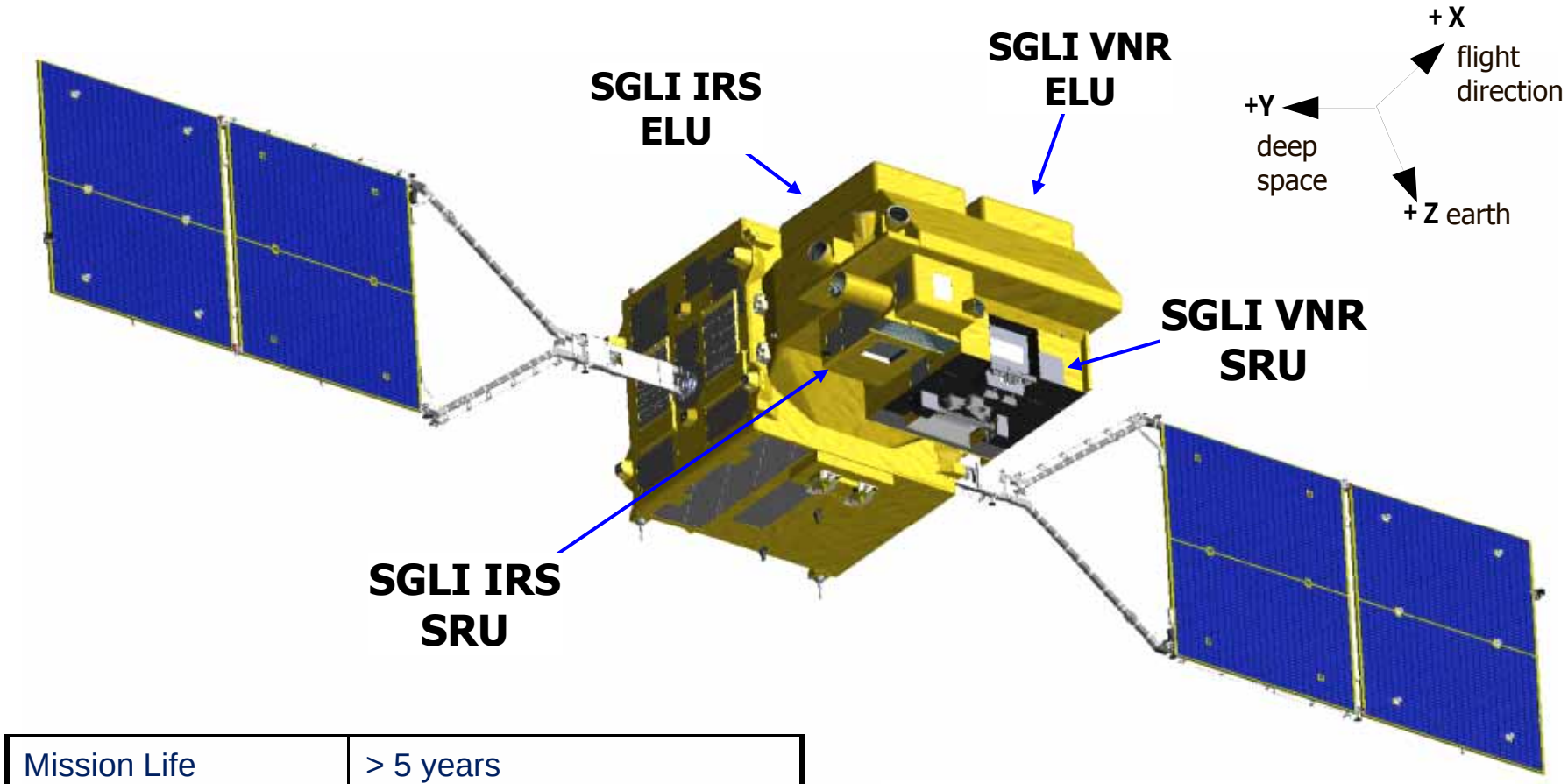


Sensor	Second Generation Global Imager (SGLI) Optical Observation 380nm – 12 micron Cloud, Aerosol, Vegetation, Chrolophl etc

GCOM Contributions to GEOSS



SGLI
on GCOM-C1 satellite

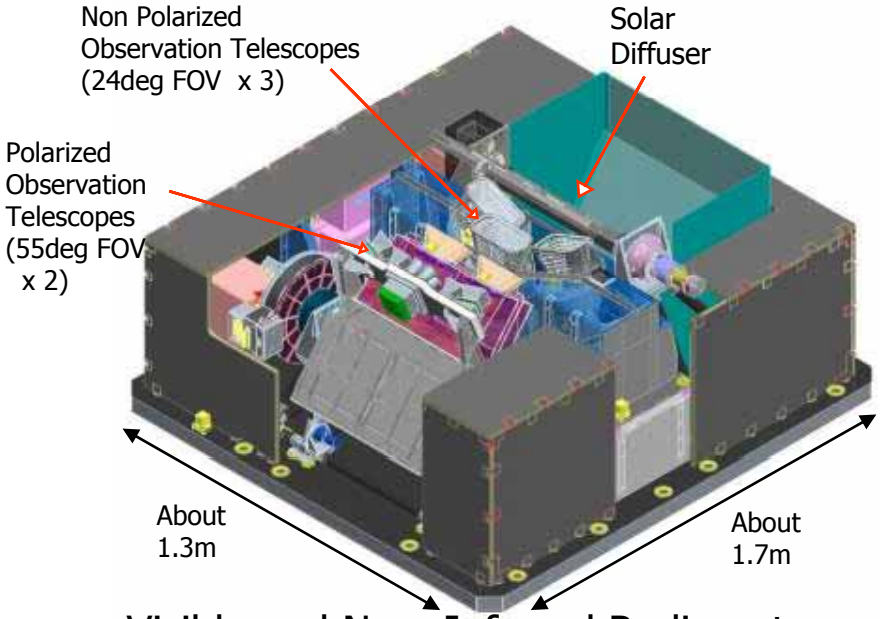


Mission Life	> 5 years
Solar Paddle	> 4000w (End of Life)
Mass	about 2,000kg

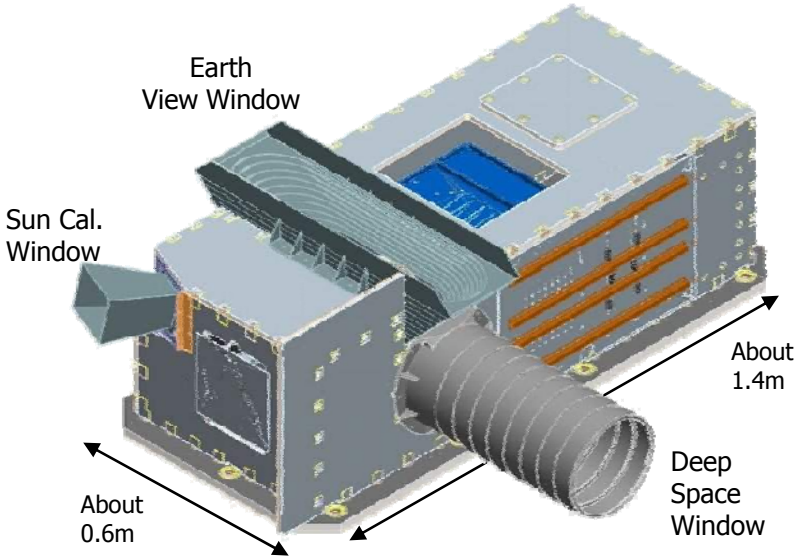
SGLI **Second Generation Global Imager**
VNR **Visible and Near Infrared Radiometer**
IRS **Infrared Scanning Radiometer**
SRU **Scanning Radiometer Unit**
ELU **Electronic Unit**

SGLI

Second Generation Global Imager



Visible and Near Infrared Radiometer
(SGLI-VNR)



Infrared Scanning Radiometer
(SGLI-IRS)

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

SGLI Specification

- 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.

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

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

SGLI channels						
CH	λ	Δλ	L_{std}	L_{max}	SNR at Lstd	IFOV
	VN, P, SW: nm T: μm		VN, P: W/m²/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

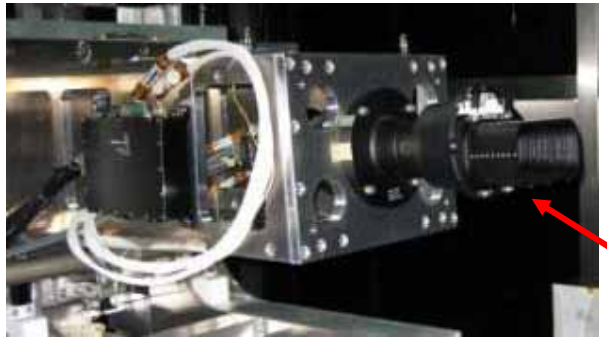
Visible and Near infrared radiometer SGLI - VNR

VNR non Polarized Obs. (VNR-NP)

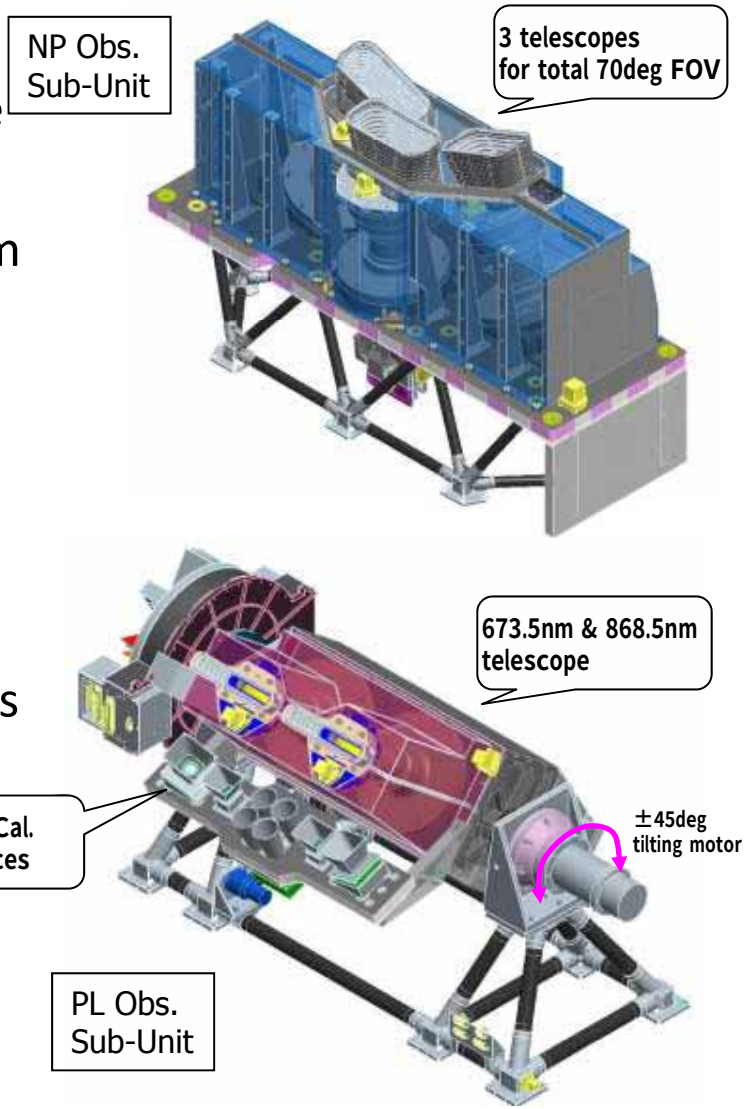
- 3 telescopes with 24deg FOV realize the total 70 deg FOV Observation (1,150km)
- Wide wavelength range Observation from 380nm to 868.5nm.

VNR Polarized Obs. (VNR-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.

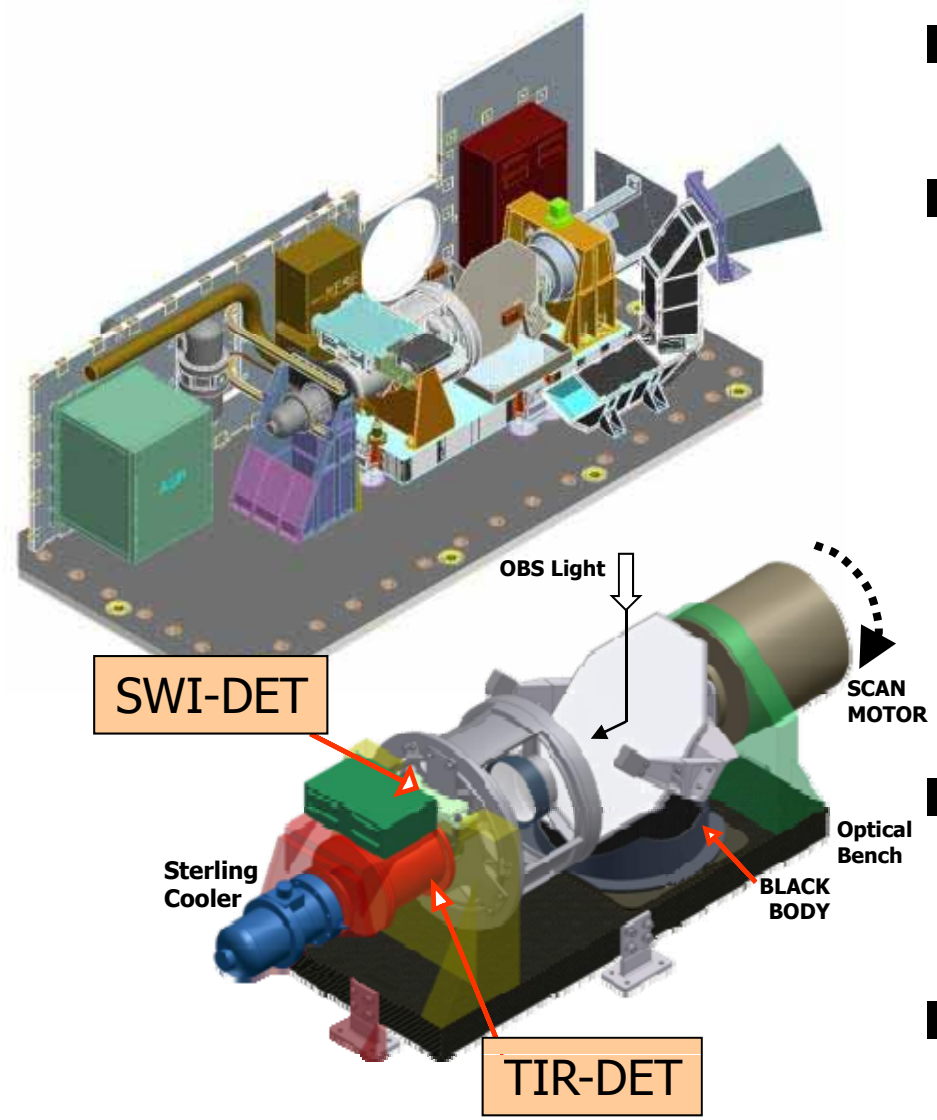


BBM NP telescope



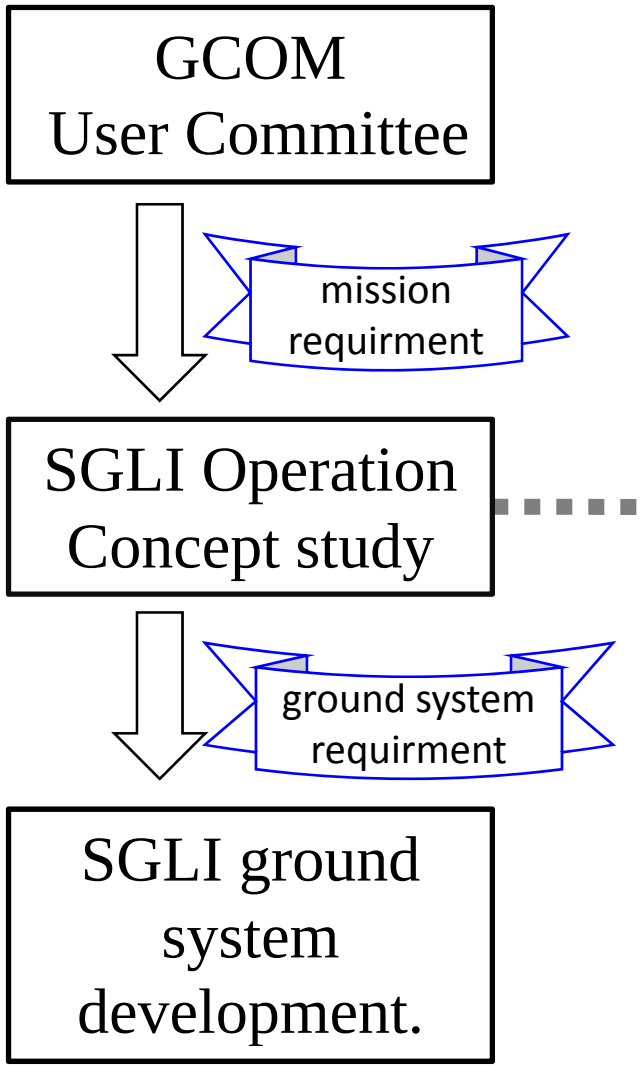
AT : Along Track Direction
CT : Cross Track Direction

Infrared Scanning Radiometer SGLI - IRS



- 45deg folding mirror rotates continuously at 81rpm.
- Observation light through Ritchey Chretien type telescope is divided with 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.

SGLI Operation Concept



SGLI Operation Concept Study

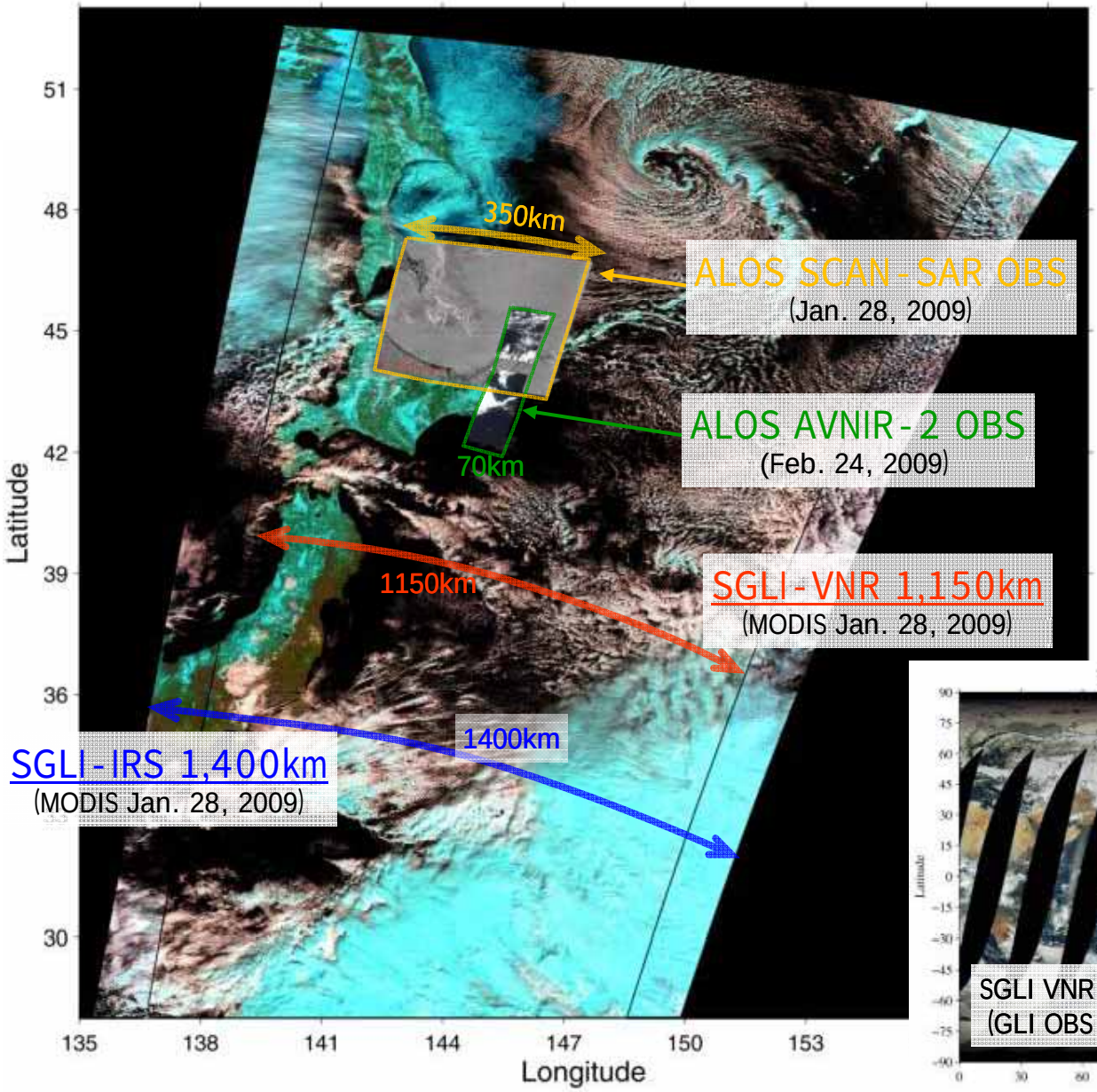
1) Wide swath / Observation Frequency
2) Daytime & Night time Observation
3) Observation Resolution
   → data volume
   → downlink stations
   → onboard recorder volume

3) VNR-PL Tilting Operation
   → Aerosol scattering angle
   → directional observation of land surface
   → F/F Control for the disturbance

4) Operational Load Simulation
   → Station load
   → Commanding load
   → plannning & realtime operation
   → data processing load
   → Off nominal case operation

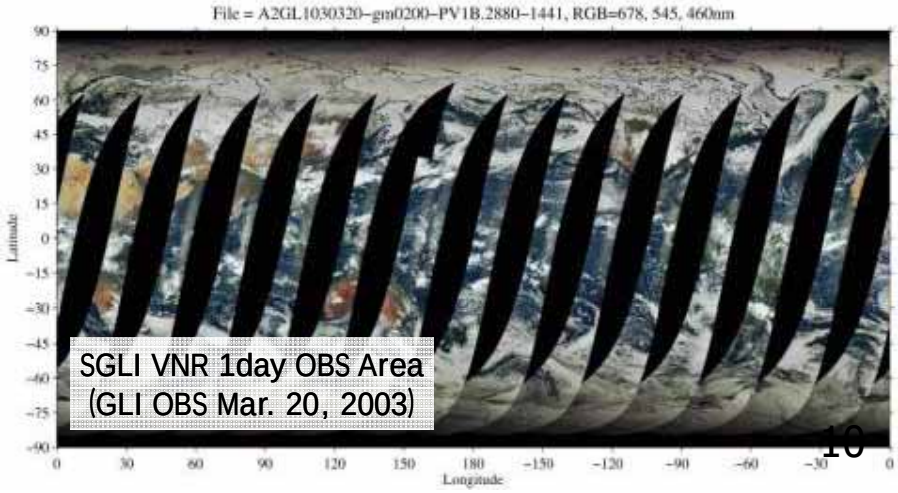
5) ground system performance req.

Observation Frequency

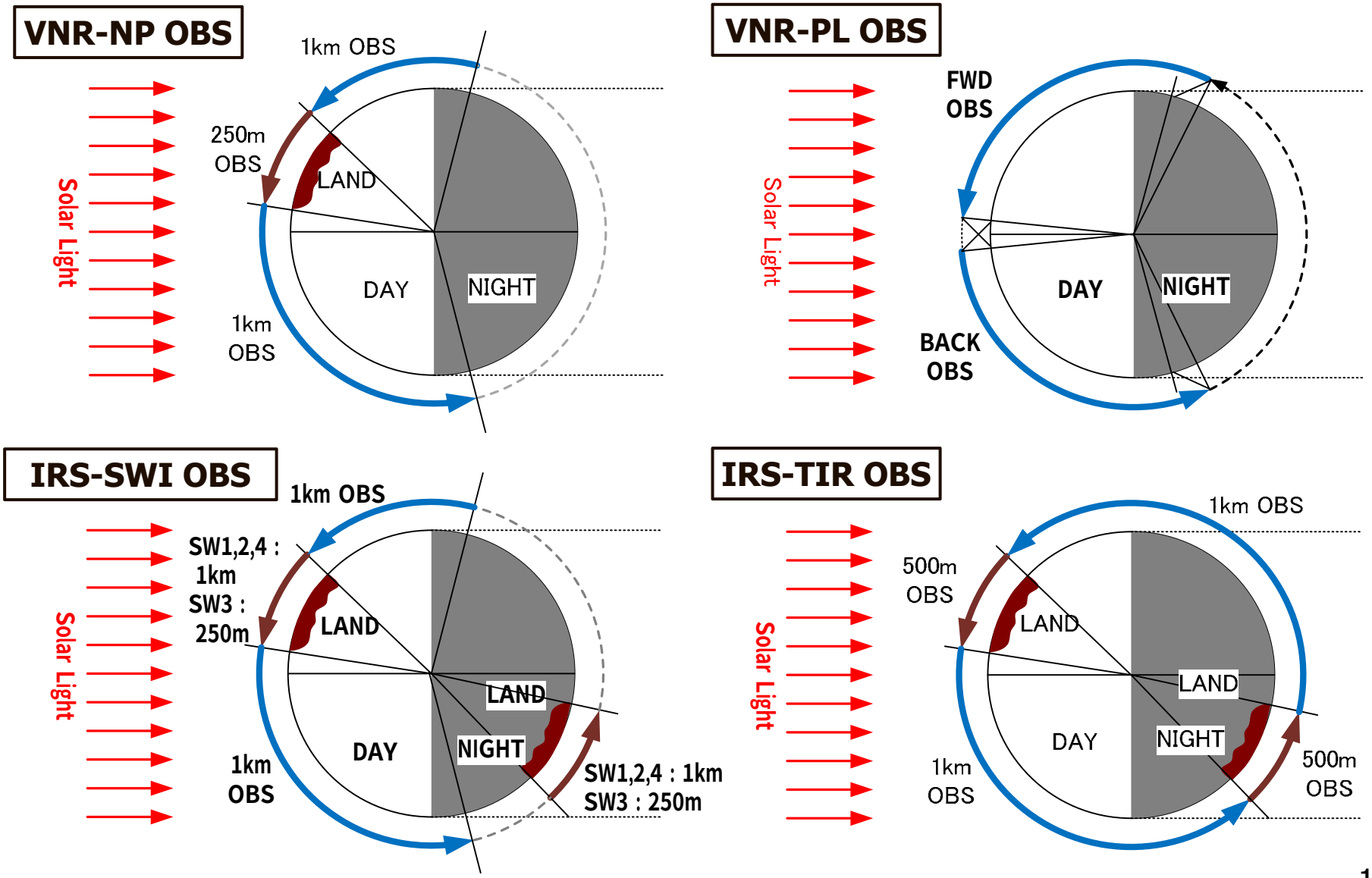


- GCOM-C1 orbit is "**34days repeat orbit**" with "**3.8days quasi repeat cycle**".

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



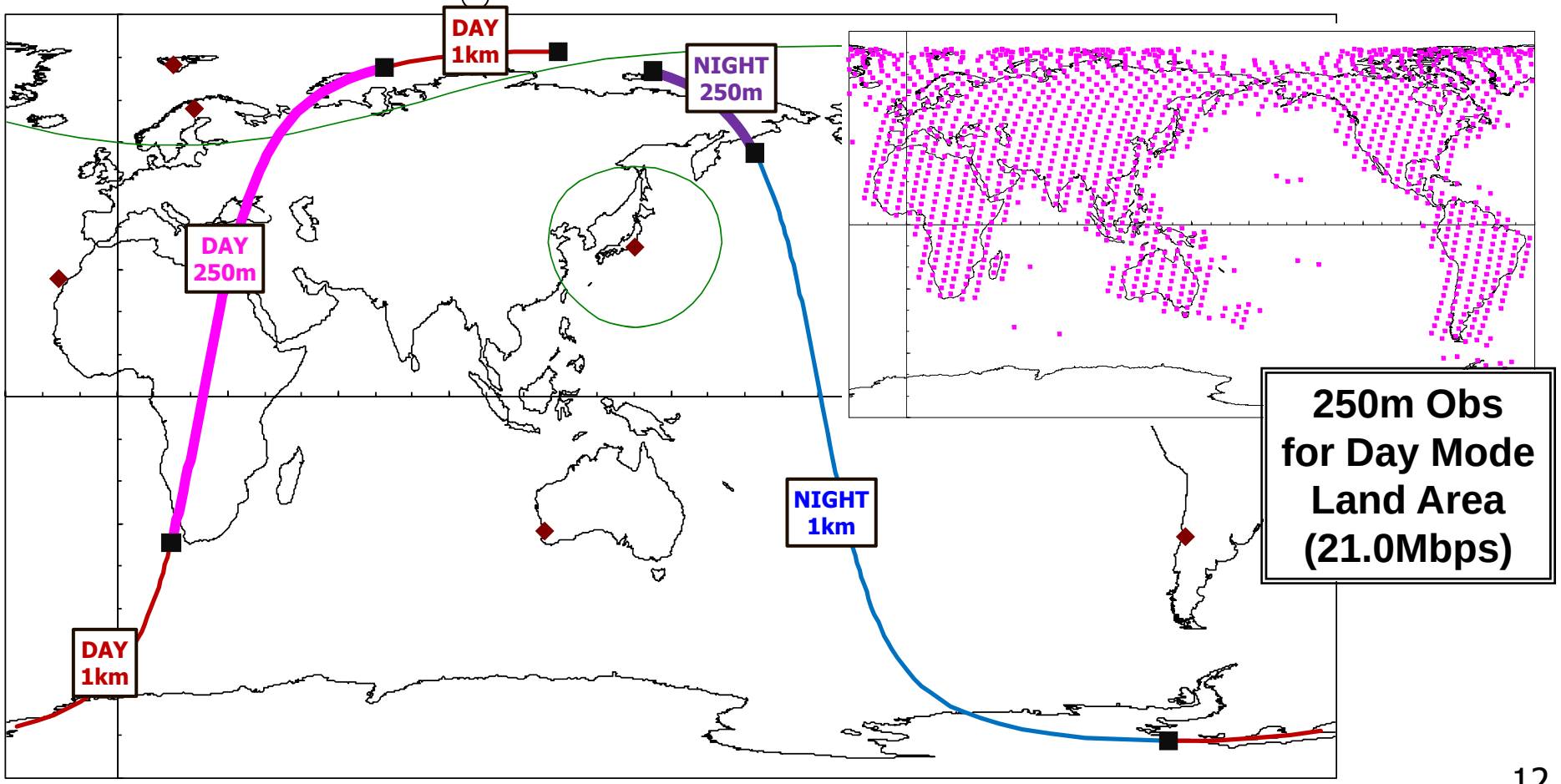
Observation Scenario



Observation Resolution

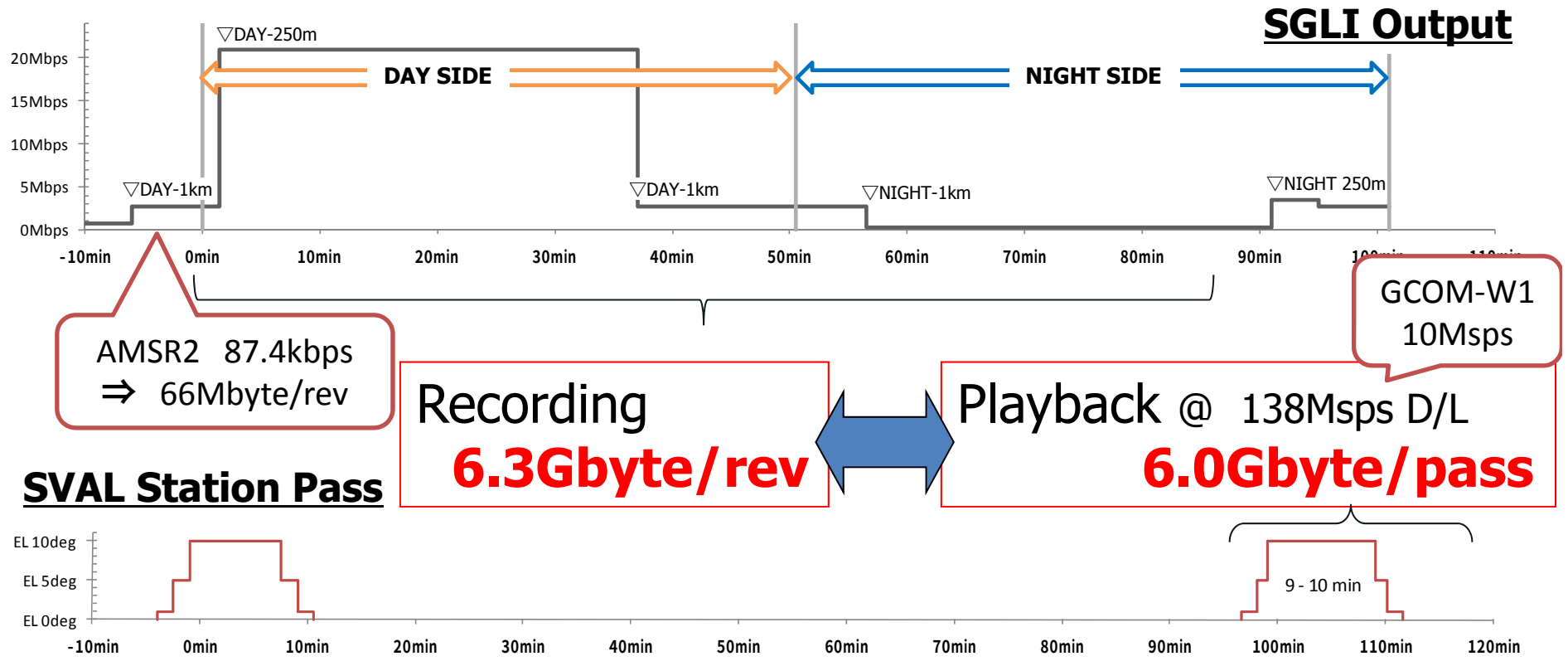
- Basic Observation Rule →

- 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.



Onboard Recorder budget & Data Latency

- **Output data rate from SGLI is two digits or more bigger than AMSR2 because of high resolution 250m observation over land.**
- **Downlink rate from GCOM-C1 is one digits or more bigger than GCOM-W1.**
  → Onboard recorder budget should be carefully studied and big impacts on data latency.



Downlink station & Onboard Recorder

Observation Scenario and Resolution req.

250m for land and coastal observation, 1km for open ocean observation

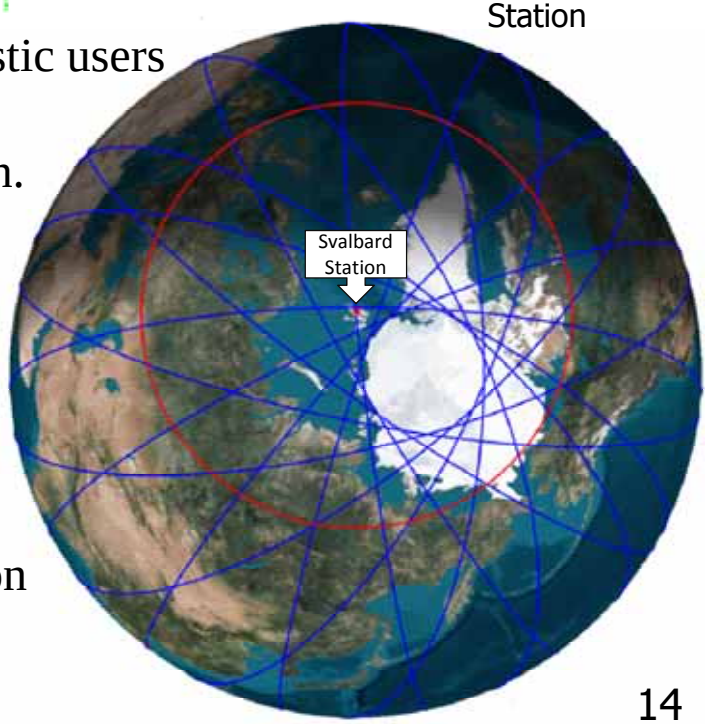
Downlink Station

- Svalbard downlink station
  → good visibility (14 or 15 passes per day) for the polar orbit satellite.
  → global observation data downlink.
- Japanese domestic station
  → quasi real time transmission to Japanese domestic users
  → backup of Svalbard station.
- Direct downlink capability to the user local station.

Onboard Recorder

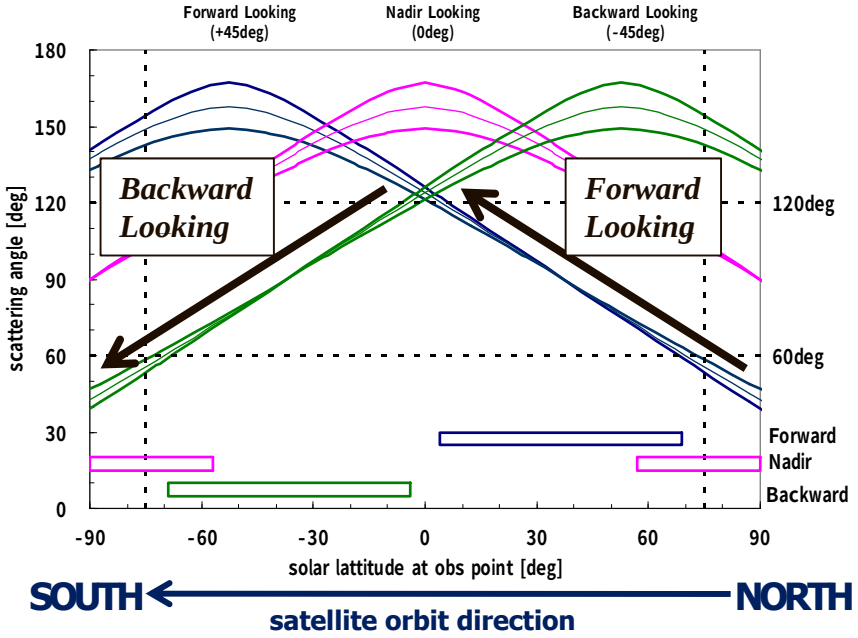
- The solid memory type recorder
  → total recorder amount in order to record and playback the global observation data without lack of data.
  → 72Gbytes (BOL) including memory degradation effects for 5 years mission life

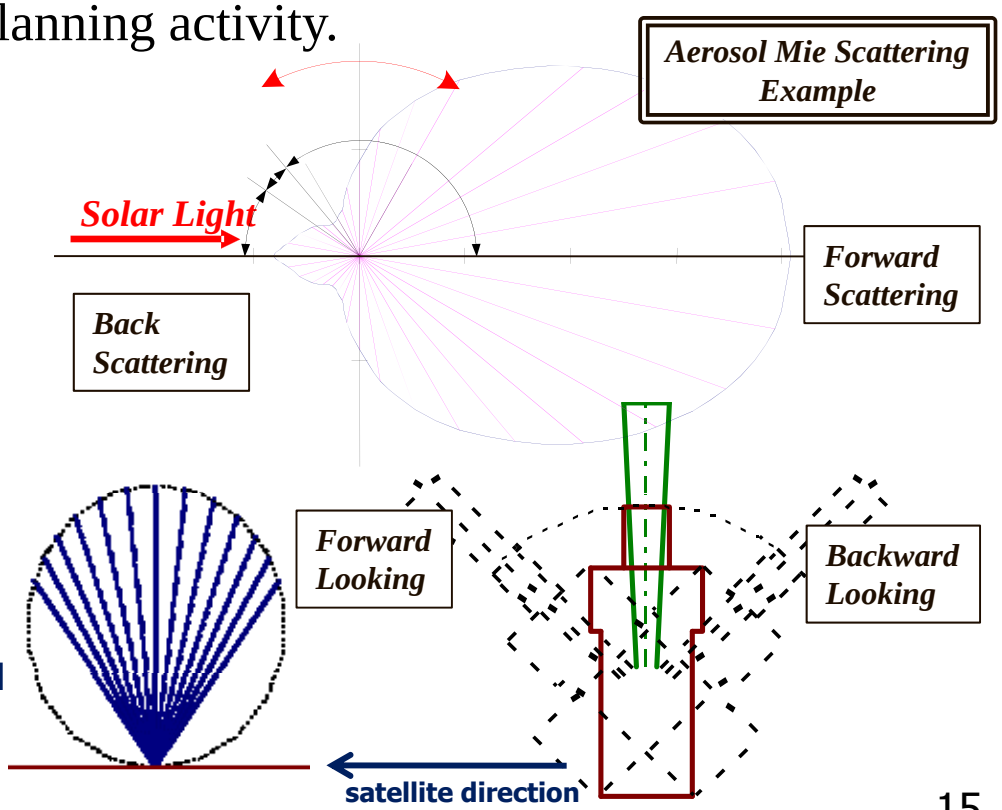
Visiblility of Svalbard Station



VNR-PL Tilting Operation

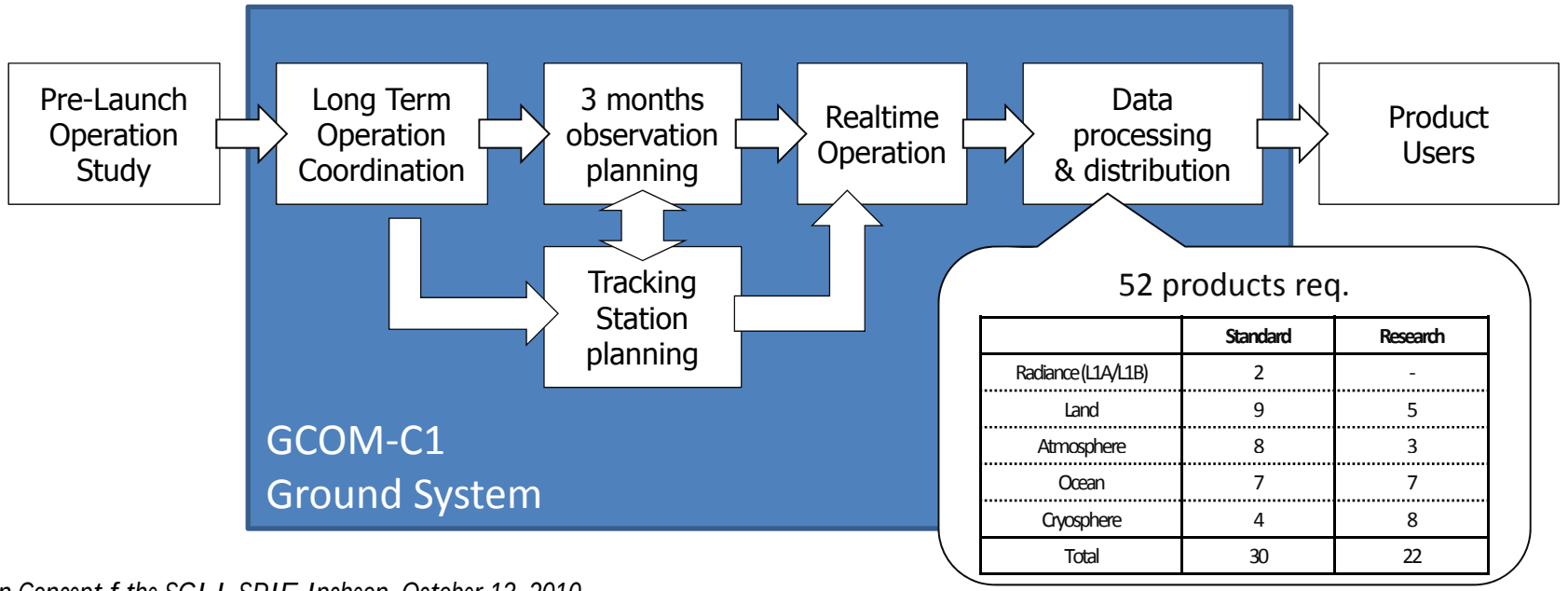
- VNR-PL tilting function from +45deg (forward looking) to -45deg (backward looking).
- Aerosol Scattering angle requirement from the retrieval algorithm
  → the forward looking for northern hemisphere, the backward looking for the southern hemisphere.
- The additional looking angle requirement like a bidirectional observation of land surface is under discussion for the planning activity.





Operational load simulation

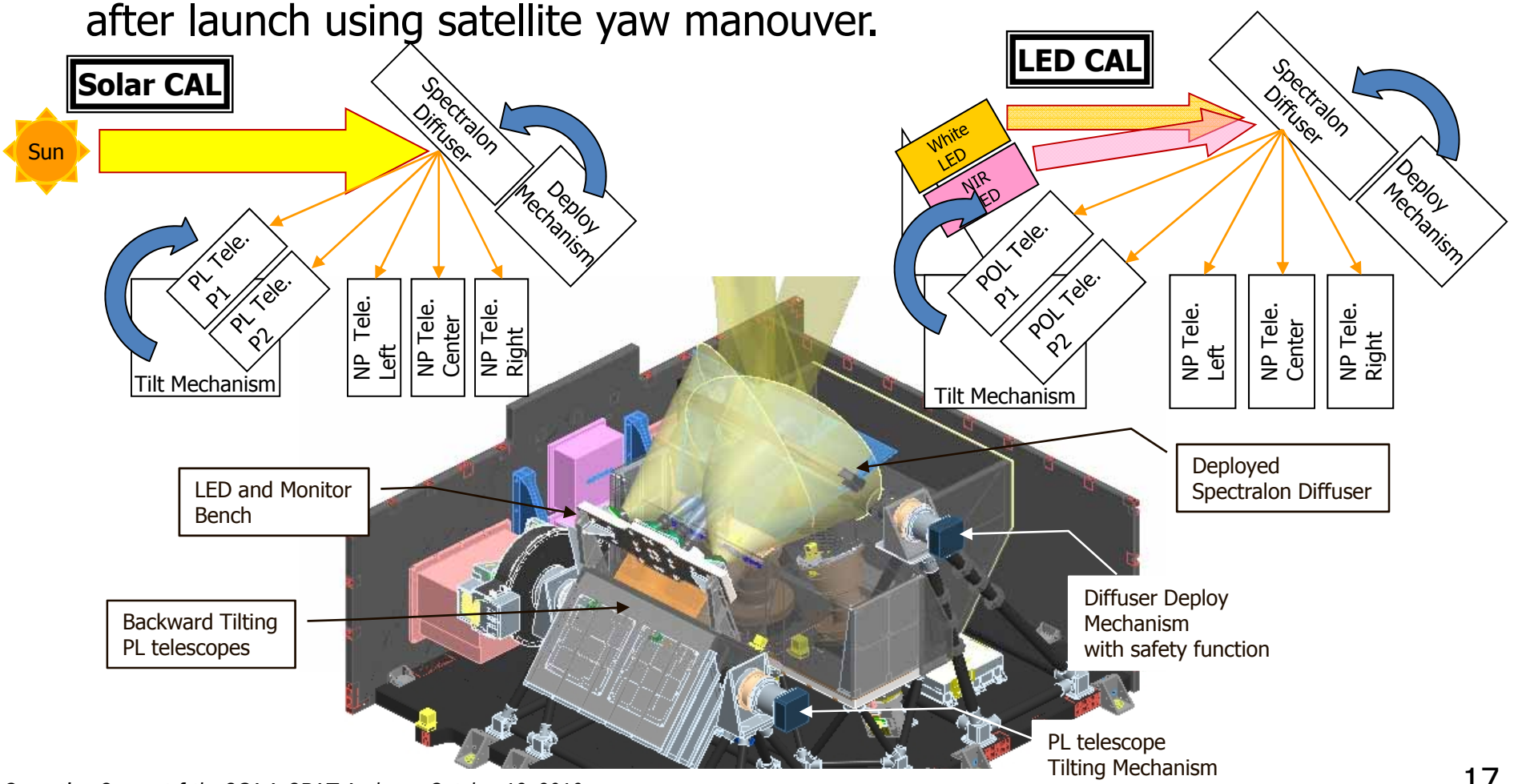
- Operational load simulation considering the operation concept
  → The planning activity for satellite operation and ground data receiving and processing are defined
- Data processing & distribution requirement
  → SGLI standard products and research products defined for both scene type and global type products (sinusoidal tile products).
  → The performance and interface specification to the other ground system.
  → The convenience for the data handling and analysis at user side.



	Standard	Research
Radiance (L1A/L1B)	2	-
Land	9	5
Atmosphere	8	3
Ocean	7	7
Cryosphere	4	8
Total	30	22

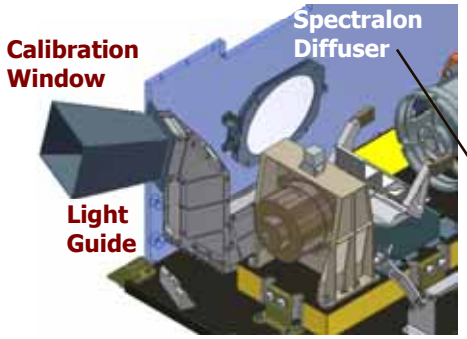
VNR Onboard CALIBRATION

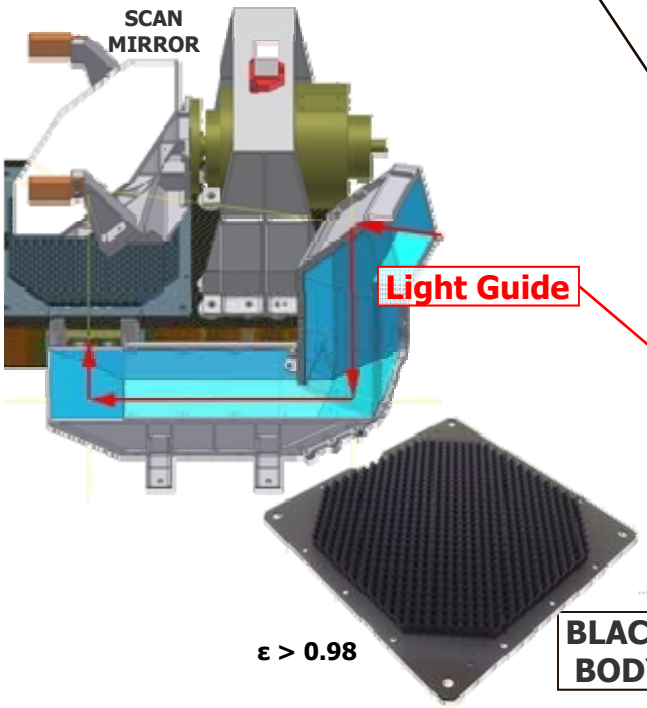
- Deployable Spectralon diffuser is used for both Solar and LED calibration. Calibration coefficient will be traced using this solar calibration data.
- **β** angle dependency for solar calibration will be characterized shortly after launch using satellite yaw manouver.

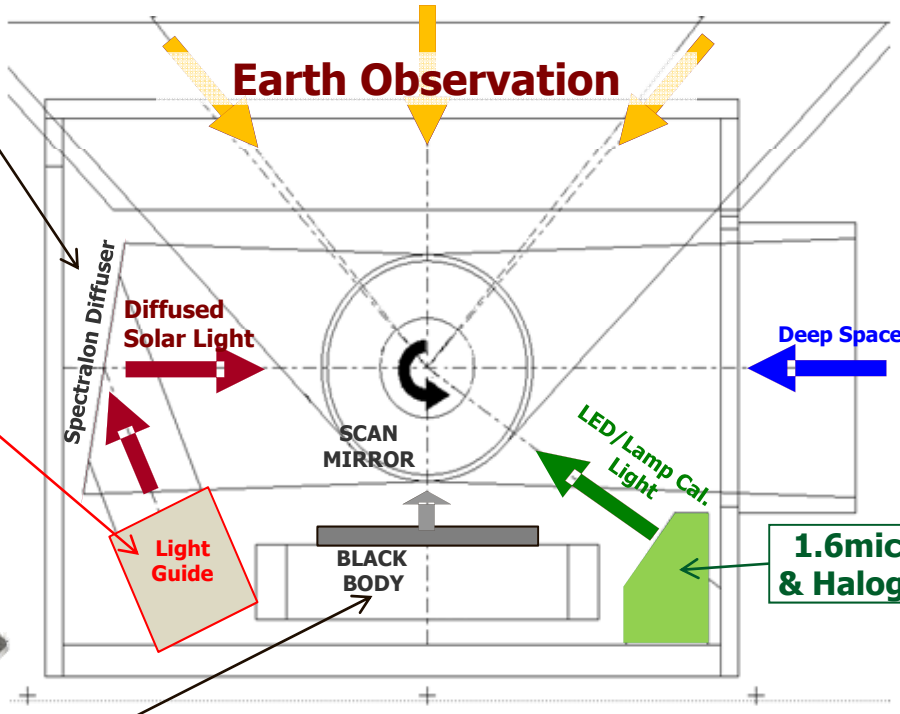


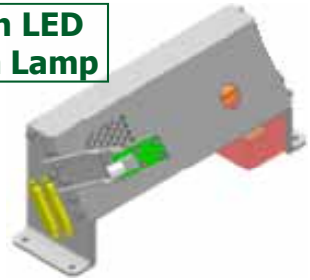
IRS Onboard calibration

- 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**"





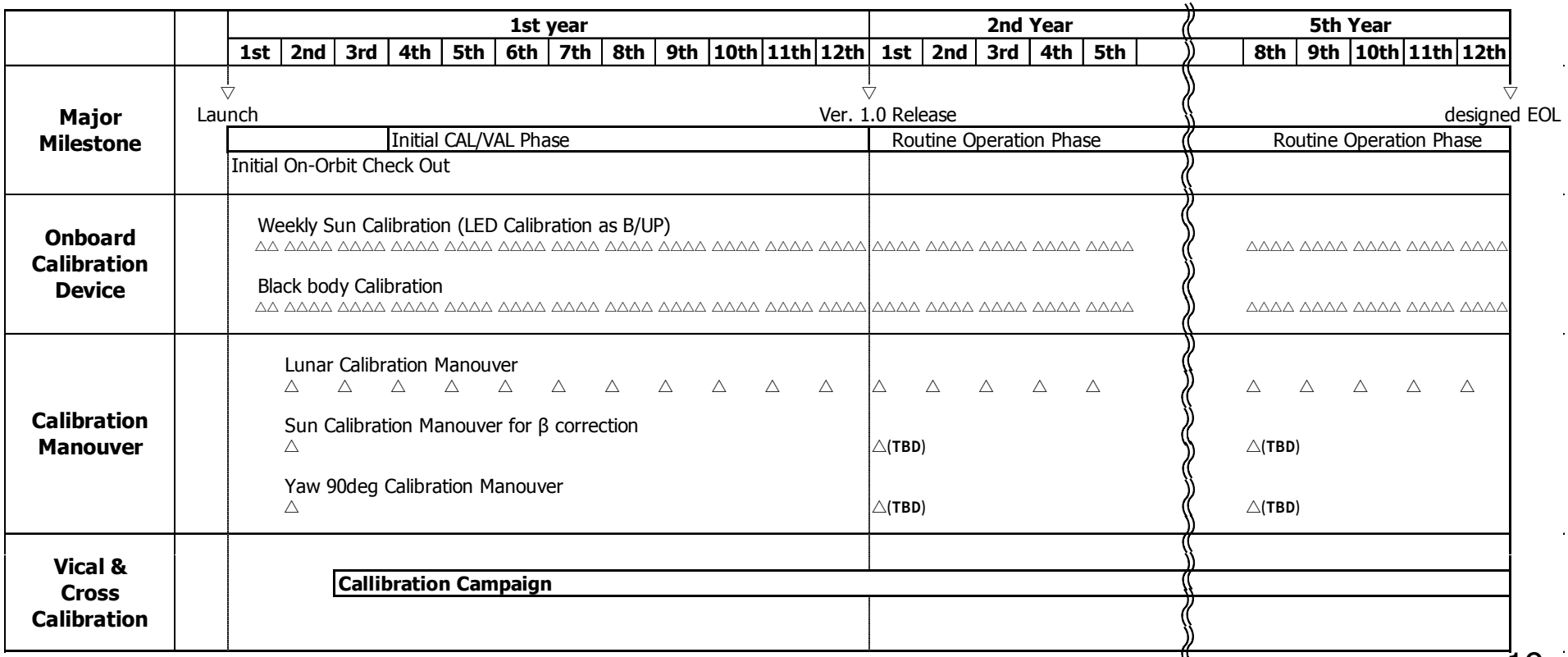




Onboard Calibration Device & Calibration Manouver

→ The calibration input from different geometric direction provides us with good information for the systematic calibration error.

→ SGLI calibration uses both onboard calibration device and calibration manouver.



Calibration Manouver

Lunar Calibration Manouver

- ✓ Moon reflecting solar light is a stable light source as a long term calibration reference of the optical sensors.
- ✓ Lunar calibration manouver is done at every 29 days interval (= synodic period of the moon and the sun)
- ✓ SGLI observes same phase angle moon (7deg) during 5 years mission for the integral lunar calibration.

ADEOS-II/GLI 250m

Sun Angle Correction Manouver

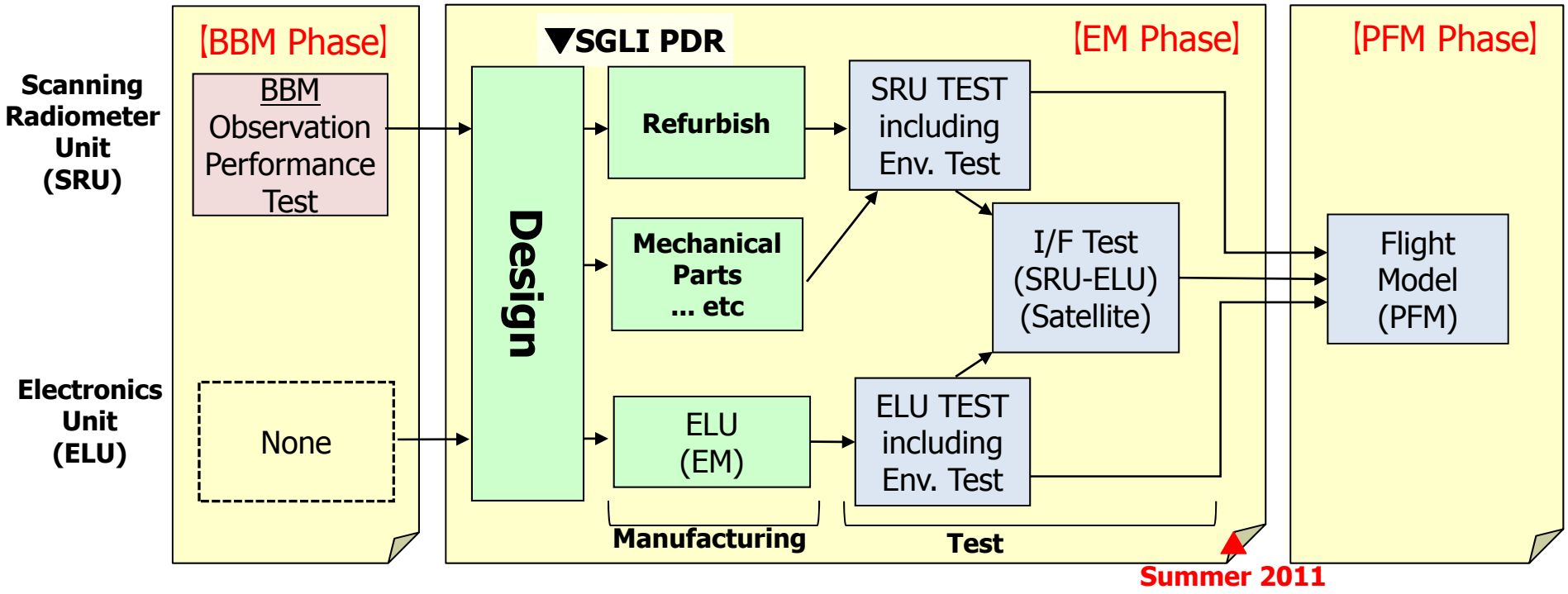
- ✓ As earth rotates around the sun, solar direction gradually change because of the elliptical and inclined orbit of the earth.
- ✓ The local sun time tolerance is another factor for this solar angle change.
- ✓ Solar angle calibration manouver is done to establish the solar angle dependency database for this calibration.

Obs. Angle Correction Manouver

- ✓ Because VNR uses wide FOV's pushbroom type CCD sensor, the satellite observation angle dependency is another key calibration factor.
- ✓ The satellite yaw axis is 90deg rotated to observe the almost same earth target with different CCD detectors.
- ✓ The homogeneous target is used for this calibration.

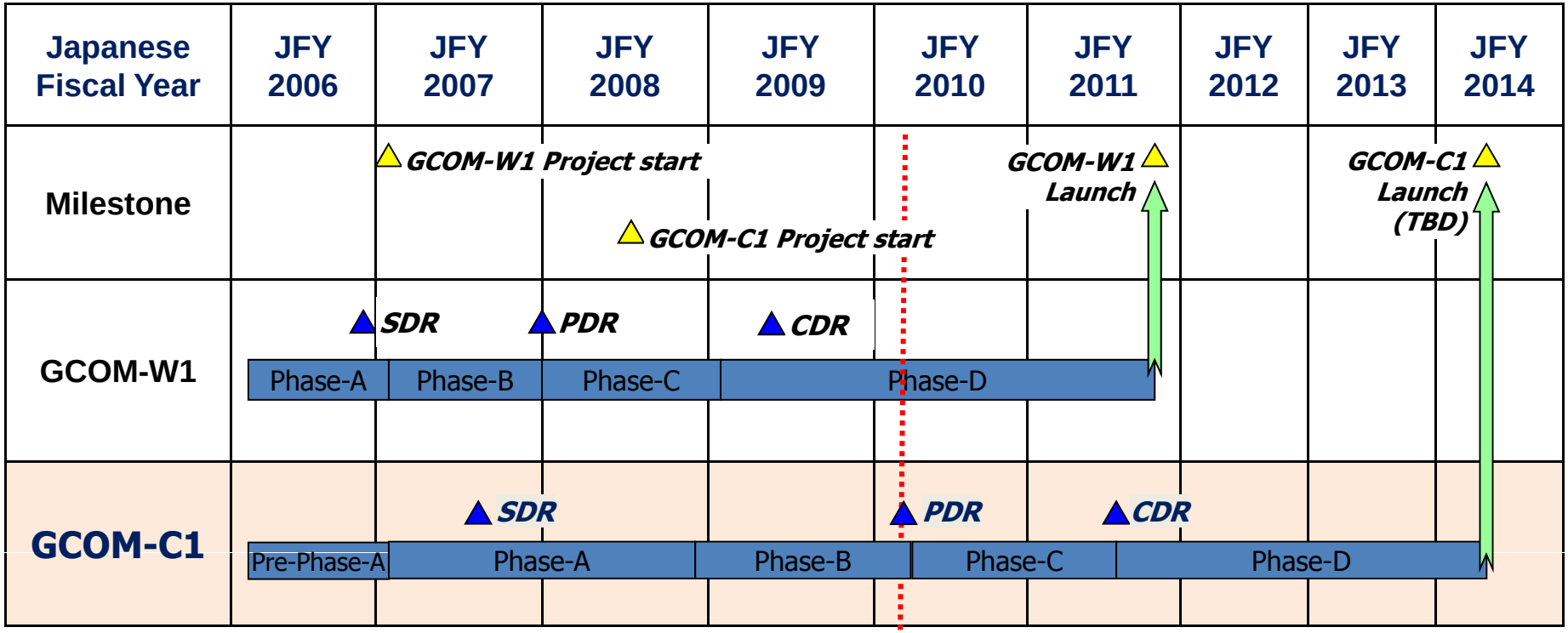
SGLI EM phase activity

- 1st SGLI preliminary design review (PDR-1) was held on Dec. 22, 2009
- 2nd SGLI PDR (PDR-2) for CCD was held on March 23, 2010.
- Based on these design review SGLI BBM refurbishment and Engineering Model (EM) manufacturing is approved.
- Full EM test is planned including environmental test, such as Vibration, Shock and Thermal Vacuum Test.



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 for July-October, 2010.
- The target launch of GCOM-C1 is JFY2014.



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.
- SGLI PDR is complete on March 23, 2010. Engineering Model (EM) manufacturing is under way.
- The EM testing including environmental test and I/F test with satellite system is planned.
- The operation concept is under study for the input to the SGLI supporting ground system design.

Back up slides

SGLI Standard Products (1 of 2)

Area	group	Product	Day/night	Grid size	Release threshold*1	Standard accuracy*1	Target accuracy*1
Common	radiance	TOA radiance (including system geometric correction)	TIR and land 2.2μm: both Other VNR,SWI: daytime (+special operation)	VNR,SWI Land/coast: 250m, offshore: 1km, polarimetory:1km TIR Land/coast: 500m, offshore: 1km	Radiometric 5% (absolute*3)*5 Geometric<1pixel	VNR,SWI: 5% (absolute*3), 1% (relative*4) TIR: 0.5K (@300K) Geometric<0.5pixel	VNR,SWI: 3% (absolute*3), 0.5% (relative*4) TIR: 0.5K (@300K) Geometric<0.3pixel
Land	Surface reflectance	Precise geometric correction	both	250m	<1pixel*6	<0.5pixel*6	<0.25pixel*6
		Atmospheric corrected reflectance (incl. cloud detection)	Daytime	250m	0.3 (<=443nm), 0.2 (>443nm) (scene) *7	0.1 (<=443nm), 0.05 (>443nm) (scene) *7	0.05 (<=443nm), 0.025 (>443nm) (scene)*7
	Vegetation and carbon cycle	Vegetation index		250m	Grass:25%(scene), forest:20%(scene)	Grass:20%(scene), forest:15%(scene)	Grass:10%(scene), forest:10%(scene)
		Above-ground biomass		1km	Grass:50%, forest: 100%	Grass:30%, forest:50%	Grass:10%, forest:20%
		Vegetation roughness index		1km	Grass&forest: 40% (scene)	Grass& forest:20% (scene)	Grass&forest:10% (scene)
		Shadow index		250m, 1km	Grass&forest: 30% (scene)	Grass& forest:20% (scene)	Grass&forest:10% (scene)
		fAPAR		250m	Grass:50%, forest: 50%	Grass:30%, forest:20%	Grass:20%, forest:10%
		Leaf area index		250m	Grass:50%, forest: 50%	Grass:30%, forest:30%	Grass:20%, forest:20%
	temperature	Surface temperature	Both	500m	<3.0K (scene)	<2.5K (scene)	<1.5K (scene)

Common note:

*1: The "release threshold" is minimum levels for the first data release at one year from launch. The "standard" and "research" accuracies correspond to full- and extra success criteria of the mission respectively. Accuracies are shown by RMSE basically.

Radiance data note:

*2: TOA radiance is derived from sensor output with the sensor characteristics, and other products are physical parameters estimated using algorithms including knowledge of physical, biological and optical processes

*3: absolute error is defined as offset + noise

*4: relative error is defined as relative errors among channels, FOV, and so on.

*5: Release threshold of radiance is defined as estimated errors from vicarious, onboard solar diffuser, and onboard blackbody calibration because of lack of long-term moon samples

Land data note:

*6: Defined as RMSD from GCP

*7: Defined with land reflectance~0.2, solar zenith<30deg, and flat surface. Release threshold is defined with AOT@500nm<0.25

SGLI Standard Products (2 of 2)

Area	Group	Product	Day/night	Grid size	Release threshold*1	Standard accuracy*1	Target accuracy*1
Atmosphere	Cloud	Cloud flag/Classification	Both	1km	10% (with whole-sky camera)	Incl. below cloud amount	Incl. below cloud amount
		Classified cloud fraction	Daytime	1km (scene), 0.1deg (global)	20% (on solar irradiance)*8	15%(on solar irradiance)*8	10%(on solar irradiance)*8
		Cloud top temp/height	Both		1K*9	3K/2km (top temp/height)*10	1.5K/1km (temp/height)*10
		Water cloud OT/effective radius	Daytime		10%/30% (CloudOT/radius) *11	100% (as cloud liquid water*13)	50%*12 / 20%*13
		Ice cloud optical thickness			30%*11	70%*13	20%*13
	aerosol	Aerosol over the ocean			0.1(Monthly τa_670,865)*14	0.1(scene τa_670,865)*14	0.05(scene τa_670,865)
		Land aerosol by near ultra violet			0.15(Monthly τa_380)*14	0.15(scene τa_380)*14	0.1(scene τa_380)
		Aerosol by Polarization			0.15(Monthlyτa_670,865)*14	0.15(scene τa_670,865)*14	0.1(scene τa_670,865)
Ocean	Ocean color	Normalized water leaving radiance (incl. cloud detection)	Daytime	250m (coast) 1km (offshore) 4~9km (global)	60% (443~565nm)	50% (<600nm) 0.5W/m²/str/um (>600nm)	30% (<600nm) 0.25W/m²/str/um (>600nm)
		Atmospheric correction param			80% (AOT@865nm)	50% (AOT@865nm)	30% (AOT@865nm)
		Photosynthetically available radiatioin			20% (10km/month)	15% (10km/month)	10% (10km/month)
	In-water	Chlorophyll-a concentration			–60~+150% (offshore)	–60~+150%	–35~+50% (offshore), –50~+100% (coast)
		Suspended solid concentration			–60~+150% (offshore)	–60~+150%	–50~+100%
		Colored dissolved organic matter			–60~+150% (offshore)	–60~+150%	–50~+100%
	temperature	Sea surface temperature	Both	500m (coast) 1km (offshore) 4~9km (global)	0.8K (daytime)	0.8K (day&night time)	0.6K (day&night time)
Cryosphere	Area/ distribution	Snow and Ice covered area (incl. cloud detection)	Daytime	250m (scene) 1km (global)	10% (vicarious val with other sat. data)	7%	5%
		OKhotsk sea-ice distribution		250m	10%	5%	3%
	Surface properties	Snow and ice surface Temperature		500m (scene) 1km (global)	5K (vicarious val with other sat. data and climatology)	2K	1K
		Snow grain size of shallow layer		250m (scene) 1km (global)	100%(vicarious val with climatology between temp-size)	50%	30%

Atmosphere note:

*8: Comparison with in-situ observation on monthly 0.1-degree

*9: Vicarious val. on sea surface and comparison with objective analysis data

*10: Inter comparison with airplane remote sensing on water clouds of middle optical thickness

*11: Release threshold is defined by vicarious val with other satellite data (e.g., global monthly statistics in the mid-low latitudes)

*12: Comparison with cloud liquid water by in-situ microwave radiometer

*13: Comparison with optical thickness by sky-radiometer (the difference can be large due to time-space inconsistence and large error of the ground measurements)

*14: Estimated by experience of aerosol products by GLI and POLDER

SGLI Research Products (1 of 1)

Area	Group	Product	Day/night	Grid size	Release threshold*1
Land	Application	Land net primary production	Daytime	1km	30% (yearly)
		Water stress trend	N/A	500m	10% *15 (error judgment rate)
		Fire detection index	Both	500m	20% *16 (error judgment rate)
		Land cover type	Daytime	250m	30% (error judgment rate)
		Land surface albedo		1km	10%
Atmosphere	Cloud	Water cloud geometrical thickness	Daytime	1km (scene), 0.1deg (global)	300m
	Radiation budget	Long-wave radiation flux			Downward 10W/m2, upward 15W/m2 (monthly)
		Short-wave radiation flux			Downward 13W/m2, upward 10W/m2
Ocean	Ocean color	Euphotic zone depth	Daytime	250m (coast), 1km (offshore), 4~9km (global)	30%
	In-water	Inherent optical properties			a(440): RMSE<0.25, bbp(550): RMSE<0.25
	Application	Ocean net primary productivity		500m (coast), 1km (offshore), 4~9km (global)	70% (monthly)
		Phytoplankton functional type		250m (coast), 1km (offshore), 4~9km (global)	error judgment rate of large/ small phytoplankton dominance<20%; or error judgment rate of the dominant phytoplankton functional group <40%
		Redtide			error judgment rate <20%
		multi sensor merged ocean color		250m (coast), 1km (offshore)	–35~+50% (offshore), –50~+100% (coast)
		multi sensor merged SST	Both	500m (coast), 1km (offshore)	0.8K (day&night time)
Cryosphere	Area/ distribution	Snow and ice classification	N/A	1km	10%
		Snow covered area in forest and mountain	Daytime	250m	30%
	Surface propaties	Snow grain size of subsurface layer		1km	50%
		Snow grain size of top layer		250m(scene), 1km (global)	50%
		Snow and ice albedo		1km	7%
		Snow impurity		250m(scene), 1km (global)	50%
		Ice sheet surface roughness	N/A	1km	0.05 (height/width)
	Boundary	Ice sheet boundary monitoring	N/A	250m	<500m

Research product note:
*15: Evaluate in semiarid regions (steppe climate etc.)
*16: Fires >1000K occupying >1/1000 on 1km pixel at night (using 2.2um of 1 km and thermal infrared channels)