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Status of Advanced Land Observing Satellite (ALOS) - Daichi

This document reports on an overview and the status of JAXA's Advanced Land Observing Satellite (ALOS)

1. Overview

The Japanese Earth observing satellite program consists of two series: those satellites used mainly for atmospheric and marine observation, and those used mainly for land observation. The Advanced Land Observing Satellite (ALOS) follows the Japanese Earth Resources Satellite-1 (JERS-1) and Advanced Earth Observing Satellite (ADEOS) and will utilize advanced land-observing technology. ALOS will be used for cartography, regional observation, disaster monitoring, and resource surveying.

ALOS's objectives are:

- to provide maps for Japan and other countries including those in the Asian-Pacific region (Cartography)
- to perform regional observation for "sustainable development", harmonization between Earth environment and development (Regional Observation),
- to conduct disaster monitoring around the world (Disaster Monitoring) including Sentinel Asia and Disaster Charter,
- to survey natural resources (Resources Surveying),
- to develop technology necessary for future Earth observing satellite (Technology Development)

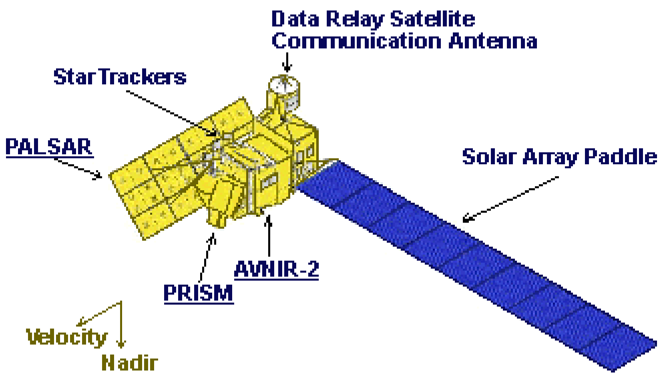

Figure 1: ALOS Configuration

The ALOS has three remote-sensing instruments: the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping, the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) for precise land coverage observation, and the Phased Array type L-band Synthetic Aperture Radar (PALSAR) for day-and-night and all-weather land observation. In order to utilize fully the data obtained by these sensors, the ALOS was designed with two advanced technologies: the former is the high speed and large capacity mission data handling technology, and the latter is the precision spacecraft position and attitude determination capability. They will be essential to high-resolution remote sensing satellites in the next decade.

ALOS have been successfully launched on an H-IIA launch vehicle from the Tanegashima Space Center, Japan on 24 January, 2006, and renamed Daichi.

Table 1: ALOS Characteristics

Launch Date	January 24, 2006	
Launch Vehicle	H-IIA	
Launch Site	Tanegashima Space Center	
Spacecraft Mass	Approx. 4 tons	
Generated Power	Approx. 7 kW (at End of Life)	
Design Life	3 -5 years	
Orbit	Sun-Synchronous Sub-Recurrent	
	Repeat Cycle: 46 days Sub Cycle: 2 days	
	Altitude: 691.65 km (at Equator)	
	Inclination: 98.16 deg.	
Attitude Determination Accuracy	2.0×10^{-4}degree (with GCP)	
Position Determination Accuracy	1m (off-line)	
Data Rate	240Mbps (via Data Relay Technology Satellite) 120Mbps (Direct Transmission)	
Onboard Data Recorder	Solid-state data recorder (90Gbytes)	

2. Observation Instruments

2.1 Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)

The Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) is a panchromatic radiometer with 2.5m spatial resolution at nadir. Its extracted data will provide a highly accurate digital surface model (DSM).

PRISM has three independent optical systems for viewing nadir, forward and backward producing a stereoscopic image along the satellite's track. Each telescope consists of three mirrors and several CCD detectors for push-broom scanning. The nadir-viewing telescope covers a width of 70km; forward and backward telescopes cover 35km each.

The telescopes are installed on the sides of the optical bench with precise temperature control. Forward and backward telescopes are inclined +24 and -24 degrees from nadir to realize a base-to-height ratio of 1.0. PRISM's wide field of view (FOV) provides three fully overlapped stereo (triplet) images of a 35km width without mechanical scanning or yaw steering of the satellite. Without this wide FOV, forward, nadir, and backward images would not overlap each other due to the Earth's rotation.

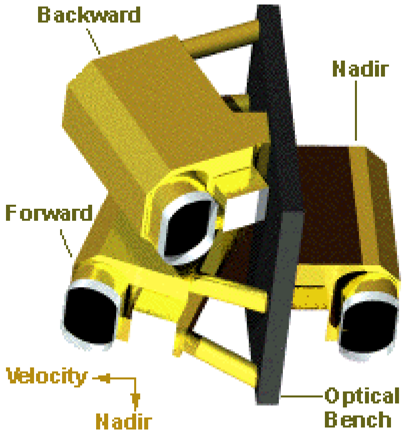

Figure 2: PRISM Configuration

Table 2: PRISM Characteristics

Number of Bands	1 (Panchromatic)
Wavelength	0.52 to 0.77 micrometers
Number of Optics	3 (Nadir; Forward; Backward)
Base-to-Height ratio	1.0 (between Forward and Backward view)
Spatial Resolution	2.5m (at Nadir)
Swath Width	70km (Nadir only) / 35km (Triplet mode)
S/N	>70
MTF	>0.2
Number of Detectors	28000 / band (Swath Width 70km) 14000 / band (Swath Width 35km)
Pointing Angle	-1.5 to +1.5 degrees (Triplet Mode, Cross-track direction)
Bit Length	8 bits

Note: PRISM cannot observe areas beyond 82 degrees south and north latitude.

Table 3: PRISM Observation Modes

Mode 1	Triplet observation mode using Forward, Nadir, and Backward views (Swath width is 35km)
Mode 2	Nadir (70km) + Backward (35km)
Mode 3	Nadir (70km)
Mode 4	Nadir (35km) + Forward (35km)
Mode 5	Nadir (35km) + Backward (35km)
Mode 6	Forward (35km) + Backward (35km)
Mode 7	Nadir (35km)
Mode 8	Forward (35km)
Mode 9	Backward (35km)

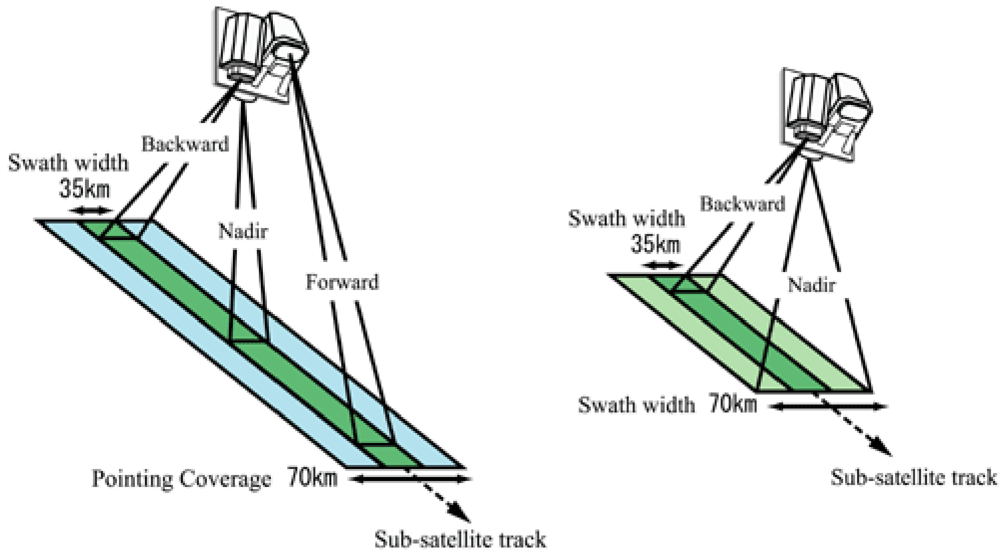

Figure 3: Swath of PRISM

2.2 Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2)

The Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) is a visible and near infrared radiometer for observing land and coastal zones. It provides better spatial land-coverage maps and land-use classification maps for monitoring regional environments. AVNIR-2 is a successor to AVNIR that was on board the Advanced Earth Observing Satellite (ADEOS), which was launched in August 1996.

Its instantaneous field-of-view (IFOV) is the main improvement over AVNIR. AVNIR-2 also provides 10m spatial resolution images, an improvement over the 16m resolution of AVNIR in the multi-spectral region. Improved CCD detectors (AVNIR has 5,000 pixels per CCD; AVNIR-2 7,000 pixels per CCD) and electronics enable this higher resolution. A cross-track pointing function for prompt observation of disaster areas is another improvement. The pointing angle of AVNIR-2 is +44 and - 44 degree.

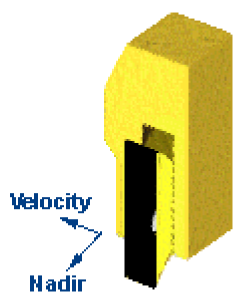

Figure 4: AVNIR-2 Configuration

Table 4: AVNIR-2 Characteristics

Number of Bands	4
Wavelength	Band 1 : 0.42 to 0.50 micrometers Band 2 : 0.52 to 0.60 micrometers Band 3 : 0.61 to 0.69 micrometers Band 4 : 0.76 to 0.89 micrometers
Spatial Resolution	10m (at Nadir)
Swath Width	70km (at Nadir)
S/N	>200
MTF	Band 1 through 3 : >0.25 Band 4 : >0.20
Number of Detectors	7000/band
Pointing Angle	- 44 to + 44 degree
Bit Length	8 bits

Note: AVNIR-2 cannot observe the areas beyond 88.4 degree north latitude and 88.5 degree south latitude.

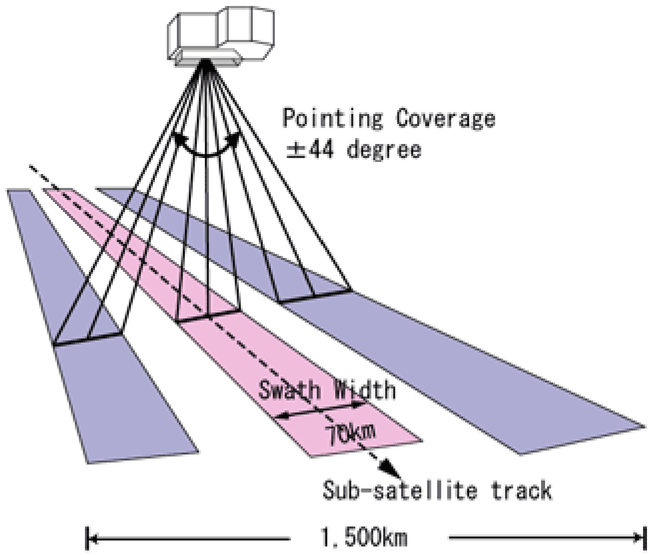

Figure 5: Swath of AVNIR-2

2.3 Phased Array type L-band Synthetic Aperture Radar (PALSAR)

The Phased Array type L-band Synthetic Aperture Radar (PALSAR) is an active microwave sensor using L-band frequency to achieve cloud-free and day-and-night land observation. It provides higher performance than theJERS-1's synthetic aperture radar (SAR). Fine resolution in a conventional mode, but PALSAR will have another advantageous observation mode. ScanSAR, which will enable us to acquire a 250 to 350km width of SAR images (depending on the number of scans) at the expense of spatial resolution. This swath is three to five times wider than conventional SAR images. The development of the PALSAR is a joint project between JAXA and the Japan Resources Observation System Organization (JAROS).

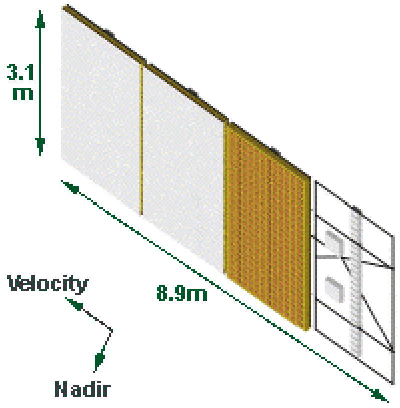

Figure 6: PALSAR Configuration

Table 5: PALSAR Characteristic

Mode	**Fine**		**ScanSAR**	**Polarimetric (Experimental mode)*1**
Center Frequency	1270 MHz(L-band)			
Chirp Bandwidth	28MHz	14MHz	14MHz,28MHz	14MHz
Polarization	HH or VV	HH+HV or VV+VH	HH or VV	HH+HV+VH+VV
Incident angle	8 to 60deg.	8 to 60deg.	18 to 43deg.	8 to 30deg.
Range Resolution	7 to 44m	14 to 88m	100m (multi look)	24 to 89m
Observation Swath	40 to 70km	40 to 70km	250 to 350km	20 to 65km
Bit Length	5 bits	5 bits	5 bits	3 or 5bits
Data rate	240Mbps	240Mbps	120Mbps,240Mbps	240Mbps
NE sigma zero *2	< -23dB (Swath Width 70km) < -25dB (Swath Width 60km)		< -25dB	< -29dB
S/A *2,*3	> 16dB (Swath Width 70km) > 21dB (Swath Width 60km)		> 21dB	> 19dB
Radiometric accuracy	scene: 1dB / orbit: 1.5 dB			

Note: PALSAR cannot observe the areas beyond 87.8 deg. north latitude and 75.9 deg. south latitude when the off-nadir angle is 41.5 deg.

**1 Due to power consumption, the operation time will be limited.*
**2 Valid for off-nadir angle 34.3 deg. (Fine mode),*
34.1 deg. (ScanSAR mode),
21.5 deg. (Polarimetric mode)
**3 S/A level may deteriorate due to engineering changes in PALSAR.*

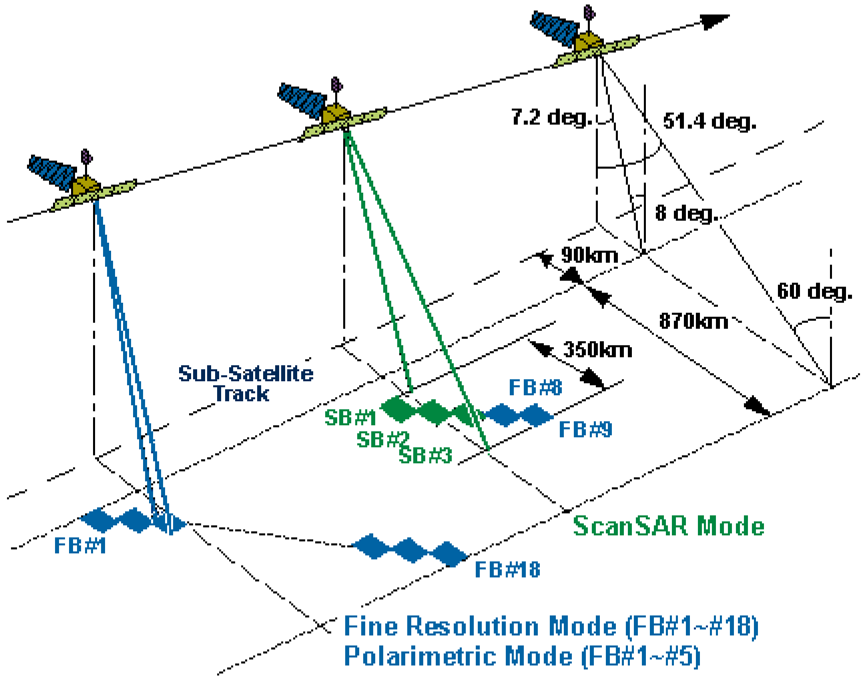

Figure 7: Swath of PALSAR

3. Data Level definitions

Definitions of ALOS instrument data levels are shown in the tables below. Level 1 products are defined as Standard Products of ALOS.

Level	Definition	Option	Note
Raw	Demodulated bit stream		Packetized

(1) PRISM

Level	Definition	Option	Note
0	Frame synchronization and PN decoding of CADUs (Channel Access Data Units) and Reed-Solomon error detection and correction of VCDUs (Virtual Channel Data Units) Extracted mission telemetry, orbit and attitude data are stored on separate files		Distribution level for Data Nodes Separate data files for each VCID
1A	Uncompressed, reconstructed digital counts appended with radiometric calibration coefficients and geometric correction coefficients (appended but not applied) Individual files for forward, nadir and backward looking data		Separate image files for each CCD
1B1	Radiometrically calibrated data at sensor input		Separate image files for each CCD
1B2	Geometrically corrected data Option G: Systematically Geo-coded R: Systematically Geo-referenced Option G or R is alternative	Map projection Resampling Pixel spacing	Single image file

(2) AVNIR-2

Level	Definition	Option	Note
0	Frame synchronization and PN decoding of CADUs (Channel Access Data Units) and Reed-Solomon error detection and correction of VCDUs (Virtual Channel Data Units) Extracted mission telemetry, orbit and attitude data are stored on separate files		Distribution level for Data Nodes Separate data files for each VCID
1A	Uncompressed, reconstructed digital counts appended with radiometric calibration coefficients and geometric correction coefficients (appended but not applied)		Separate image files for each band
1B1	Radiometrically calibrated data at sensor input		Separate image files for each band
1B2	Geometrically corrected data Option G: Systematically Geo-coded R: Systematically Geo-referenced D: Correction with coarse DEM (Japan area only) Option G or R is alternative	Map projection Resampling Pixel spacing	Separate image files for each band

(3) PALSAR

Level	Definition	Option	Note
0	Frame synchronization and PN decoding of CADUs (Channel Access Data Units) and Reed-Solomon error detection and correction of VCDUs (Virtual Channel Data Units) Extracted mission telemetry, orbit and attitude data are stored on separate files		Distribution level for Data Nodes Separate data files for each VCID
1.0	Reconstructed, unprocessed signal data appended with radiometric and geometric correction coefficients (appended but not applied)		Separate image files for each polarization (HH, VV, HV, VH)
1.1	Range and azimuth compressed Complex data on slant rang		Separate image files for each polarization (HH, VV, HV, VH)
1.5	Multi-look processed image projected to map coordinates Option G: Systematically Geo-coded R: Systematically Geo-referenced Option G or R is alternative	Map projection Resampling Pixel spacing	Separate image files for each polarization (HH, VV, HV, VH)

4. ALOS Systematic Observation Strategy

The ALOS mission features a systematic observation strategy which comprises pre-launch, systematic global observation plans for all three instruments. The strategy is implemented as a top-level foreground mission and with a priority level second only to that of emergency observations.

The observation strategy is developed by JAXA/Earth Observation Research Center (EORC) and aims to provide spatially and temporally consistent, multi-seasonal global coverage, on a repetitive basis, with all three sensors, during the life-time of the ALOS satellite. It is foreseen to result in a comprehensive and homogeneous global archive of PALSAR, PRISM and AVNIR-2 data, in which a consistent time-series for data can be found for any arbitrary point or region on Earth. Presently, such consistent data archives only exist for coarse resolution satellites.

The plans are designed to fulfil the following general acquisition concepts:

- Spatial and temporal consistency over continental scales at fine resolution;
- Adequate revisit frequency;
- Accurate timing:
- Consistent sensor configuration;
- Long-term continuity.

While the observation strategy is foreseen to serve the major data needs of both scientific and commercial users, additional acquisition requests can still be placed by individual users (via the ALOS Data Nodes) or Principal Investigators participating in Announcements of Opportunities organized by JAXA and/or the ALOS Data Nodes. As such requests however have lower priority than the strategy observations, users are strongly encouraged to align individual observation requests with the observation strategy in order to avoid programming conflicts and thereby to improve individual request success rates.

4.1 PALSAR Observation Strategy

The PALSAR acquisition strategy features routine observations at four pre-selected sensor modes (Table 6). The mode selection represents a compromise solution where scientific requirements, user requests, programmatic aspects and satellite operational constraints have been taken into consideration.

Table 6: PALSAR sensor default modes

Sensor mode	Polarization	Off-nadir angle	Pass designation	Coverage	Time window	Observation frequency
Fine Beam Single pol.	HH	41.5°	Ascending	Global	Dec-Feb	1-2 obs/year
Fine Beam Dual pol.	HH+HV	41.5°	Ascending	Global	May-Sept	1-4 obs/year
Fine Beam Polarimatric	HH+HV+ VH+VV	21.5°	Ascending	Regional	March-May	2 obs/2 years
ScanSAR 5-beam Short burst	HH	20.1° - 36.5°	Descending	(a) Global (b) Regional	Jan-Dec	(a) 1 obs/year (b) 8 obs/1 year

To assure spatially and temporally homogeneous data collection over regional scales, acquisitions are planned in units of whole (46-day) repeat cycles, during which only one of the available default modes is selected. The PALSAR strategy is furthermore separated into one plan for ascending (evening) passes, and one for descending (morning) ditto.

(1) Ascending acquisitions (evening, ~22.30)

The PALSAR ascending mode plan comprises repetitive, global-scale observations with a constant off-nadir angle of 41.5° in both single polarisation (HH) and dual polarisation (HH+HV). To maintain mode-consistency in the multi-annual time series to be acquired, single-pol observations are scheduled during the northern hemisphere winter, and dual-pol observations around the summer months.

The minimum requirement for any land area on Earth is to perform at least one single-pol and one dual-pol acquisition annually, and in addition, two dual-pol acquisitions during consecutive 46-days cycles on a bi-annual basis to enable interferometric applications. Most areas are however to be acquired significantly more often than this, typically 3-5 times per year. In general, regions in the eastern hemisphere (Asia, Australia, eastern Europe and Africa) within the coverage of the Data Relay Satellite (DRTS) are acquired most frequently, while the western hemisphere (the Americas, western Europe and Africa) is restrained by the recording and down-link capacity of the on-board data recorder (HSSR).

To promote research relating to SAR polarimetry and polarimetric interferometry, polarimetric observation campaigns are planned once every two years, during which selected regions around the globe are acquired in full polarimetric mode during two consecutive cycles. As polarimetric operations at large off-nadir angles are not possible however, acquisitions will be performed at 21.5°.

(2) Descending acquisitions (morning, ~10.30)

To minimize resource conflicts with PRISM and AVNIR-2, which only can be operated during day-time passes, the descending acquisition plan for PALSAR is principally limited to low data-rate (120 Mbps) ScanSAR observations at HH polarization.

The ScanSAR scenario comprises one global coverage on an annual basis, and in addition - given the LHH-band sensitivity to detect inundation phenomena - intensive monitoring over a number of selected regional-scale wetland environments of global significance. To adequately capture the hydrological changes that occur throughout the year, ScanSAR observations will typically be performed every 46-days during 8-9 consecutive satellite cycles (12-13 months).

4.2 PRISM and AVNIR-2 Observation Strategy

PRISM and AVNIR-2 are programmed for repetitive, global-scale observations, and like PALSAR, the observation strategy implemented aims to maintain both spatial and temporal consistency over regional scales. The timing of the regional observations has been determined based on cloud statistics, seasonality and sun elevation, although cloud cover inevitably limits the amount of useful data acquired.

The default mode for PRISM operations is the 3-telescope triplet mode to enable along-track stereo viewing. As the swath width in triplet mode is 35 km, two 46-day cycles are required to achieve a full regional coverage, during which the instrument is tilted alternately (+/- 1.2°) in across-track direction.

The PRISM plan can be summarized as follows:
- Odd cycle numbers: +1.2° viewing angle
- Even cycles: -1.2° viewing angle

The default mode for AVNIR-2 is nadir view.

For any given region, AVNIR-2 is typically scheduled for "one acquisition during two consecutive cycles", meaning that if an acquisition is successfully programmed the first of the two cycles in question, it will not be included in the plan during the second (regardless of cloud cover).

5. ALOS Data System overview

An overview of the ALOS Data System is shown in Figure 8.

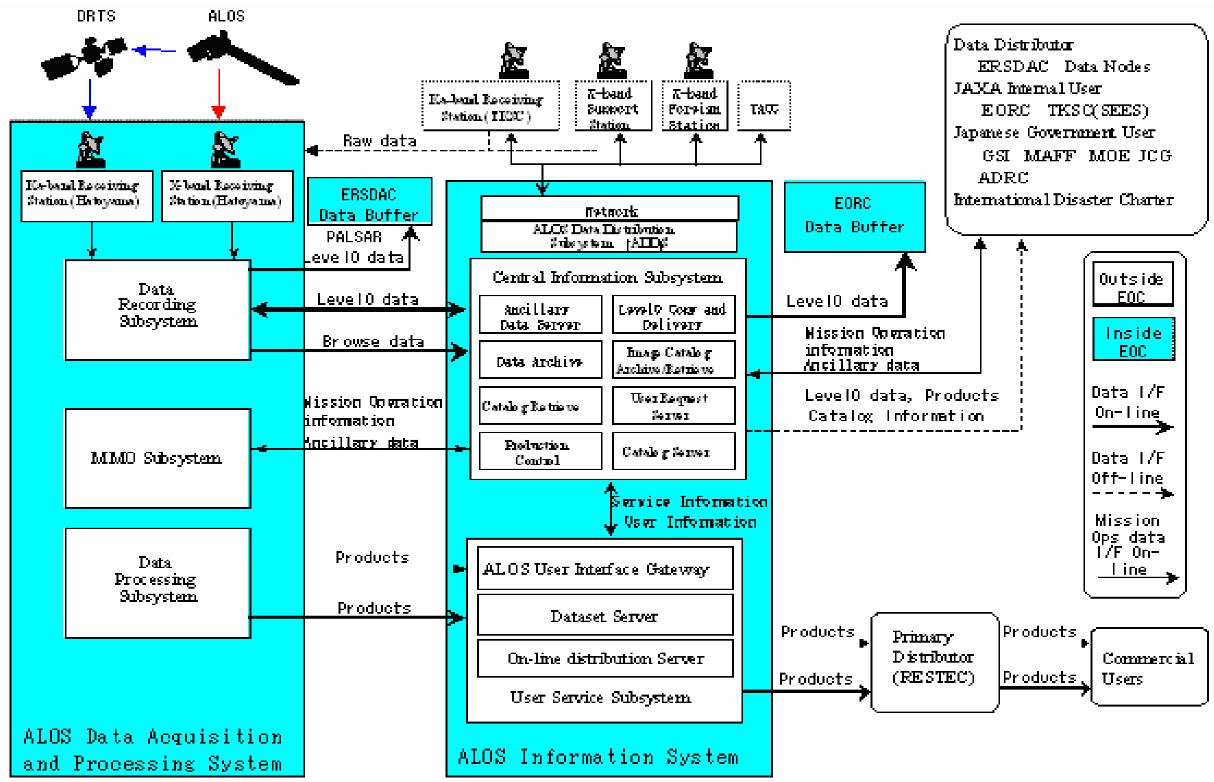

Figure 8: Overview of the ALOS data system

The primary path for reception of ALOS data is via JAXA's Data Relay Test Satellite, DRTS, at 90.75 degree East longitude (launched 10th September 2002) down-linked to JAXA/Earth Observation Center (EOC) at Hatoyama, where Level 0 data for ALOS will be generated. The receiving station at Tsukuba is a backup path for reception via DRTS.

ALOS data may also be down-linked directly by X-band transmission to JAXA's EOC and to JAXA's overseas ground stations as backup options for DRTS transmission. There is also provision for routine X-band transmission of ALOS data to ground stations of the ALOS Data Node partners, including for near real time data utilisation.

6. ALOS Data Node (ADN)

Recognising that the total data produced by the ALOS sensors on a daily basis (1 Terabyte) is beyond the capabilities of any single agency or country to attempt to manage, but that there was world-wide interest in the use of that data, JAXA proposed the concept of the ALOS Data Nodes with local archives, as a mechanism for sharing the processing and distribution load.

To promote international data use and operational use of ALOS data, data node organizations are appointed for different regions world-wide. The data node organizations will receive ALOS Level 0 data from JAXA and generate and distribute products to regional users in accordance with their agreement with JAXA. And also the data node organizations will be able to receive ALOS data via X band ground stations by agreement with JAXA.

The benefits of the ADN concept are:

- increased capacity for ALOS Data processing and archiving;
- accelerated scientific and practical use of ALOS data;
- increased international co-operation including on validation and science study activities;
- enhanced service for potential users of ALOS data.

The ADN concept is envisaged as a new model for the provision of Earth observation missions, bringing mutual benefits for both the funding agency and the global partners involved in the distribution and application of the data.

The current concept envisages 4 Nodes world-wide in order to achieve the necessary global coverage:

Table 7: ADN Partners and relevant Zones

ADN Partners	General zone of responsibility
ESA*	Europe and Africa
NOAA/ASF	North and South America
Geoscience Australia	Oceania
JAXA	Asia

**CNES withdrew from the project in September 2003*

In addition, GISTDA of Thailand was accepted to the ADN scheme as a 'sub-Node' within Asia, including for direct reception of ALOS data to promote ALOS data utilization.

Each Node is associated with a geographical zone - which defines the physical location of the ALOS users which the Node has a mandate to support as an ADN partner. These zones are approximately defined in Figure 9.

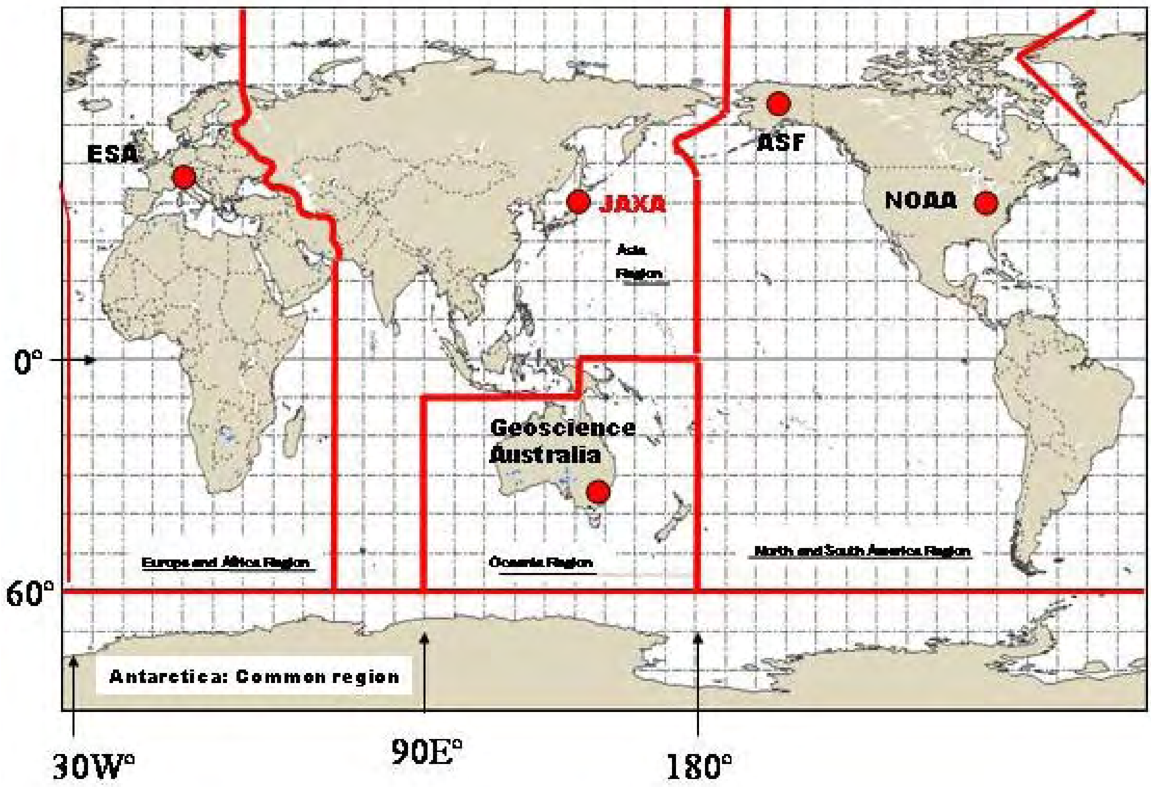

Figure 9: ADN Zone definitions

JAXA appoints a Primary Distributor to take care of data distribution in the Asian Zone and to serve as an interface between JAXA and the Nodes for the management and administration of all issues relating to commercial use of ALOS data for all other Zones.

Remote Sensing Technology Center (RESTEC) is appointed as the PD by JAXA. Thus, RESTEC will distribute the ALOS products for commercial use within the Asian Zone.

A Regional Distributor may be designated by each Node for commercial distribution of the ALOS products within the relevant Zone.

After Initial Cal./Val. Phase, ALOS routine operation will begin in the late of October, 2006 (currently scheduled on October 24, 2006), and the ALOS Level 0 data will be distributed to the Nodes in regular basis. Then, users will be able to obtain the ALOS products through the user's Node.