

KEY TECHNOLOGY DEVELOPMENT FOR THE ADVENACED LAND OBSERVING SATELLITE

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ABSTRACT:

This paper introduces the outline of key technology that is under development for the Advanced Land Observing Satellite (ALOS). Overview of mission objectives, sensors, and satellite system is also provided.

1 INTRODUCTION

1.1 Japanese Earth Observation Satellite Program

Japanese Earth Observation Satellites are divided into two categories: land observation satellite series and atmospheric and oceanic observation satellite series. Land observation satellite series, such as the ALOS, is mainly for practical use and high-resolution observation is one of the most important characteristics. On the other hand, atmospheric and oceanic observation satellite series, such as the ADEOS-II, is mainly for scientific use and characterized by multi-channel observation. History of Japanese Earth observation program is shown in Fig.1. Japan's Earth observation satellite program began with the Marine Observation Satellite (MOS-1) in February 1987. The MOS-1 was followed by the MOS-1b in February 1989 and the Japanese Earth Resources Satellite (JERS-1) in February 1992. JERS-1 has 18m resolution optical sensor and 18m resolution L-band (1.2GHz) synthetic aperture radar on-board. The Advanced Earth Observing Satellite (ADEOS) was launched in August 1996; however, operation was terminated by a solar array failure in June 1997. It marked a significant increase in capability and provided 8m resolution panchromatic and 16m resolution multi-spectral optical image in addition to six scientific sensor's data.

The Advanced Earth Observing Satellite II (ADEOS-II) will be launched in November 2001. The resolution of the ADEOS-II sensors is limited up to 250m because it focuses on global environmental change and multi-channel observation has a higher priority than high-resolution observation. The ALOS is planned for launch in August 2002.

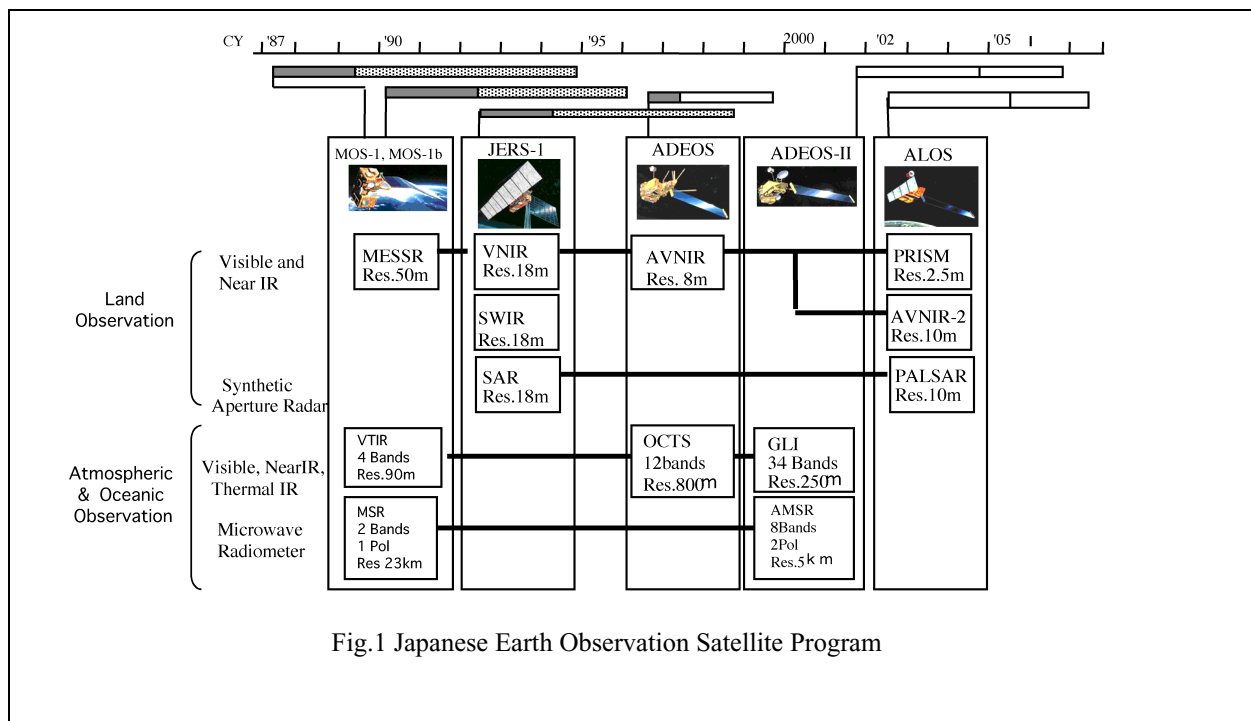
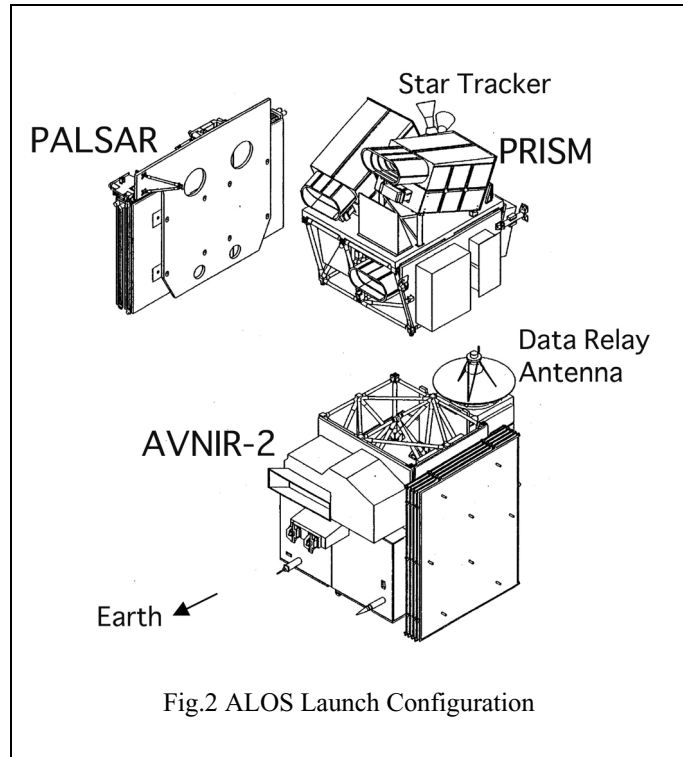


Fig.1 Japanese Earth Observation Satellite Program

The resolution of the panchromatic channel is improved to 2.5m. The multi-spectral and L-band SAR resolution is 10m.

1.2 ALOS Overview

Mission objective of the ALOS is to advance land-observing technology and to contribute to cartography, regional observation, disaster monitoring and Earth resources survey. The ALOS has three major sensors; Panchromatic Remote Sensing Instruments for Stereo Mapping (PRISM), Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), and Phased Array type L-band Synthetic Aperture Radar (PALSAR). ALOS launch configuration is shown in Fig.2. The ALOS is planned for launch in August 2002 by the H-IIA launch vehicle from Tanegashima Space Center in Japan.



2 ALOS SENSORS

2.1 PRISM

The PRISM is what is called a three line sensor and provides 2.5m resolution image and 3 to 5meter accuracy Digital Elevation Model with triplet stereo mapping capability. The PRISM consists of three optics that look nadir, forward, and backward respectively. Base to height ratio between forward and backward optics is equal to one. Observation swath width is 35km in triplet stereo observation mode and 70km in nadir observation mode. This data is mainly for cartography and will be used to generate and revise 1/25,000 scale maps and digital data for Geographical Information System (GIS). The Geographical Survey Institute of Japan (GSI) that is the Japanese national mapping authority is expected to be a biggest user for PRISM data. Offset-axis triplet mirror optics and higher order aspheric surface mirror is developed in order to realize the unique combination of high-resolution and wide swath width for the PRISM. Size of the primary aperture mirror is 600mm by 300mm. Eight 5000-pixel linear CCDs are allocated on the 300mm length half mirror prism and works as a 40,000 pixels linear array sensor. Thermal distortion of the PRISM internal truss structure must be minimized in order to achieve both 3 to 5meter altitude determination accuracy and 2.5 meter position determination accuracy. This is realized by the accommodation of integrated optical bench concept, that is, three optics, star trackers, and attitude sensor unit, and jitter sensors are integrated on one rigid optical bench and temperature of the entire optical bench is controlled within plus and minus 3 degree Kelvin. PRISM optical bench concept is shown in Fig.3 and PRISM characteristics is shown in Table.1.

Number of Optics	3
Wave Length	0.52-0.77 x10 μ m
Base/Height Ratio	1.0
IFOV	2.5m
Swath Width	70km(Nadir)/ 35km(Forward,Nadir, Backward)
S/N	>70
MTF	>.2

Table 1 PRISM characteristics

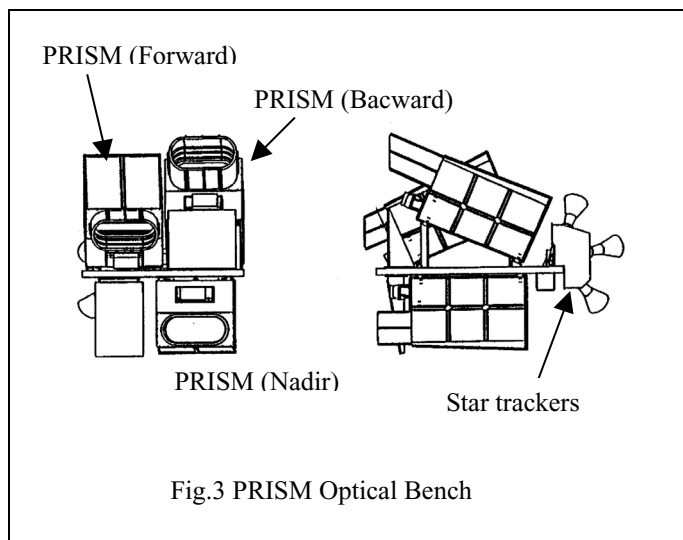


Fig.3 PRISM Optical Bench

2.2 AVNIR-2

The AVNIR-2 is an improved version of AVNIR on the ADEOS. The AVNIR-2 provides 10m-resolution multi-spectral image over 70km swath width. The AVNIR-2 and the PALSAR are used mainly for regional observation, disaster monitoring, and Earth resources survey. For the disaster monitoring mission, the AVNIR-2 and the PALSAR has a cross track pointing capability and able to observe anywhere in the world within 48 hours. World's first simultaneous observation with optical sensor and SAR is also possible. This unique data set is expected to contribute the improvement of classification capability. AVNIR-2 characteristics is shown in Table.2.

Wave Length	Band1: 0.42-0.50 μ m Band2: 0.52-0.60 μ m Band3: 0.61-0.69 μ m Band4: 0.76-0.89 μ m
IFOV	10m
Swath Width	70km
Pointing Capability	+44deg/-44deg
S/N	>200
MTF	Band1-3: >0.25 Band4 : >0.20

Table 2. AVNIR-2 Characteristics

2.3 PALSAR

The PALSAR is an improved version of SAR on board JERS-1. The NASDA and the Ministry of International Trade and Industry (MITI) are jointly developing the PALSAR. The PALSAR consists of 8.9m by 3.2m active phased array antenna with 80 transmitter and receiver modules and electric unit. Off nadir angle is variable between 10 to 51 degree. PALSAR has four operations mode: high-resolution mode, ScanSAR mode, Full polarimetry mode, and direct transmission mode. The resolution of the PALSAR is 10m in the high-resolution mode and maximum swath width is 350km in ScanSAR mode. PALSAR characteristics is shown in Table.3.

Mode	High Resolution		Direct Downlink	ScanSAR	Polarimery
	Single Polarization	Dual Polarization			
Frequency	L band (1270MHz)				
Chirp Bandwidth	28MHz	14MHz	14MHz	14/28MHz	14MHz
Polarization	HH or VV	HH/HV or VV/VH	HH or VV	HH or VV	HH/HV+VV/VH
Incidence Angle	8-60deg (typ 39deg)	8-60deg (typ 39deg)	8-60deg (typ 39deg)	18-43deg	8-30deg (typ 24deg)
Range Resolution	7-44m 10m@39deg	14-88m 20m@39deg	14-88m 20m@39deg	100m (Multi-look)	24-89m 30m@24deg
Swath Width	40-70km	40-70km	40-70km	250-350km	20-65km
Bit Length	5 bits	5 bits	3/5 bits	5 bits	3/5 bits
Data Rate	240Mbps	240Mbps	120Mbps	120/240Mbps	240Mbps

Table 3. PALSAR characteristics

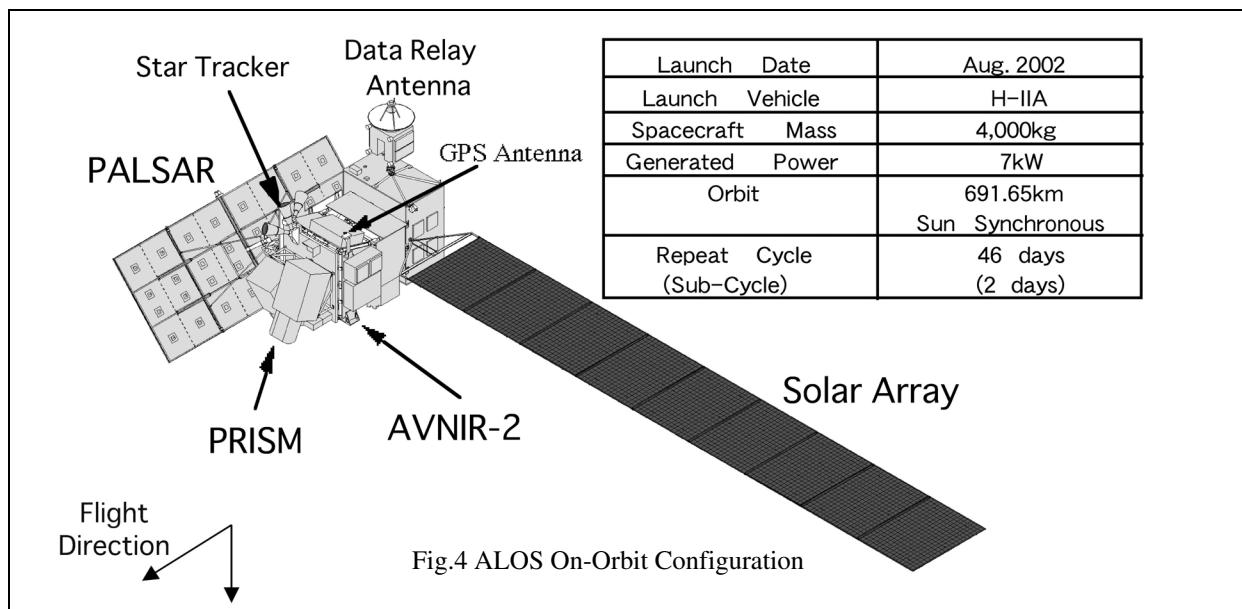
3 ALOS SATELLITE SYSTEM

3.1 Overview

The ALOS is one of the biggest class earth observation satellites in the world. The size of the ALOS is roughly 9m in length and 28m in width and mass is 4,000kg. Primary structure is divided into upper, middle, and lower part and consists of CFRP truss members. Thermal expansion is strictly controlled with negative expansion CFRP truss, metal fittings, and precise heater control in order to minimize the thermal distortion in the orbit. The ALOS on-orbit configuration is shown in Fig.4.

3.2 Highly Stable Attitude Control System

In order to minimize geometric distortion of the image, satellite attitude movement (angular velocity) is stabilized within 2×10^{-4} degree per 5sec (equivalent to 2.5m distortion within 70km square scene). The disturbance from major vibration sources, such as data relay communication antenna pointing mechanics, AVNIR-2 pointing mirror drive mechanics, and solar array drive mechanics PALSAR antenna, are carefully controlled using feed forward technique and onboard parameter tuning. Newly developed 64bit Micro Processor Unit (MIPS-R4900 core on 1 Mega Gate Array) is adopted for attitude and orbit control system (AOCS).



3.3 Autonomous Position and Attitude Determination System

High precision satellite position and attitude determination system enables users to locate exact position of any ground objects without any ground reference points. This capability is crucially important for cartography for unmapped region. This is achieved with accurate star trackers, dual-frequency carrier phase tracking GPS receivers, and jitter sensors on board.

In order to get sub arc-second accuracy with star trackers, list of target stars are carefully chosen (moving stars or adjacent stars are excluded) and stored in the on-board AOCS computer. Expected positions of target stars are sent to star trackers from AOCS computer every one second and exact position is observed and calculated by star trackers and this information is sent back to AOCS computer.

Combining the data from dual-frequency carrier phase tracking GPS receiver on board ALOS and that of ground GPS reference stations, ALOS position is determined within 0.2m accuracy

3.4 Data Compression

The PRISM generates 960Mbps data stream and data rate is reduced to 240Mbps using Discrete Cosine Transformation (DCT) and Huffman coding technology. Similarly, AVNIR-2 data rate is reduced from 160Mbps to 120Mbps with Differential Pulse Code Modulation (DPCM) technology.

3.5 Data Transmission

Inter-satellite communication capability allows real-time data acquisition via Japanese and European data relay satellites. This capability is of great importance for disaster monitoring mission. The ALOS has a conventional 120Mbps X-band direct down link capability for back up and additional services for foreign receiving stations. Bit error rate is drastically reduced to the order of 10^{-16} with Reed-Solomon error correction code. Solid state mission data recorder has 768Gbits memory and allows 50minutes recording at 240Mbps.



Fig.5 ALOS Mechanical Test Model (MTM)

4 DEVELOPMENT STATUS

Technology development with ALOS Mechanical Test Model (MTM), Thermal Test Model (TTM), and Electrical Engineering Model (EM) has almost completed. Fabrication and test for flight model components has already been started. System level Critical Design Review (CDR) will be held in November 2000. Final Proto-Flight Test for system flight model will be completed by April 2002. Overview of MTM is shown in Fig.5.

5 DATA AVAILABILITY

After the data reception, raw data is processed and distributed by NASDA and foreign regional data node organization in U.S., Europe, and Oceania. ALOS data will be widely distributed and available. Especially for research and public use, NASDA is planning to distribute ALOS data in low cost. Data distribution and pricing policy is under discussion.

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