Outline of MOS-1 Verification Program (MVP)

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Abstract

Marine Observation Satellite 1 (MOS-1) was successfully launched from Tanegashima Space Center, NASDA by N-II launch vehicle at 10:23 JST (1:23 UT) on Feb.19,1987. The MOS-1 has 4 mission instruments:(1)Multi-Spectral Electronic Self Scanning Radiometer(MESSR) (2)Visible and Thermal Infrared Radiometer(VTIR) (3)Microwave Scanning Radiometer(MSR) and (4)Data Collection System Transponder(DCST). All mission instruments were found to be satisfactory during mission check period (three months after the launch) though there was interference problem in DCS due to the outer radio interference source which was resolved by changing the frequency of Data Collection Platform (DCP).

NASDA planned and initiated MOS-1 Verification Program(MVP) to evaluate MOS-1 observation system since March,1987. NASDA is conducting MVP in collaboration with joint research organizations, domestic and foreign organizations. As a part of the MVP, NASDA conducted airborne experiments in summer and winter in several test sites in FY 1987 in Japan on passing days of MOS-1 and will conduct summer airborne experiment in FY 1988. The first symposium for MVP was successfully conducted by NASDA on Nov.10 and 11,1987 in Tokyo. The second symposium will be held in July 12,13 and 14,1988 in Tokyo Yubin Tyokin Kaikan in Hamamatsucho, Tokyo near NASDA Headquarter and the third final symposium will be held in February,1989.

In this paper, the outline of MVP will be described and some initial results of MVP will be presented.

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1. Introduction

NASDA developed space and ground segments of Marine Observation Satellite-1 (MOS-1) observation system and succeeded in launching the MOS-1 from Tanegashima Space Center by N-Ⅱ rocket at 10:23 JST (1:23 UT) on Feb.19,1987. This was launched into specified sun-synchronus orbit and called "Momo (Peach) 1". The MOS-1 carries 4 mission instruments (1)Multi-Spectral Electronic Self Scanning Radiometer(MESSR)(2)Visible and Thermal Infrared Radiomater (VTIR) (3)Microwave Scanning Radiometer (MSR) and (4)Data Collection System Transponder (DCST). It was confirmed that all mission instruments are very good during mission check period (three months after the launch) though DCS suffered from harmful radio interference due to outer source which was eliminated by changing the center frequency of Data Collection Platform (DCP).

In order to evaluate MOS-1 total observation system,NASDA planned and initiated MOS-1 Verification Program (MVP) since March,1987. NASDA is conducting MVP in collaboration with joint research organizations, domestic and foreign organizations. As a part of MVP, NASDA conducted airborne experiments on MOS-1 passing days in 1987-1988.

In this paper, the outline of MVP will be described and the some initial results of MVP will be presented.

2. The outline of MVP

Main mission objectives of MOS-1 are to establish fundamental earth observation technology and to observe ocean, land and atmosphere by using three radiometers (MESSR,VTIR,MSR) covering visible,near-infrared,thermal infrared and microwave wavelengths.

In order to achieve these mission objectives and to evaluate MOS-1 observation system, NASDA conducted field experiments by using MSR breadbord model (BBM) on the ground, tower and others in 1981-1983, airborne verification experiments by using MOS-1 sensor engineering model(EM) mounted on an aircraft in 1984-1985 Based upon these experiments NASDA planned MOS-1 Verification Program. The content of the MVP is shown as follows.

2.1 Purpose of MVP

Purpose of the MVP is as follows:

(1) Evaluation of geometoric and radiometoric distortion compensation accuracy
(2) Evaluation of performance of MOS-1 observation system
(3) Evaluation of effectiveness of MOS-1 observation parameter from various fields of remote sensing
(4) Reflection of the above results in the development and operation of advanced earth observation system in the future

2.2 Methodology of MVP

In order to evaluate MOS-1 observation system, MOS-1 data, airborne data, truth data,other earth observation satelite data are required in the framework of the MVP.

Verification items of MVP are classified into

(1)verification for instrumentation and (2)verification for physical measurement. The former is evaluation of geometric and radiometric performance such as various distortion, spatial resolution, signal to noise ratio (S/N), dynamic range. The latter is evaluation of physical measurement accuracy. These verification items are shown in Table 1. The MVP consists of the following activity.

(1)Verification experiment

Based upon field experiments in 1981-1983 and MOS-1 airborne verification experiments in 1984-1985, NASDA conducted MVP airborne experiments in summer,1987, in winter, 1987 and 1988, and NASDA will conduct airborne experiment in comming summer,1988. Figure 1 shows the schedule of MVP . In these airborne experiments, aircraft Merlin ⅣA flys over several test sites in Japan on MOS-1 passing days where observation equipments equivalent in performance to MOS-1 sensors are mounted and comparison between MOS-1 data, airborne data and truth data is made. Table 2 shows outline of MVP airborne experiments and Figure 2 shows test sites for MVP airborne experiments.

(2) Routine-base verification

MOS-1 data is evaluated routinely by using various processing and analyzing software installed in MOS-1 processing facility.

(3) Overall evaluation

Based upon test results in the labolatory obtained before the launch, results obtained during mission check period and results for compatibility test, considering the above-mentioned (1) and (2), overall evaluation must be made.

2.3 Cooperative relationship

In order to evaluate MOS-1 observation system from various point of view, NASDA is conducting the MVP in collaboration with joint research organizations, domestic and foreign organizations which were selected at MOS-1 verification committee. The selected organizations and themes are domestic 60 organizations 73 themes foreign 11 countries (Belgium, Canada,France,India,Italy (ESA), Korea,Philippines,Singapore,Sri lanka Thailand,U.S.A) 17 organizations 22 themes.

3. Initial results

3.1 MESSR

The MESSR is an electronic-scanning radiometer using CCD detector elements with the four bands (1)0.51-0.59μm (2)0.61-0.69 μm (3)0.72-0.80μm and (4)0.80-1.1μm. Nominal spatial resolution is 50m. The main mission objectives of the MESSR is to observe land surface and sea conditions such as transparence.

(1)Radiometoric distortion compensation evaluation

In case of radiometrically corrected imagery (level 1), it was confirmed that residual radiometric distortion(RMS of the difference of neighboring intensity) were 0.75,0.67,0.25,0.38 for band 1,2,3 and 4 which meet the one quantized level.

(2)S/N evaluation

By applying the two dimensional Fourier transformation to uniform area such as snow field, S/N are 24.0,24.7,24.0,21.5 dB for band 1,2.3 and 4,respectively.

(3)Geometric distortion compensation evaluation

The geometric compensation accuracies measured by using 8-10 GCPs 4.7km,46m,17m for level 2,3 and 4 were obtained which is under the specified value 7.5km,50m,25m for level 2,3 and 4. By eliminating bias error of attitude, the position error for level 2 decreases to be 666m.

(4)Spatial resolution evaluation

By using edge in reclaimed land in Tokyo Bay, line spread function (LSF), modulation transfer function (MTF)were obtained. Example of MTF is shown in Fig.3. In Japan it is very difficult to find uniform area neighboring to edge. So, it is necessary to develop method applicable to non uniform area.

3.2 VTIR

The VTIR is a mechanical scanning type radiometer to observe in one visible (band 1:0.5-0.7μm) and three thermal infrared bands (band 2:6.0-7.0μm,band 3:10.5-11.5μm,band 4:11.5-12.5μm). The nominal spatial resolution is 900m for band 1 and 2700m for band 2,3 and 4 .The main objective of VTIR is to observe sea surface temperature, cloud,upper atmosphere and others.

(1)Radiometric distortion compensation evaluation

By comparing VTIR data and VISSR data for uniform sea, it was confirmed that radiometoric distortion is under two quantized level. When VTIR thermal band was evaluated by using standard black body, this distortion was found to be under one quantized level.

(2)S/N evaluation

Three methods : Mean-deviation method , APR (Adaptive Peak Rejection) method and one dimensional Fourier transform method were applied to VTIR data in uniform sea area to obtain S/N. By using mean-deviation method, S/N are 20.2 dB, 33.6 dB, 43.2 dB and 42.9 dB for band 1,2,3 and 4, respectively. It was confirmed that S/N for band 3 is larger than that for band 4. This is because atmospheric transparence is larger in band 3 than in band

4 and S/N of VTIR hardware measured in the factory was larger in band 3 than in band 4.

(3)Geometric distortion compensation evaluation

By using 20 GCPs in one pass scene, position error of level 2 imagery was measured to be 3.1-4.7km which is under specified value 7 pixels (6.3 km).

(4)Spatial resolution evaluation

By using edge of coast, spatial resolution was measured as follows:

	line direction	pixel direction	
Band 1	1.4 pixel	3.3 pixel	
Band 3	3.0 pixel	4.8 pixel	
Band 4	3.3 pixel	5.4 pixel	1 pixel:900m

In case of band 2, spatial resolution can not be obtained because earth surface can not be observed. Concerning thermal band (Band 2,3,4),three pixel is nominal spatial resolution.

(5)Sea surface temperature extraction evaluation

LOWTRAN 6 was applied to VTIR thermal band imagery(Path 21,May 31,1987) and the following results were obtained.

level 2 data		Atmospheric compensated data		Truth data
Band 3	Band 4	Band 3	Band 4	
17.85	16.40	19.65	18.85	19.6 (Omaezaki)
18.00	16.35	20.50	19.35	19.2 (Oshima)

Remark: Radio sonde data was used. unit: °C

3.3 MSR

The MSR is a Dicke type radiometer to measure very weak earth radiation noise at the 23 GHz and 31 GHz. Beam width of MSR is 32 km (23 GHz) and 23 km (31 GHz). Main nission objective of the MSR is to measure water vapor and liquid water, snow cover, sea ice distribution.

(1)Radiometric distortion compensation evaluation

By measuring mean and standard deviation in level 2 imagery, the following results were obtained.

23 GHz 10msec	1.14 K
23 GHz 47msec	1.13 K
31 GHz 10msec	1.33 K
31 GHz 47msec	1.30 K

In case of evaluation of internal calibration source, the

0.579 K (23GHz) and 0.616 K (31GHz) were obtained.

(2)S/N evaluation

S/N for MSR imagery (path 21 April 10,1987) are as follows:

23 GHz 10msec	36.1 dB
23 GHz 47msec	37.7 dB
31 GHz 10msec	32.2 dB
31 GHz 47msec	32.5 dB

(3)Geometric distotion compensation evaluation

Position error is measured by using GCPs in one path scene and mean value of this error is 25km (23 GHz) and 17km (31GHz) which is under the specified value 60km (23GHz) and 40km (31GHz).

(4)Spatial resolution evaluation

By using edge of coast, the following results for MSR imagery (level 2, path 25,April 14,1987) were obtained.

	pixel direction	line direction
23 GHz 10 msec	64.6 km	74.6 km
23 GHz 47 msec	63.1 km	68.4 km
31 GHz 10 msec	43.7 km	48.0 km
31 GHz 47 msec	49.0 km	45.6 km

3 dB down width

(5)Physical value extraction evaluation

a) water vapor and liquid water

By using recurrence equation developed for extraction of water vapor and liquid water, the following results were obtained.

	May 27,1987	Nov.29,1987
Water vapor	55.2 (43.7)	43.6 (31.8)
Liquid water	1.2	1.1

unit:kg/m ( ):truth data obtained by using radio sonde data in Titizima (very distant small island in Pacific Ocean)

It was found that bias error was about 10 kg/m . It is necessary to accumulate MSR data from now on.

b)typhoon, front,rain

Example of front, rain region and typhoon were observed in MSR data obtained in path 21,April,27,1987 ,path 25,April 4,1987 and path 24 August 27,1987,respectively. Rain region obtained by using MSR data corresponds with the region obtained by using rain radar.

c)sea ice

Example of sea ice was observed through cloud in MSR data obtained in path 21, April 10, 1987. Since sea brightness temperature of sea ice is very high, sea ice distribution can be obtained under all weather condition. MSR data is routinly used to forcast drift sea ice in northern ocean of Hokkaido.

3.4 DCS

The DCST transponds data from buoys to Earth Observation Center, where the position of the buoys are determined utilizing doppler frequency measurement. Bit error rate, position estimation error and DCS success rate are 7.3 x10 , 500m and 90 %. Transmitting frequency of DCP was changed from 401.53MHz to 401.47 MHz to prevent from outer radio interference.

4. Conclusion

As a result of initial evaluation of MOS-1 data, MOS-1 observation system was found to show satisfactory condition. NASDA continue evaluation in collaboration with domestic and foreign investigators.

Acknowledgement

The authors would like to thank investigators who participated in the MVP and related staff in NASDA.

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Table 1 Verification items for MVP

	Multispectral Electronic Self-scanning Radiometer (MESSR)		Visible and Thermal Infrared Radiometer (VTIR)		Microwave Scanning Radiometer (MSR)		Data Collection System (DCS)	
	Verification Item	Parameters	Verification Item	Parameters	Verification Item	Parameters	Varification Item	Parameters
Verification for Instrumentation	11 Radiometric performance	Deviation of CCD sensitivity Input/output performance Image quality evaluation	21 Radiometric performance	Temperature resolution Input/output performance Image quality evaluation	31 Radiometric performance	Receiver sensitivity Input/output performance Effect of antenna pattern Image quality evaluation	41 Transmission performance	Transmission quality Multiple accessibility
	12 Geometric performance	Accuracy of distortion correction Spacial resolution	22 Geometric performance	Accuracy of distortion correction Special resolution	32 Geometric performance	Accuracy of distortion correction Spacial resolution	42 Determination accuracy of DCP position	Estimation of DCP position
Verification for Physical measurement	13 Atmospheric and solar effects	Atmosheric effect Sun glitter	23 Atmospheric and solar effects	Atmospheric effect Rim darkening Effect of cloud Sun glitter	33 Atmospheric and solar effects	Sky radiation Effects of water vapor, cloud, rain, wind and sea surface temperature Sun glitter	43 Verification of effectiveness of DCS parameters	Data transmission of oceanographic and meteorological information
	14 Derivation accuracy of geophysical information (Including verification of effectiveness of sensor parameter)	Applicability of high-gain and compression mode Comparative usage with other sensor data Applicability for land and sea area	24 Derivation accuracy of geophysical information (Including verification of effectiveness of sensor parameter)	Estimation of sea surface temperature Estimation of cloud top height Applicability for 6-7 μm band Usefulness of gain selection for particular area Comparative usage with other sensor data	34 Derivation accuracy of geophysical information (Including verification of effectiveness of sensor parameter)	Estimation of water vapor content Estimation of liquid water content estimation of snow sover Estimation of sea ice cover Effect of sea surface widn Comparative usage with other sensor data Applicability for land and sea area, and for weather		

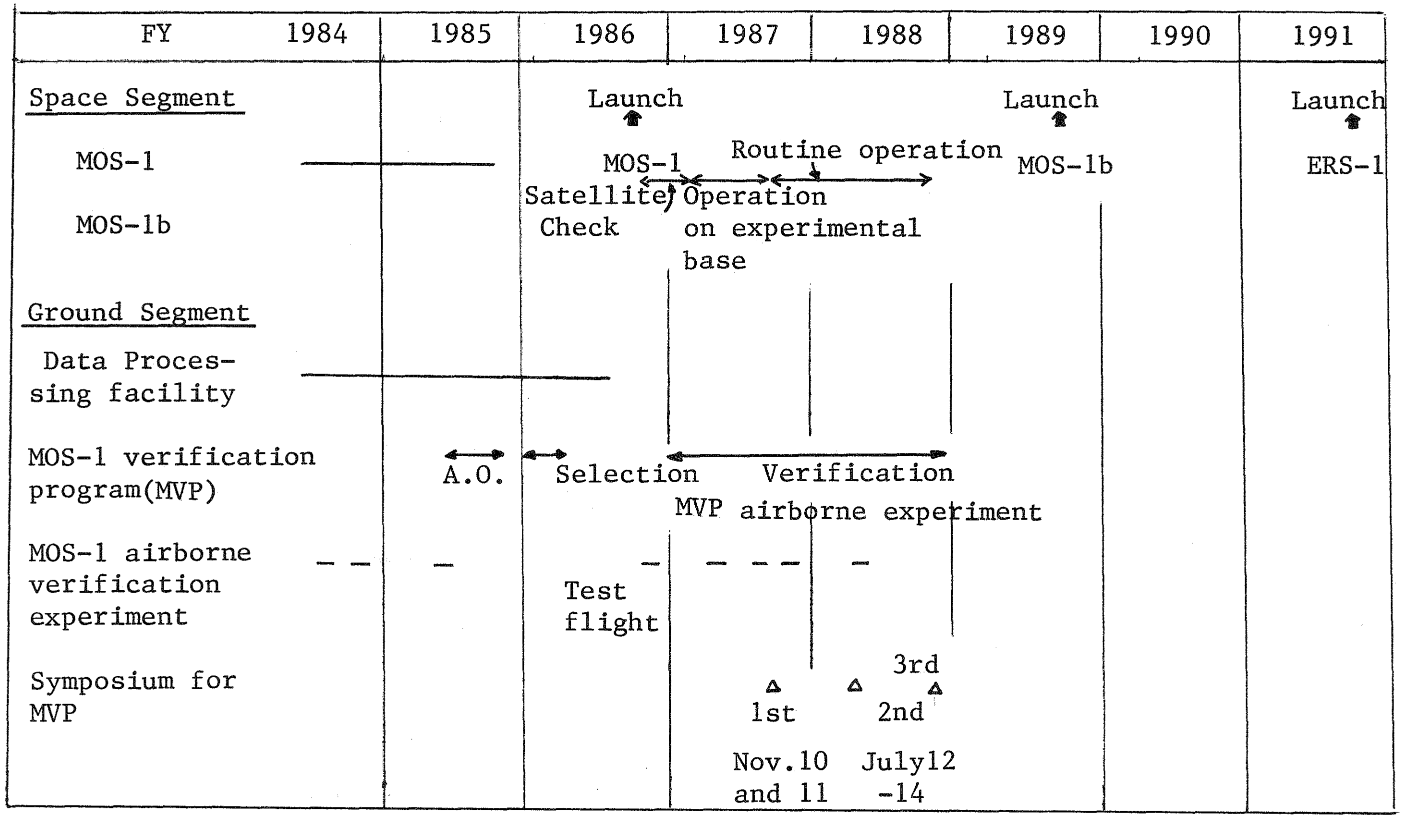

Fig.1. Schedule of MVP.

Table 2 Outline of MVP airborne experiment

Test Site	Observation Date	Altitude	Objectives
Boso-Hachijo	Aug.5,1987	6000m	MSR antenna pattern evaluation
Hachijo-Miyake-jima	Aug.8,1987	500m	VTIR sea surface temperature evaluation
Suruga Bay Ensyunada	ditto	6000m	VTIR spatial resolution evaluation
Kasumigaura Tsukuba	Dec.3,1987	500m/ 3000m/ 7000m	MESSR atmospheric compensation, radiometric evaluation, spatial resolution evaluation
Kashimanada	Dec.4,1987	500m	VTIR sea surface temperature evaluation
Monbetsu	Feb.9,1988	500m/ 5000m	MSR sea ice evaluation
Asahikawa-Nayoro Sapporo	Feb.10,1988	500m/ 5000m	MSR snow evaluation
Biwa Lake (planning)	Summer,1988	-	MESSR radiometric evaluation

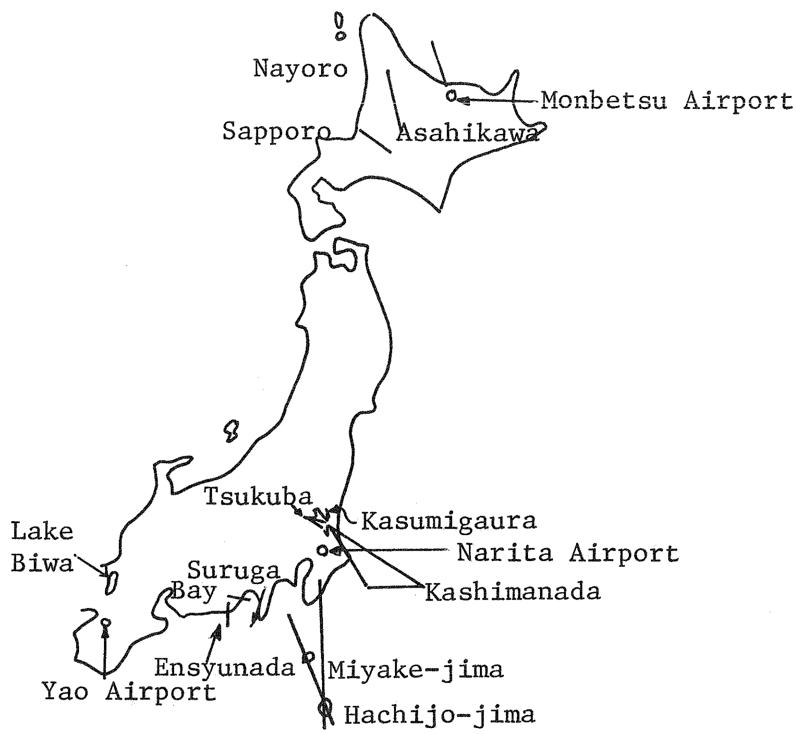

Fig.2. Test sites for MVP airborne experiments

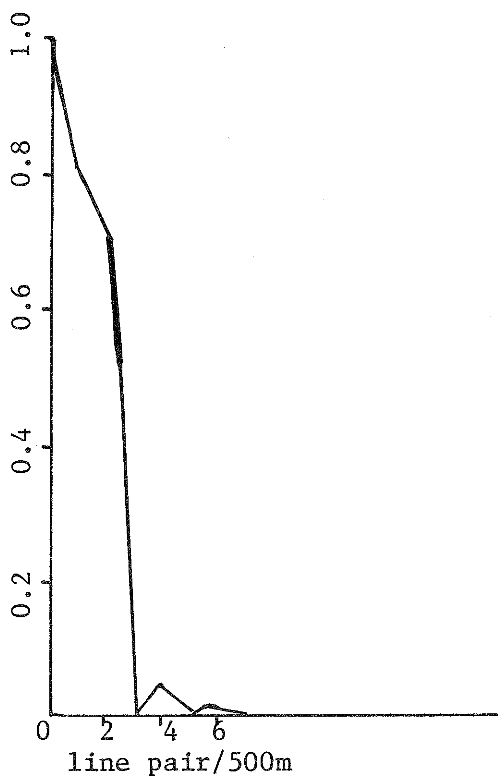

Fig.3. Example of calculation of MTF for MESSR