MSAS Status and Preliminary Performance Evaluation

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BIOGRAPHY

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ABSTRUCT

MTSAT- 1R (New MTSAT-1) is going to be launched in early 2003 to mitigate the impact of the launch failure of H-II rocket in November 1999. The new satellite is now being manufactured to be in time for this schedule.

On the other hand, Phase 1 MSAS ground systems has completed its installation according to the original schedule. It consists of 4 GMS's (Ground Monitor Station) in Japan (Sapporo, Tokyo, Fukuoka and Naha), 2 MCS's (Master Control Station: Kobe and Hitachiota) and 2 MRS's (Monitor and Ranging Station: Hawaii and Australia). Domestic MRS is also included in each MCS, which makes up additional 2 MRS's. System integration incorporating all the ground subsystems is also underway as long as it can be performed without the actual MTSAT satellite.

Every effort is being made to recover the delay due to the launch failure. JCAB (Japan Civil Aviation Bureau) decided to utilize Satellite Emulator to continue the activity regarding evaluation and certification of MSAS. It was specially developed so that continuous MSAS message generation can be done. It is a base-band satellite simulator tool (No RF signal) in order to trick MSAS ground system as if the actual MTSAT is broadcasting MSAS messages.

This paper briefly discusses about the satellite simulator tool architecture, data collection scheme and preliminary performance of MSAS particularly in terms of En-route (ER) and Non-Precision approach (NPA). System availability was calculated using actually generated MSAS message based on collected GMS data. The computation result will be presented geographically over areas including Japan Flight Information Region (FIR). Preliminary result shows that the MSAS seems that the En-route/NPA performance could be met. Availability computed by Service Volume Model (SVM) is also shown for comparison.

As a near term plan, MSAS enhancement toward LNAV/VNAV and GLS (GNSS landing System) capability is also being pursued as well as the enhancement regarding integrity monitoring.

INTRUDUCTION

ICAO (International Civil Aviation Organization) proposed Future Air Navigation Systems concept at the end of 1980's. It covers the entire aviation system, which is called CNS/ATM (Communication, Navigation and Surveillance/Air Traffic Management).

GNSS (Global Navigation Satellite System) is a major part of Navigation area and ICAO established GNSS Panel in 1993 and the 1st Panel meeting was held in 1994 [1]. In the course of this movement, JCAB decided to develop MTSAT (Multi-functional Transport SATellite) and its relevant system. MTSAT is literally multi-functional. More specifically, it has Aeronautical Mobile Satellite Service (AMSS) function, Meteorological function and GNSS function.

MSAS is one of the Satellite Based Augmentation System (SBAS) such as US Wide Area Augmentation System (WAAS) and European Geo-stationary Navigation Overlay Service (EGNOS). MSAS is expected to contribute to the wide area navigation service in Asia/ Pacific region in the future.

Development of MSAS Phase 1 started in early 1997, since then, each design Review have been successfully passed and at the end of 1999, the MTSAT 1 (1st satellite) was supposed to be launched. However, it was failed as presented in GNSS-2000 last year [2]. In the meantime, Phase 1 MSAS system was deployed in the field, and system integration activity has been going on as much as possible without the actual satellite.

Even under such adverse circumstances, evaluation had to be continued and it is necessary to reach a certain degree of confidence so that the initial service level could be met. However, SBAS system like MSAS has to establish two signal loops. One of them is the one between NES/GES (Navigation Earth Station/Ground Earth Station) and MTSAT in order to establish Code Carrier Coherence. Another one is a big loop of the SBAS messages through the satellite, GMS/MRS and the ground network in order for MSAS CPF (Central Processing Facility) to continue its operation updating each MSAS messages, otherwise, it declares an alarm which disables to obtain continuous data for evaluation. Therefore, JCAB decided to further develop Satellite Emulator System (SES) to achieve these signal loops on a base-band.

This paper presents the brief description of SES and the preliminary evaluation result regarding ER/NPA service level which could be acquired by the use of SES. The result will be compared with the SVM computation. It also describes briefly the future issues and plans of MSAS.

MSAS STATUS

MSAS SYSTEM OVERVIEW

Phase 1 MSAS deployed in the field is composed of the following subsystems.

- 2 MCS's (Master Control Station: Kobe and Hitachiota)
- 4 GMS's (Ground Monitor Station: Sapporo, Tokyo, Fukuoka and Naha)
- 2MRS's (Monitor and Ranging Station: Hawaii and Australia)

MCS further consists of MRS, CPF, M&C (Monitor and Control Subsystem) and NES (Navigation Earth Station)/GES. NES/GES is MSAS ground uplink station.

Specific sites are shown in Figure 1.

Also, Figure 2 and 3 are sample pictures of MSAS. Figure 2 is M&C and peripheral processors installed in the operation room of Kobe Aeronautical Satellite Center and Figure 3 shows the overview of MRS site in Canberra, Australia.

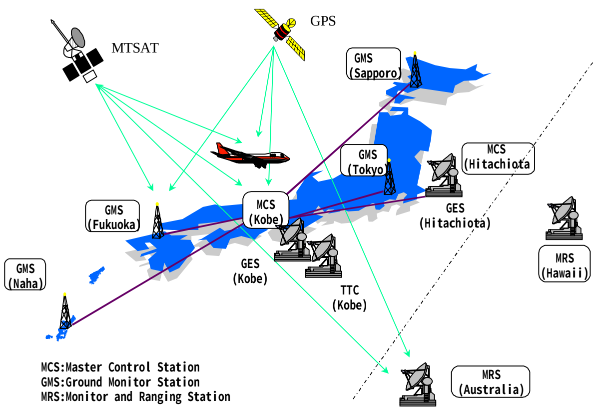

Figure 1 Phase 1 MSAS deployment

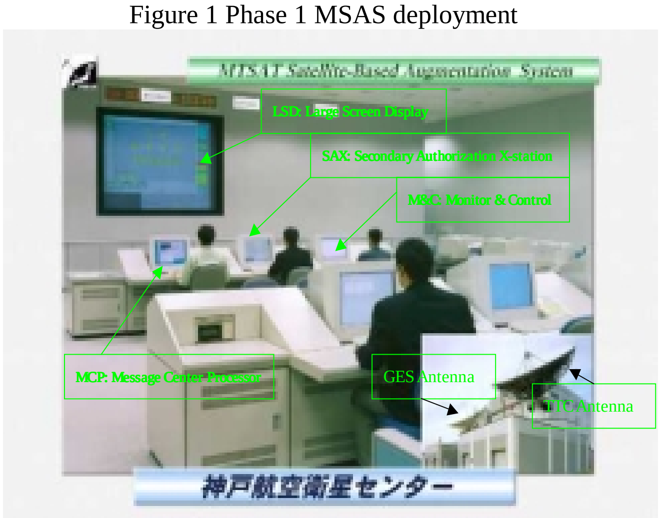

Figure 2 M&C Subsystem in Kobe Aeronautical Satellite Center

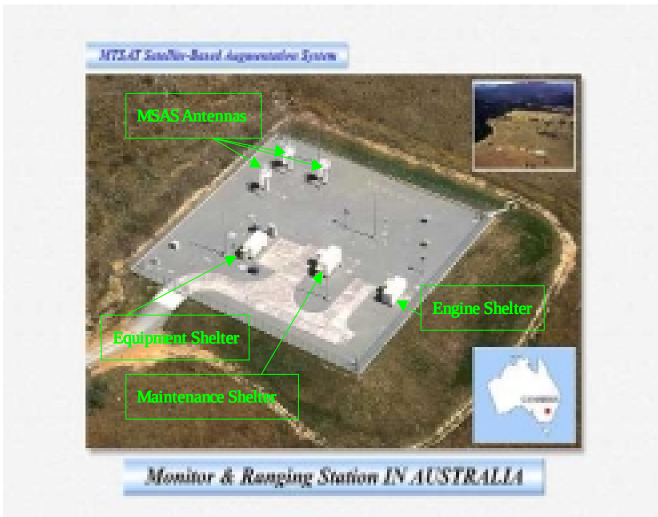

Figure 3 Overview of MRS in Canberra, Australia

PHASE 1 MSAS SYSTEM TEST APPROACH

Figure 4 shows the entire schedule for both Phase 1 and Phase 2 MSAS although the details of Phase 2 are yet to be determined. According to Figure 4, New MTSAT1, which is now called MTSAT 1R (R stands for Replacement.) is supposed to be launched at the end of Fiscal Year (FY) 2002. This is 3 years behind from the original plan. However, it is possible for MSAS system to continuously operate without MTSAT by introducing the SES, although GEO cannot be functional as a ranging source. GPS related data can be collected and analyzed together with the confidence level (UDRE/GIVE) so that MSAS is to calculate on a real time basis. Therefore, during the past 1 year, SES was developed and set-up at Kobe and Hitachiota sites in order to support the preliminary certification activity by obtaining MSAS data as much as possible before the actual MTSAT 1R is launched in FY 2002. Relevant test and integration is also conducted with 2 steps, the 1st one with SES (without MTSAT) and the 2nd one is with MTSAT (without SES).

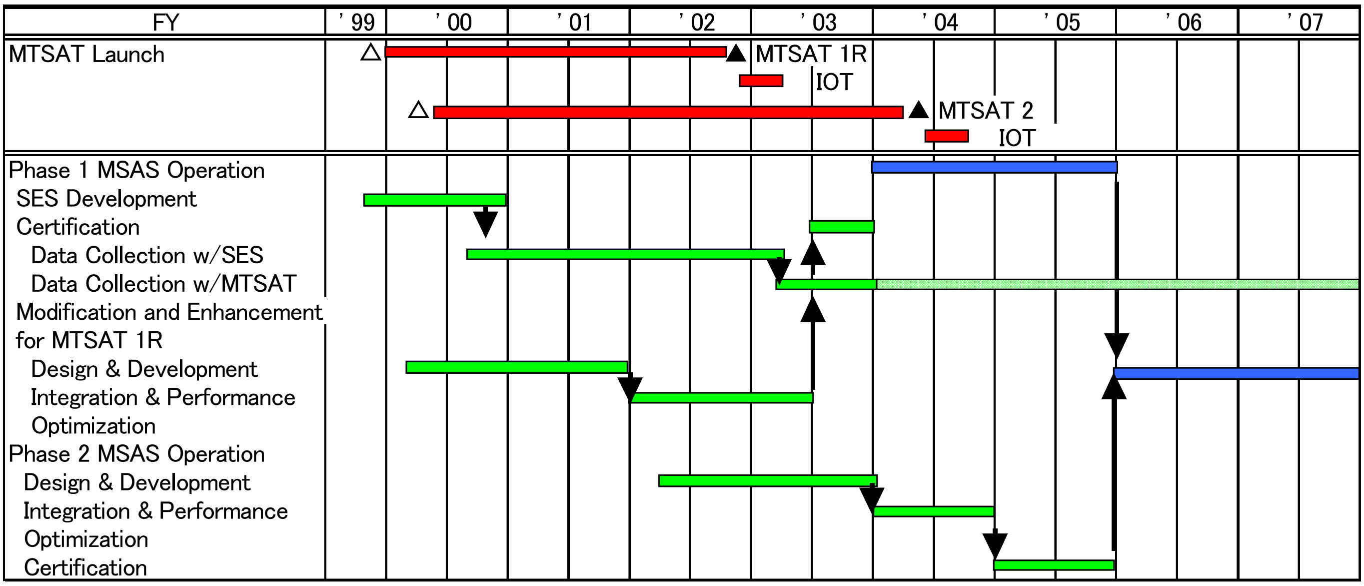

Figure 4 Entire Plan to Implement Phase1 and Phase 2 MSAS

OVERVIEW OF SES

Followings are primary SES features to enable real time data collection by tricking MSAS ground system as if there was the actual MTSAT satellite in the space.

- MSAS ground system operational without actual MTSAT
- No modification needed on MSAS operational software.
- Generate real time augmentation of the GME (*1) Rate Group Data by combining simulated MTSAT pseudo range measurement, simulated GME statistics, and active navigation message. (GEO Emulator #1)
- Emulation of NES external interfaces, provides MTSAT-GES pseudo-range measurements, emulates the typical MTSAT orbit. (GEO Emulator #2)
- Loopback MSAS Navigation Message (GEO Emulator #1, #2)

(*1) GME: Ground Monitor Equipment: GMS consists of 3 GME's.

Figure 5 shows the block diagram of the test architecture implementing SES with the operational MSAS system. Brief description is shown as follows.

GMS measurement data are sent to GEO Emulator #1 through Wide Area Network, NCS and LAN interface in MSAS. Pseudo control loop is established between NES and GEO Emulator #2. GEO Emulator #2 provides GEO Emulator #1 with MTSAT orbit data as well as MSAS actual message. GEO Emulator #1 combines the real GPS pseudo-range measured at each GMS's and the simulated MTSAT pseudo-range data. They are sent back to each MSAS subsystem (CPF and M&C) without making them know that they are cheated. This is how the real time data collection continues without MTSAT satellite. It is certain that there are still quite a few test and evaluation items to be done with the actual satellite. However, it will obviously be able to support the certification activity until the actual satellite plays its real role.

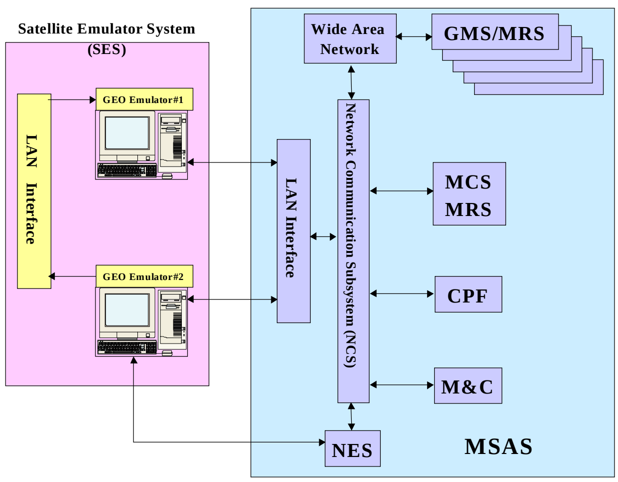

Figure 5 Block Diagram of SES integrated into MSAS

PRELIMINARY PERFORMANCE FOR ER/NPA

- RAIM AVAILABILITY (ER/NPA) -

The primary objectives of MSAS are transmission of GPS correction, transmission of integrity information and availability improvement as a stable raging source like other SBAS systems. Integrity is especially important, not only in case of Precision Approach but also ER/NPA. In ER/NPA, RAIM capability is available. However, availability cannot be met in every area of Japan FIR because of poor GPS satellite geometry

in some areas particularly in middle latitude region [3]. Sample availability data of ER/NPA on 9/30/1999 which was calculated only considering RAIM capability is shown in Figure 6. RAIM algorithm as a basis of this computation is described in [4] and [5]. In order to overcome this deficiency, augmented data by MSAS is efficient.

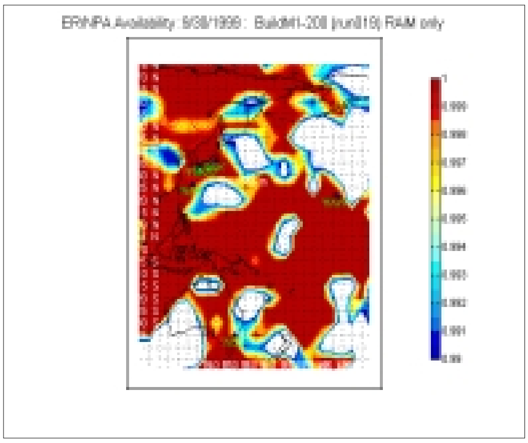

Figure 6 RAIM Availability

- MSAS AVAILABILITY (ER/NPA real data) -

Preliminary performance analysis was conducted for MSAS using actually measured data. For comparison, the data on the same day as Figure 6 were used. They were not processed by exactly the same architecture as the newly developed SES shown in Figure 5, however, it is almost equivalent in that the actual GMS data were collected and processed on a real time basis. Simulated GEO data was also incorporated into the test set-up.

Following analysis was conducted in order to make sure the sensitivity against the numbers of GMS's in ER/NPA. Essentially, the numbers of GMS's should be associated with Precision Approach because of stable measurement of ionosphere and estimate of its confidence level. Therefore, the comparison was made between the following two cases to look into the minimum configuration of GMS's in ER/NPA.

- ALL GMS's except for Sapporo and Hitachiota (Sapporo equipment was not available and Hitachiota equipment was not installed then.) , which are 6 out of 8 Phase 1 GMS'sGMS's (Deterministic Performance-A)
- Only two GMS's are available as another extreme (Deterministic Performance-B)

Another analysis is the comparison between the performance of real GMS data and Service Volume Model (SVM) computation. In the real data case, the actual ground equipment conditions are reflected in the analysis, in this sense, it is a deterministic system performance while the SVM is a probabilistic system performance. Table 1 shows the brief condition of each performance chart from Figure 7 to Figure 10.

Figure 7 shows the availability of deterministic performance-A. Phase 1 availability is met not only in Japan FIR but also wider area within MTSAT footprint.

Table 1 Conditions behind each performance

	Deterministic Performance-A	Deterministic Performance-B	SVM-A	SVM -B
Date	1999/9/30	1999/9/30	1999/9/30	1999/9/30
No. of GMS's	6	2	6	2
Alarm limit (ER/NPA:H)	556m	556m	556m	556m
UDRE/GIVE	Real	Real	Fix	Fix

Figure 8 shows the availability in case of deterministic performance-B. Phase 1 availability is also met within most of the area of Japan FIR. Availability of South-East area from Japan is a little bit worse than deterministic performance-A shown in Figure 7. However, the difference is trivial and the availability could be met dependent on which two GMS's are remained. It means the number of GMS's is not so sensitive to the deterministic performance as precision approach. Note that Pseudo MTSAT is only one, that is, this architecture is not the one to meet continuity requirement in the nominal operation. However, even the current architecture is capable to meet Accuracy and Integrity in most of Japan FIR as long as at least 2 GMS's are up.

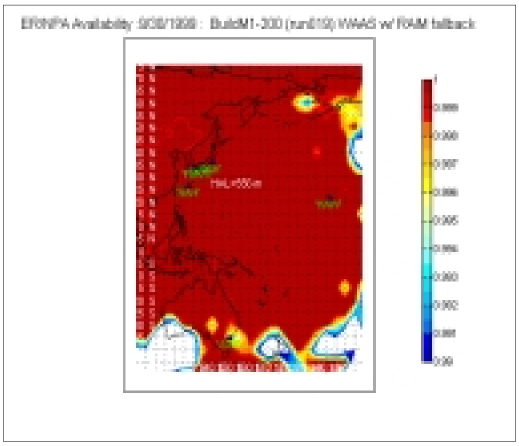

Figure 7 Availability of Det.Performance-A

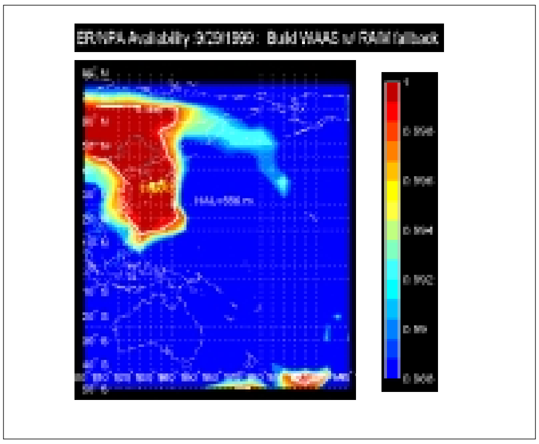

Figure 8 Availability of Det.Performance-B

- MSAS AVAILABILITY (ER/NPA SVM) -

SVM is a simulation tool of probabilistic model. This SVM has a fixed UDRE and GIVE values because it is a stand alone simulation tool which still has a limitation in case of Precision Approach computation. However, as far as the ER/NPA is concerned, it has an advantage to consider the effect of geometry of satellites and equipment failure probability. Figure 9 shows the availability computation of SVM-A case, which consists of the same 6 GMS's as deterministic performance-A shown in Figure 7. The big difference in the system architecture is that Hitachiota MCS is assumed to operate except for domestic MRS there in SVM computation, while Hitachiota MCS was not included in the deterministic case. This is because single MCS configuration as in the deterministic performance is not the one which meets the availability requirement if the failures of each equipment are taken into consideration. If exactly the same configuration was assumed in the probabilistic model (SVM), it is obvious that the result of SVM becomes worse and it cannot be compared with each other. Therefore, in order to simulate the deterministic case regarding MCS, Hitachiota MCS was also assumed in this simulation. It seems that Figure 7 and Figure 9 have relatively good much with each other.

Lastly, Figure 10 also shows the SVM-B for comparison with deterministic performance with 2 GMS's shown in Figure 8. Hitachiota MCS was also assumed in the computation for the same reason as the previous case shown in Figure 8. It looks that the availability of the south east area from Japan is better than deterministic performance-B, even though the probabilistic effect was taken into account in SVM. It is inferred that the UDRE setup as a fixed value in SVM was smaller than real data.

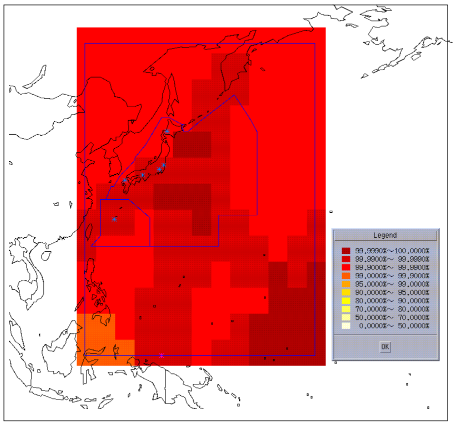

Figure 9 Availability of SVM-A

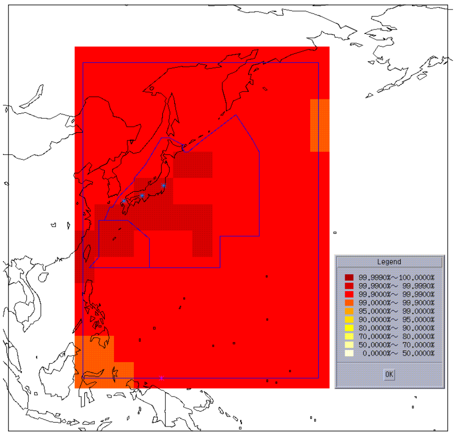

Figure 10 Availability of SVM-B

WRAP UP OF PHASE 1 MSAS PRELIMINARY PERFORMANCE

- Phase 1 MSAS is capable to meet ER/NPA availability with no continuity requirement as a prerequisite condition if redundant MCS is installed
- In order to meet continuity requirement, there must be multiple GEO satellites otherwise some alternate measure or mitigation of the requirement is needed.
- As far as GMS is concerned, they have sufficient redundancy to meet Phase 1 ER/NPA requirement.
- Phase 1 MSAS cannot be directly certified only with this result. More research and evaluation is necessary to certify the system.

FUTURE ISSUES

MSAS is based on US WAAS, however, MSAS unique circumstances surely exist. In order for MSAS to be certified in the future, there are two aspects to be considered.

Regarding the portion common to WAAS, the enhancement of WAAS should also be incorporated into MSAS. Recently, integrity issues were raised in WAAS and algorithms for monitoring integrity are to be incorporated. Particularly in this area, MSAS has the identical algorithm that WAAS has. Specific plan and schedule to incorporate integrity enhancement are big issues to be considered. LNAV/VNAV capability is also pursued as well as the integrity issues.

On the other hand, there may be some MSAS unique issues particularly taking vertical guidance such as LNAV/VNAV and future precision approach into consideration. Unlike CONUS of WAAS, Japan island is thin and most of the GMS's located in Japan are aligned. In addition, Ionospheric effect may be different because of the location of the magnetic equator. Those issues are to be resolved by collecting data as much as possible and continue evaluation.

Continuity issue should also be considered because of a single satellite in Phase 1. Since MSAS uplink is Ku-band , it is more vulnerable to rain attenuation than C-band system.

Appropriate power control is necessary. Dual PRN code is generally a way to mitigate continuity risk which should also be investigated.

CONCLUSION

Phase 1 MSAS ground system completed its deployment in the field.

Preliminary ER/NPA deterministic performance of MSAS was shown.. Though it does not prove that the availability can be met, it has a possible capability to achieve ER/NPA regarding accuracy and integrity. Continuity issue still needs to be considered toward the future operation.

ACKNOWLEDGEMENT

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