다목적 실용위성2호 관제시스템 운용

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Mission Control System for KOMPSAT-2 Operations

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요 약

한국전자통신연구원이 개발하여 항공우주연구원의 관제소에 설치한 아리랑2호 위성 관제시스템은 지난 7월 28일 발사된 아리랑2호 위성의 운용에 사용되고 있다. 아리랑2호 관제시스템의 대표적인 기능으로는 원격측정데이터 수신 및 처리, 원격명령 생성 및 송신, 위성 추적 및 거리측정, 궤도 예측 및 결정, 위성자세 조정계획, 그리고 위성 시뮬레이션 등이 있다.

아리랑2호 위성은 아리랑1호 위성의 임무를 이어받아 수행하며, MSC (Multi Spectral Camera) 및 정밀궤도결정, 정밀자세결정 등을 통해 아리랑1호에 비해 훨씬 향상된 해상도의 사진을 제공하는 성능을 가지고 있다.

키워드 : 아리랑2호 위성, 위성관제시스템, 관제소

ABSTRACT

The Mission Control System for KOMPSAT-2 was developed by ETRI and is being operated at Satellite Control Center at KARI to monitor and control KOMPSAT-2 (KOrea Multi-Purpose Satellite) which was launched in July 28th, 2006. MCE provides the functions such as telemetry reception and processing, telecommand generation and transmission, satellite tracking and ranging, orbit prediction and determination, attitude maneuver planning, satellite simulation, etc.

KOMPSAT-2 is the successor of KOMPSAT-1 which is an earth-observation satellite. KOMPSAT-2 has higher resolution image taking ability due to MSC (Multi Spectral Camera) payload in the satellite and precise orbit and attitude determination by Mission Control System. It can produce one meter resolution image compared to six meter resolution image by KOMPSAT-1.

Key Words : : KOMPSAT-2, Mission Control System, Satellite Control Center

1. Introduction

Korea Multi-Purpose Satellite-2 (KOMPSAT-2) was launched successfully on July 28th, 2006, and is currently in the phase of operational test. KOMPSAT-2 is a Low Earth Orbit (LEO) satellite, which performs the mission of earth observation in 685 km altitude sun-synchronous orbit.

Its predecessor, KOMPSAT-1, was launched in 1999 and is still performing its mission

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successfully. KOMPSAT-2 will continue the imaging mission of KOMPSAT-1 with higher resolution.

KOMPSAT-2 visits Korean Peninsula 2-3 times in the morning time and 2-3 times in the night time. Each contact time lasts around 12 minutes.

To monitor and control KOMPSAT-2, Mission Control System has been developed by ETRI (Electronics and Telecommunications Research Institute) from January, 2000 to January, 2005.

This system is fully built by Korean domestic technology accumulated through the research and development in Lab. Model Mission Control System and KOMPSAT-1 Mission Control System.

Mission Control System consists of four subsystems, i.e. TTC (Tracking, Telemetry & Command Subsystem), SOS (Satellite Operations Subsystem), MAPS (Mission Analysis and Planning Subsystem), and SIM (Satellite SIMulator Subsystem). TTC directly communicates with KOMPSAT-2 receiving telemetry signals and transmitting telecommand signals via S-band frequency. SOS receives the telemetry frames from TTC during the contact time and transmits the telecommand from the operator's monitor to TTC to be transmitted to KOMPSAT-2. MAPS evaluates the state-of-health data of KOMPSAT-2 to predict the orbit and attitude of the satellite, prepares the mission schedule of KOMPSAT-2, and generates the command plan to be transmitted. SIM is the software system that simulates the behavior of the satellite. It is used for the telecommand test, satellite mission simulation, anomaly analysis, and operator training.

This paper introduces the functions, characteristics and operations of Mission Control System. The functions of the subsystems of the Mission Control System are introduced in chapter 2, the special functions of the Mission Control System are shown in chapter 3, the early operations of the Mission Control System are described in chapter 4, and the conclusions are mentioned in chapter 5.

Figure 1 shows the architecture of MCE including four subsystem block diagram.

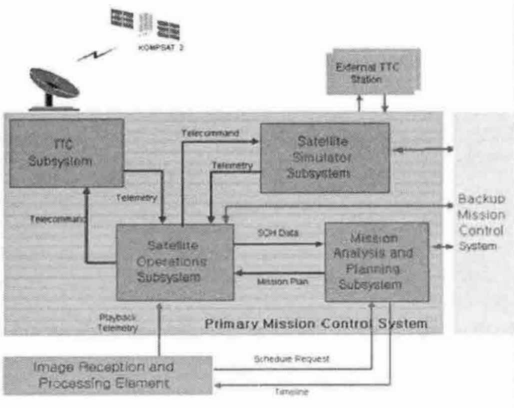

Fig. 1 MCE Architecture

2. Subsystems and Functions

TTC consists of S-band antenna equipment, RF equipment, Modem/BB equipment, Timing equipment, and C&M computer.

During the contact time with KOMPSAT-2, TTC receives either the real-time telemetry data at 2.048 Kbps rate or the playback telemetry data at 1.5 Mbps rate from the KOMPSAT-2 satellite, demodulates the received telemetry data, and transfers them to SOS for processing. Also during the contact time, TTC receives satellite control commands from SOS and transmits them to the satellite. It also performs ranging and tracking functions along with time distribution function.

TTC has C&M computer with software which monitors and controls the equipment in TTC. It shows the current status of each equipment and support the control function for the equipment.

KOMPSAT-1 TTC subsystem is reused for KOMPSAT-2 operation. One set of timing equipment is added to back up the primary timing equipment. To support this addition, C&M software is modified.

SOS provides real-time monitoring function for satellite status checking and telecommand transmission function to control the satellite during the contact time. SOS has network links to TTC, in order to send telecommands to the satellite and to receive the telemetry data from the satellite. [1]

SOS extracts satellite SOH data from telemetry data received from TTC, displays them in many different types on the operators' screens for monitoring, and sends them to other systems of other subsystems in Mission Control System. SOS stores real time and playback data for future analysis. During non-contact time, SOS reprocesses the stored data and analyzes the trend of the data. SOS prepares telecommand procedures according to themission plan generated by MAPS. The transmission of telecommand to TTC is performed by clicking the telecommands in the procedure. [2]

SOS is composed of computers, including PC's and UNIX workstations, I/O devices, and software programs to monitor and control the satellite. Figure 2 shows the telemetry alphanumeric display window for SOS.

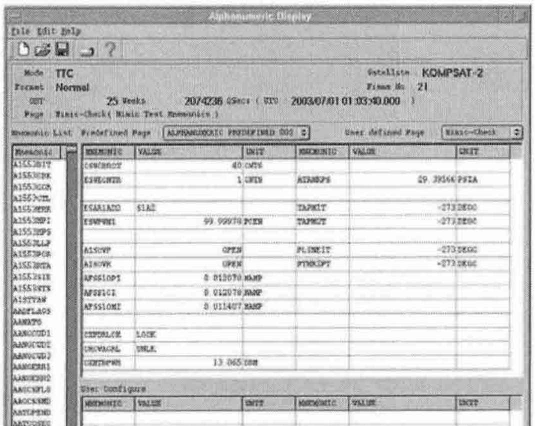

Fig. 2 Telemetry Alphanumeric Display

MAPS provides the function to make satellite operation schedules by analyzing and predicting the orbit and attitude of the satellite and by organizing the satellite user's requests. [3]

MAPS has the functions of orbit determination, orbit prediction, and event prediction. Using those functions, MAPS predicts the satellite operation schedule which is necessary for satellite maintenance.

MAPS receives the mission requests from the users and generates mission plan and mission timeline.MAPS checks the conflicts among missions and events in the timeline and informs the operator for schedule correction.

MAPS generates conflict-free daily, weekly, and monthly timeline. MAPS also generates command plan based on mission timeline and transfers it to SOS to be used to generate command procedure. This allows the automation in telecommand procedure generation.

MAPS is composed of a workstation, its peripherals and mission planning software. Figure 3 shows the mission planning window for MAPS.

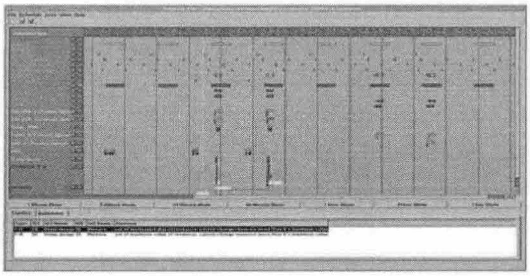

Fig. 3 Mission Planning Window

SIM is a software system that simulates the dynamic behavior of KOMPSAT-2 using mathematical models. SIM is utilized for command verification, operator training, satellite control procedure validation, and anomaly analysis. [4]

SIM simulates the behavior of each of satellite subsystems as accurate as possible with the constraint of real-time operation condition. It displays the status of satellite including orbit and attitude in alphanumeric and graphic form.

SIM can be operated either in SOS-connection mode or in stand-alone mode. When connected to SOS, it provides telecommand and telemetry verification for SOS.When used in stand-alone mode, it can be used for many different purposes such as anomaly analysis, operator training, and satellite behavior demonstration.

SIM also operates at predefined variable speeds in order to be used for anomaly analysis etc. In addition, the SIM supports simulation for the spacecraft status by providing the database containing various events and initialization data.

SIM is composed of a PC, its peripherals and simulation software. Figure 4 shows the telemetry alphanumeric display window for SOS.

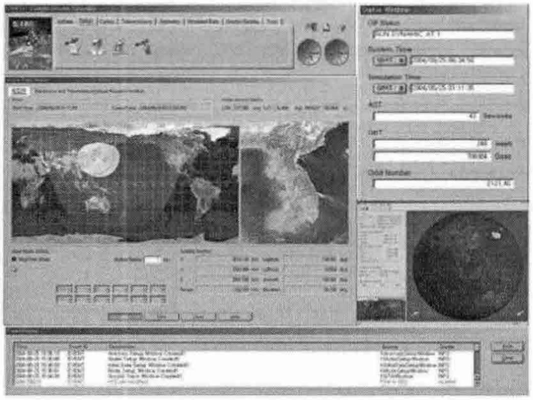

Fig. 4 Simulator Main Window

3. Special Functions for KOMPSAT-2

3.1. Precise Orbit Determination

Since KOMPSAT-2 has higher resolution camera, the orbit and attitude determination has to be more accurate than in KOMPSAT-1. To satisfy this requirement, POD (Precise Orbit Determination) function is added to Mission Control System. For precise orbit determination function, DGPS (Differential Global Positioning System) method is used. [5]

Alcatel Space TOPSTAR 3000 space borne GPS receiver with two antenna provides the reference time signal, GPS navigation solutions such as position and velocity, and GPS raw data such as C/A code pseudorange and L1 carrier phase. The reference time signal from the GPS receiver is used for time synchronization between the satellite on-board processors and GPS. The GPS navigation solutions are used as command reference of the Attitude and Orbit Control System (AOCS) in satellite and also as measurement data of the OOD in Mission Control System. The raw GPS measurements are used for POD in Mission Control System.

GPS navigation solutions are stored to On-Board Computer (OBC) mass memory in every 32-second interval for the telemetry downlink. There are two types of the GPS navigation solutions in Earth-Centered-Earth-Fixed (ECEF) coordinate system. One is the snapshot solution and the other is DIOGENE solution using Kalman filter. The snapshot solutions are mainly used for OOD in Mission Control Systemand the DIOGENE solutions are used for the integrity check of the orbit determination results in ground and on-board.

Raw GPS tracking data upto 8 channels are also stored in OBC mass memory of the satellite in every 1-second interval at maximum when GPS receiver is switched on. In this case, data sampling rate is selectable by ground commanding. The GPS raw measurements from the satellite will be transferred to ground through S-Band playback mode with 1.5 Mbps. Telemetry downlink can be performed during every available contact considering on-board storage limitation.

The strategy of POD requires continuous tracking of the visible GPS satellites by on-board GPS receiver and ground reference station GPS receivers. MCE receives the KOMPSAT-2 on-board L1 single frequency GPS raw data through telemetry and archives L1/L2 frequency GPS tracking data from worldwide reference GPS ground stations via Internet. POD software performs preprocessing to generate double differenced measurement data between KOMPSAT-2 GPS raw data and reference ground station GPS raw data in 30-second interval. And then, the POD software estimates the precise orbit parameters using double differenced measurement data. The result of POD execution will be provided once a day for the enhancement of the image quality and generation of value added product.

The operation concept and data flow of the

OOD (Operational Orbit Determination) and POD for the KOMPSAT-2 are illustrated in Figure 5.

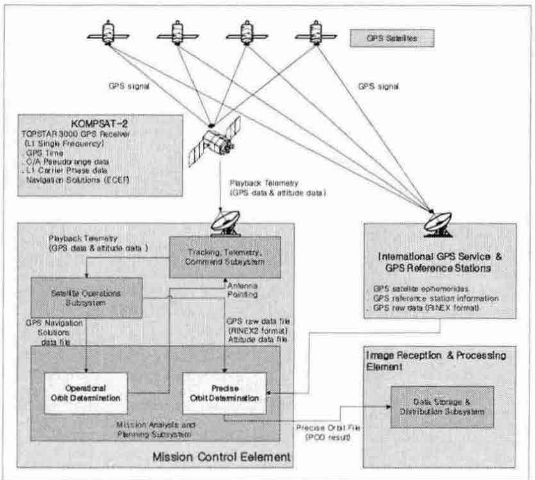

Fig. 5 Operation concept of orbit determination

3.2. Automation on Command Planning and Telecommand Verification

When MAPS generates the operation schedule and the command plan, the file is sent to SOS where it can be loaded to the system and ready to be transmitted. This function prevents the operatorsfrom making operation error. An eXtensible Markup Language (XML) is used for transmitting of the command planning results to SOS.

MCE system provides automatic telecommand execution verification function using knowledge base and expert system. Telecommand verification factors are stored in the knowledge base, and when the telecommand is transmitted, the expert system automatically searches the factors in the knowledge base, verifies if the telecommand has executed successfully, and shows the verification result on the screen.

4. Operation of Mission Control System

The development of Mission Control System has been completed on January 31st, 2005. The developed Mission Control System was installed at KARI's Mission Control Center and went through various types of tests.

KOMPSAT-2 was launched on July 28th, 2006. and the first contact was mad through Kenya's ground station. When the first telemetry data was received from KOMPSAT-2 to Kenya's station, to Modem of Mission Control System, and finally to the screens of Mission Control System's telemetry display page., it was clear that the Mission Control System was successfully developed. Figure 6 shows the first telemetry displayed on the screen.

Fig. 6 First Telemetry from KOMPSAT-2 Displayed on the Screen

In the next contact, telecommand transmission was performed. The telecommand procedure was prepared on the operator's screen before the contact. When the satellite contact was made, the telecommands in the prepared procedure were sent to the satellite one by one, and the telemetry which shows the telecommand count was increasing by one, which means the transmitted telecommand was accepted by the satellite.

After the single command was sent, several telecommands were sent as a group, which is also possible using the telecommand procedure, and this attempt also shows the successful result by telecommand count was increased by the number of telecommands sent.

Figure 7 shows the telecommand transmission window that sent the first telecommand to KOMPSAT-2.

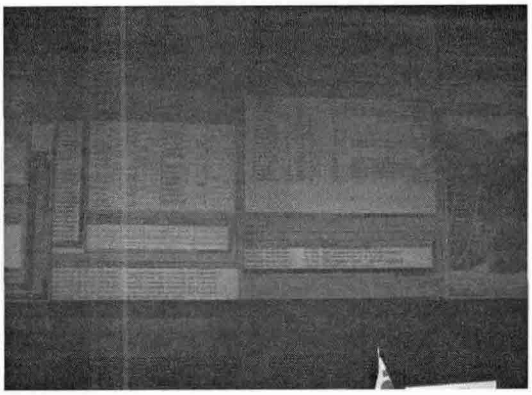

Fig. 7 First Telecommand to KOMPSAT-2

When the Mission Control System received telemetry frame which was broken, it showed the message that the telemetry frame was invalid. Since the invalid telemetry frame can be received in the early operation phase when the satellite is not in a stable position, the operators found this information was very useful.

After several contact via external ground stations, KOMPSAT-2 passed over Korean Peninsula at 11 o'clock at night. The data exchange was very successful and stable.

Through the phases of earth acquisition and science coarse mode, the functional performances of Mission Control System were very stable, and the operators felt very comfortable with the system.

5. Conclusions

KOMPSAT-2 Mission Control System is briefly introduced in this paper. The functions of the subsystems are mentioned, the newly added functions are described, and the operations of the Mission Control System are explained.

KOMPSAT-2 Mission Control System was developed by domestic technology. It increased the automation features while providing more useful information to the operators.

KOMPSAT-2 Mission Control System provides precise orbit determination function for 1m resolution camera and automated functions for telecommand planning and verification.

The technologies gathered during the development of KOMPSAT-2 Mission Control System will be well analyzed and evaluated for the development of future Mission Control Systems for various types of satellites.

The future work includes the development of Mission Control System for the satellites such as COMS (Communications, Ocean, and Meteorological Satellite), which is a geostationary earth orbit satellite, KOMPSAT-3, and KOMPSAT-5.

ETRI is also preparing for the mobile mission control system development, which can be installed on top of a trailer, so it can be moved to different places for satellite mission control. The necessary information and research are currently being performed.

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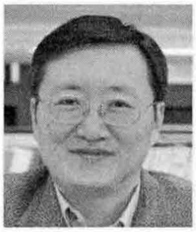

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