통신해양기상위성 관제시스템 설계

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Design of the COMS Satellite Ground Control System

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요 약

복합임무를 갖는 정지궤도 위성인 통신해양기상위성은 항공우주연구원, 전자통신연구원, 해양연구원, 기상청과 국내외 기업이 공동으로 개발을 수행하고 있다. 통신해양기상위성의 주 계약자는 EADS Astrium이며 전자통신연구원은 정보통신부의 재원으로 Ka 대역 통신탑재체와 지상 관제시스템을 개발하고 있다. 통신해양기상위성의 관제시스템은 궤도상의 위성을 감시하고 제어할 수 있는 유일한 시스템이다. 통신해양기상위성에 탑재되어 있는 세 개의 탑재체와 위성체 버스에 대한 임무운용을 위해서 지상 관제시스템은 원격측정 신호의 수신과 처리, 위성의 추적과 거리측정, 원격명령의 생성 및 송출, 위성의 임무계획, 비행역학데이터 처리, 그리고 위성 시뮬레이션을 수행한다. 이와 같은 기능을 적절히 할당해서 통신해양기상위성의 관제시스템은 TTC, 실시간운영, 임무계획, 비행역학, 그리고 위성시뮬레이터와 같은 5개의 서브시스템으로 구성되었다. 본 논문에서는 통신해양기상위성 관제시스템을 구성하는 5 개의 서브시스템에 대한 기능 설계와 인터페이스를 기술한다.

키워드 : 정지궤도, 통신해양기상위성, 위성관제

ABSTRACT

As a multi-mission GEO satellite, COMS system is being developed jointly by KARI, ETRI, KORDI, KMA, and industries from both abroad and domestic. EADS ASTRIUM is the prime contractor for manufacturing the COMS. ETRI is developing the COMS Ka-band payload and SGCS with the fund from MIC. COMS Satellite Ground Control System (SGCS) will be the only system for monitor and control of the satellite in orbit. In order to fulfill the mission operations of the three payloads and spacecraft bus, COMS SGCS performs telemetry reception and processing, satellite tracking and ranging, command generation and transmission, satellite mission planning, flight dynamics operations, and satellite simulation. By the proper functional allocations, COMS SGCS is divided into five subsystems such as TTC, ROS, MPS, FDS, and CSS. In this paper, functional design of the COMS SGCS is described as five subsystems and the interfaces among the subsystems.

Key Words : GEO, COMS, Satellite Mission Control

I. Introduction

As a multi-mission GEO satellite, COMS is being developed jointly by KARI, ETRI, KORDI, KMA, and industries from both abroad and domestic. EADS ASTRIUM is the prime contractor for manufacturing the COMS satellite. ETRI is developing the COMS Ka-band payload and SGCS with the fund from MIC. The COMS is scheduled to be launched in the year 2008.

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Major missions of the COMS are described as follows.

- Satellite Communications Mission:
  - Next generation communication payload technology for space qualification
  - Broadband satellite multimedia test service
- Ocean Observation Mission:
  - Observation of marine ecology and environment around Korean peninsula
  - Assessment of oceanic life and generation of high quality fishery information
- Meteorological Observation Mission:
  - Continuous observation of high-resolution multi-channel meteorological images and generation of meteorological elements
  - Early detection of abnormal meteorological phenomena such as typhoon, torrential rain, yellow sand, sea fog etc.
  - Generation of long-term sea surface temperature and cloud data

In order to carry out the three kinds of multi-mission, the COMS system consists of three payloads, a spacecraft bus and ground system as shown in Figure 1. From the functional point of view, COMS ground segment comprises SGCS for satellite operation, IDACS for MI/GOCI data processing, and CTES for Ka-band payload. SGCS and IDACS will be installed in SOC and MSC as cross backup for higher availability[1].

For the control and monitor of the COMS, the SGCS performs the following functions.

- Reception and processing of telemetry data from COMS via S-band link
- Planning and transmission of telecommand to COMS via S-band link
- Tracking and ranging of COMS
- Control and monitoring of SGCS equipment
- Analysis and simulation of COMS
- Processing and analysis of flight dynamics data
- Mission scheduling and reporting

SGCS consists of five subsystems: TTC, ROS, MPS, FDS, and CSS as shown in Figure 2.

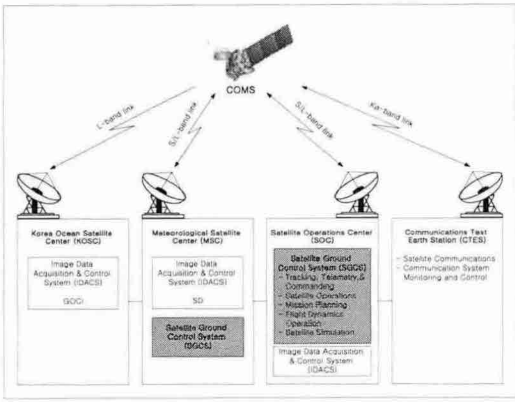

Figure 1: COMS System Architecture

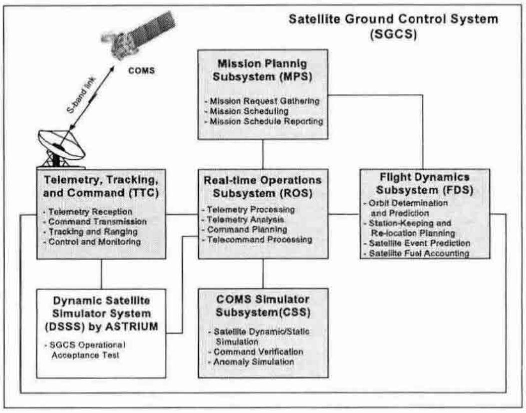

Figure 2: SGCS Functional Architecture

2. SGCS Functional Design

2.1 TTC Subsystem

TTC receives the satellite control command data from ROS and performs the modulation of command data, and the transmission of S-band signal. Also, TTC receives the antenna pointing data from FDS and performs the satellite tracking and ranging. The subsystem also receives the telemetry data from the COMS satellite. TTC demodulates the received telemetry data and transfers it to ROS. TTC transfers the satellite tracking and ranging data to FDS. The antenna equipment and a part of TTC are co-used for MSC. TTC comprises antenna equipment, RF equipment, MODEM/BB equipment, timing equipment, C&M equipment. Figure 3 shows the functional structure of TTC.

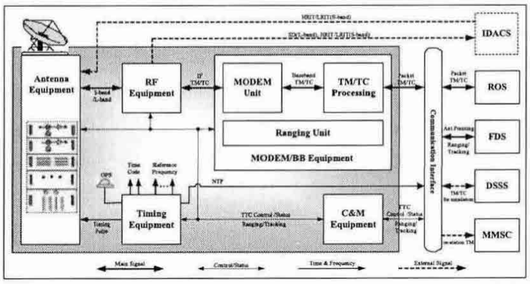

Figure 3: TTC Functional Structure

Telemetry Reception and Processing

TTC receives S-band RHCP signal including telemetry and ranging signals from COMS and demodulatesit. The demodulated telemetry signal shall be bit/frame synchronized. The processed telemetry data are transmitted to ROS.

Polarization Diversity

TTC shall have the function of polarization diversity for the downlink signals of RHCP and LHCP.

Command Processing and Transmission

The command generated from ROS is encoded, modulated, up-converted at TTC and transmitted to the COMS via S-band RHCP.

Tracking

TTC tracks the position of the satellite via program mode, auto track mode. The antenna angle tracking data acquired by TTC are transmitted to FDS.

Ranging

TTC performs the ranging function. The ranging request is given from FDS, and the result of the ranging is archived and sent to FDS.

Interface with IDACS

TTC provides the RF interface at antenna feed with IDACS for reception of SD signal from the COMS, and transmission of HRIT and LRIT signal to the COMS.

Interface with DSSS

TTC transmits the command from ROS to the DSSS for simulation and receives the telemetry from DSSS.

Interface with ASTRIUM MMSC

TTC in primary SGCS shall be capable of transmitting on-station telemetry to ASTRIUM MMSC in Toulouse, France, if necessary.

2.2 ROS Subsystem

ROS provides real-time monitoring of satellite status and transmits telecommands to control the satellite. ROS has communication (or network) links to TTC, MPS, and FDS in order to send telecommands, to receive telemetry data from the satellite, and to analyze the mission of the satellite. ROS extracts satellite SOH data from telemetry data received from TTC, displays it for monitoring, and sends it to FDS. ROS stores real-time telemetry data for the future analysis. ROS reprocesses the stored data and analyzes the trend of the data. ROS receives mission timeline from MPS, prepares command plan and telecommandprocedures in order to process the mission timeline generated by MPS and sends telecommand to TTC. ROS is composed of computers like PC servers and clients, I/O devices, and software to control and monitor the COMS satellite. Figure 4 shows the functional structure of ROS.

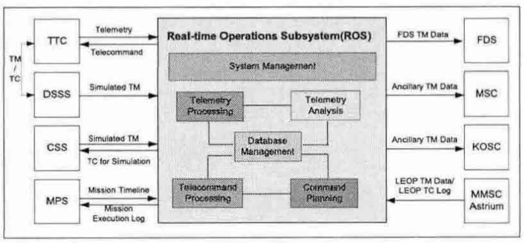

Figure 4: ROS Functional Structure

Telemetry Processing

Telemetry Processing functions receives telemetry data from TTC, CSS or MMSC and then process telemetry data in real-time. At the same time it stores raw telemetry data during all life-time of the COMS mission. After receiving telemetry data, it displays variable kind of formats and it generates audible and visible alarm in case of error.

Telemetry Analysis

Telemetry Analysis function processes archived telemetry data in replay mode and provides trend analysis from past time to future time. It also transmits FDS-related data automatically and manually and transmits ancillary data to MSC and KOSC at every 30 seconds interval.

Command Planning

Command Planning function translates Mission timeline into Command Mnemonics and provides template editor which defines Command Sequence. It also provides Mapping rule which converts Mission Task into Command Sequence and generates Command Plan.

Telecommand Processing

Telecommand Processing function converts Command plan into telecommand procedure and generates transferframe compatible to CCSDS standard and then transmit telecommand to spacecraft or simulator. It also provides automatic transmission of telecommandsand verifies telecommand link and execution. Telecommand processing function manages Onboard Master Schedule and reports the result of mission execution to MPS.

Data Management

Data Management function manages CAD, TAD, S/C characteristics and system configuration data. It also initializes and control data base and supports retrieving database for other subsystem.

System Management

This package takes charge of starting up, managing and terminating ROS. Managing ROS includes log operations, process monitoring and controlling, user management, takeover management and connection management.

2.3 MPS Subsystem

MPS gathers mission requests from the mission requesters, which are CTES, KOSC and MSC. Thereafter, with its own mission scheduling algorithm, MPS generates mission timeline by collecting and analyzing the mission requests and event information received from FDS. The mission timeline is transmitted to ROS to be used for command planning. The mission timeline is also converted to a mission schedule and the mission schedule is transmitted to the mission requesters. Figure 5 shows the functional structure of MPS.

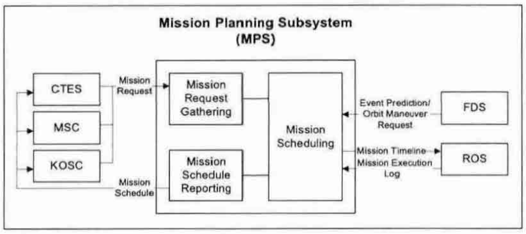

Figure 5: MPS Functional Structure

Mission Request Gathering

This function receives mission requests from CTES, KOSC, and MSC and summarizes the mission requests to be used for the mission scheduling.

Mission Scheduling

This function performs mission scheduling with the mission requests and the event information read from FDS. Thereafter, this function creates a missiontimeline. The timeline is transmitted to ROS, displayed on the screen and printed through a printer.

Mission Schedule Reporting

This function converts the mission timeline to a mission schedule that contains additional information required by the mission requester. Then, the mission schedule is transmitted to the mission requester.

System Management

This function manages the mission scheduling systemwhere the mission scheduling is performed. This function also takes charge of user management, data synchronization between primary and backup mission scheduling system, and log operations. All events related system management should be logged.

Web Management

This function manages the Web system where the mission request gathering and mission schedule reporting are performed. This function alsotakes charge of mission requester management, database management, and log operations. All events related Web management should be logged.

2.4 FDS Subsystem

FDS provides spacecraft flight dynamics operations support. Flight dynamics operations support includes spacecraft orbit determination, orbit prediction, event prediction, fuel accounting, station-keeping maneuver planning, and station-relocation maneuver planning. All of the orbit dynamics functions in FDS consider specific COMS daily wheel off-loading operations affecting the COMS orbit[2]. FDS also provides COMS operation related functions such as oscillator updating parameter calculation and Earth acquisitionparameter calculation after emergency Sun reacquisition. In general, FDS is a computer-based system, which is comprisedof flight dynamics software and computer hardware. FDS in the COMS SGCS includes only the functions required for the geostationary orbit spacecraft operations. Figure 6 shows the functional structure of FDS.

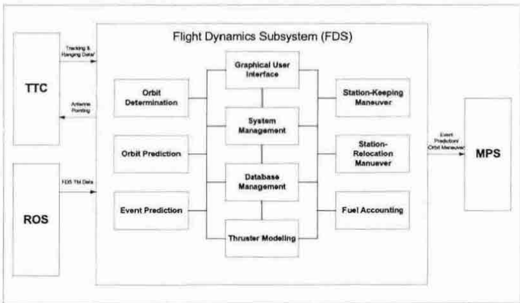

Figure 6: FDS Functional Structure

Orbit Determination and Prediction

Satellite ephemeris propagated by the operational orbit determination and prediction needs to operate the satellite all the time. The operational orbit determination provides the operational orbit solution of the spacecraft using ranging and angle tracking data[3],[4].The orbit prediction provides COMS orbit prediction ephemeris and generates the ground track data, the antenna pointing data, and the orbit predicted state for specific ground station. Those data files from orbit prediction are used to find the position of the satellite and operate the satellite.

Event Prediction

Event prediction provides eclipse time due to the Earth andthe Moon, sensor intrusion time, sun-interference time, and box boundary of the spacecraft. The event prediction also provides the various orbital events such as nodal crossing time and apsidal passing time. Especially in the COMS satellite case, oscillator updating and Earth acquisition parameters are also computed for the satellite operation.

Station Keeping and Relocation

The station keeping provides the analysis, planning, and reconstruction of the station keeping maneuver, calculates the burn parameter for maneuver, and determines on-orbit thruster calibration according to the each velocity increment. The station relocation provides the analysis and planning, and reconstruction of the station relocation maneuvers. In addition, station relocation calculates theburn parameter to put the satellite at new location.

Fuel Accounting

Fuel accounting consists of two programs. PVT method using temperature and pressure of the fuel tank transmitted from telemetry data and thruster-on-time (TOT) method that calculates remaining fuel accounts using pulse of the thruster firing from telemetry data. Thus, the fuel accounting provides the capabilities for analysis of remained fuel mass inside the spacecraft fuel tank by telemetry data.

FDS System Management

The FDS system management function provides the management of the FDS processes, interfaces, and database. This function starts up and shut down the FDS system and manages functional processes and databases. Process management provides FDS operator to monitor and control FDS process related to the all FDS jobs. Data management also supplies all FDS related database such as spacecraft information, astronomical information and files, and orbit data. Interface management involves all database files through standard FTP exchanging among other subsystems.

2.5 CSS Subsystem

CSS is a software system of simulating the dynamic behavior of COMS by use of mathematical models. CSS is utilized for command verification, operator training, satellite control procedure validation, and anomaly simulation. CSS models each of satellite subsystems as accurate as possible with the constraint of real operation condition, and display status of satellite including orbit and attitude in alphanumeric and graphical format. CSS receives telecommands from ROS, distributes them to corresponding subsystems, and sends the simulated results to ROS in telemetry frame format. CSS is capable of operating in on-line as well as stand-alone modes. CSS, also, supports real-time and variable speeds simulation in terms of multiple or fraction of real-time, anomaly simulation for analysis purpose etc. In addition, CSS supports simulation for the spacecraft status by various events and initialization data. Figure 7 shows the functional structure of CSS.

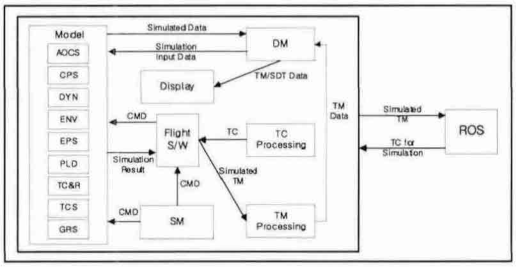

Figure 7: CSS Functional Structure

System Management

This function starts up and shuts down the CSS system and manages user accounts. This function sets CSS mode for ROS connection and manages simulation control such as initialize, run, stop, and pause. The stand-alone mode may set simulation speed and static simulation mode. All CSS events including source and contents of event, error criticality status, telecommand information should be logged.

Simulation Management

Thisfunction loads and sets up initial data for simulation. Model fidelity and parameters can be selected or changed by an operator. CSS provides the management of anomaly states and simulation mode such as dynamic or static mode.

Telecommand and Telemetry Processing

Telecommand processing function generates, modifies, and saves telecommands. This function also manages scenario file using telecommands. Telemetry processing function processes the received telemetry data frame into mnemonics and converts to engineering values and status values.

Spacecraft Subsystem Simulation

This function provides S/C subsystem simulation such as AOCS, CPS, EPS, TC&R Subsystem, TCS and PLD subsystem. This function includes orbit and attitude dynamics model, space environment model and ground simulation model.

Data Management and Display

This function receives, saves and processes the simulated TM and simulation data. Data management function provides interface with other subsystem such as ROS and FDS and manages file conversion and data backup. Display function provides telemetry alphanumeric/plot window, ground track window, station keeping box window, and sensor field of view window for data analysis.

3. SGCS Interfaces

The external and internal interfaces are shown in Figure 8. The SGCS has the external interface with the COMS satellite, CTES, KOSC, MSC, IDACS in SOC, and MMSC in Astrium (Toulouse, France). The SGCS gives and takes the data relevant to mission operation request to/from CTES, KOSC, and MSC. The SGCS also sends the data needed to image processing to KOSC and MSC. IDACS in SOC co-uses TTC antenna of SGCS. Thus the SGCS has the interface at the level of RF signal with IDACS in SOC. As another external interface, the SGCS is able to not only receive the LEOP TM data and TC log from MMSC in LEOP phase but also send the TM data to MMSC in on-station phase.

The SGCS has the internal interface among TTC, ROS, MPS, FDS, CSS, and DSSS. The DSSS is not a development item but it is included within the internal interface because it is connected to the MODEM/BB of TTC and ROS and plays a role as simulator. The DSSS will be provided by EADS Astrium.

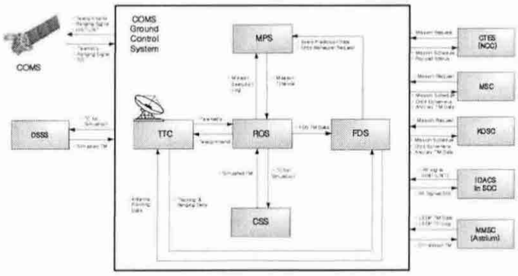

Figure 8: SGCS External and Internal Interfaces

The primary-backup SGCS interface is shown in Figure 9. The SGCS consists of primary system andbackup system. This interface is used for the operational data transfer between the primary TTC and backup ROS/FDS or vice versa. Also, the interface is used to exchange the data between the same subsystems in primary and backup SGCS.

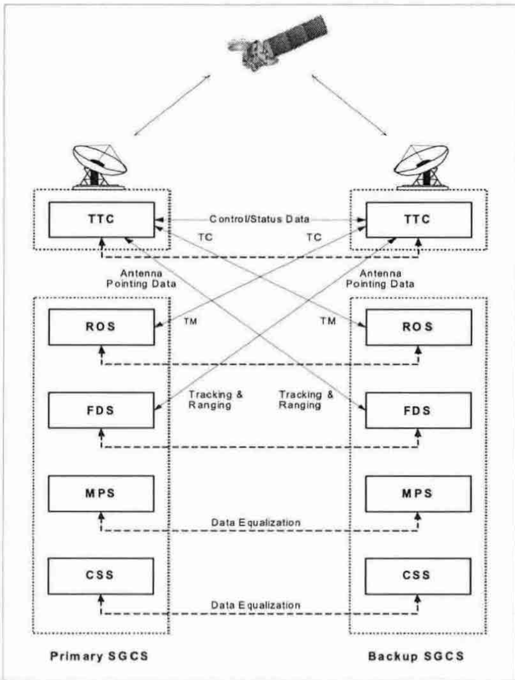

Figure 9: SGCS Primary and Backup Interface

4. Conclusions

Functional design of the COMS SGCS system was described. In order to control and monitor the geostationary satellite COMS, SGCS functions were allocated into the five subsystems such as TTC, ROS, MPS, FDS, and CSS.

Preliminary design review of COMS Ground Segment was completed at the end of March 2006. Now, SGCS development is in the detailed design phase. All of the system and subsystem design will be completed by the end of 2006. Also, the contents and format of the data for external and internal interfaces will be fixed. Manufacturing of the SGCS hardware and software will be finished by the third quarter of 2007. Integration and test will be completed by the first quarter of 2008.

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Abbreviations

AOCS	Attitude and Orbit Control Subsystem
BB	Base Band
C&M	Control and Monitoring
CMD	Command
COMS	Communications, Ocean, and Meteorological Satellite
CPS	Chemical Thruster Subsystem
CSS	COMS Satellite Simulator
CTES	Communications Test Earth Station
DSSS	Dynamics Satellite Simulator System
DYN	Dynamics
EADS	European Aerospace and Defense System
ENV	Environments
EPS	Electrical Power Subsystem
ETRI	Electronics and Telecommunications Research Institute
FDS	Flight Dynamics Subsystem
FTP	File Transfer Protocol
GEO	Geostationary Earth Orbit
GOCI	Geostationary Ocean Color Imager
GRS	GRound Simulation
HRIT	High Rate Information Transmission
I/O	Input/Output
IDACS	Image Data Acquisition and Control System
KARI	Korea Aerospace Research Institute
KMA	Korea Meteorological Administration
KORDI	Korea Ocean Research and Development Institute
KOSC	Korea Ocean Satellite Center
LEOP	Launch and Early Orbit Phase
LHCP	Left Hand Circular Polarization
LRIT	Low Rate Information Transmission
MI	Meteorological Imager
MIC	Ministry of Information and Communication
MMSC	Multi-Mission Satellite Center
MPS	Mission Planning Subsystem
MSC	Meteorological Satellite Center
PC	Personal Computer
PLD	Payload subsystem
PVT	Pressure, Volume, and Temperature
RF	Radio Frequency
RHCP	Right Hand Circular Polarization
ROS	Real-time Operations Subsystem
SD	Sensor Data
SGCS	Satellite Ground Control System
SOC	Satellite Operations Center
TC	TeleCommand
TC&R	Telemetry, Command and Ranging subsystem
TCS	Thermal Control Subsystem
TM	Telemetry
TOT	Thruster On-Time
TTC	Telemetry, Tracking, and Command

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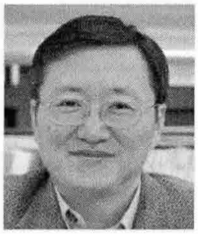

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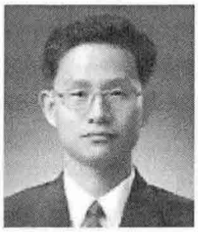

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