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ELECTRICAL GROUND SUPPORT EQUIPMENT (EGSE) DESIGN FOR SMALL SATELLITE

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ABSTRACT

This paper describes EGSE design for the small satellite such like KOMPSAT-2 satellite. Recent design trend of small satellite and EGSE is to take short development time and less cost. For this purpose, the design for KOMPSAT-2 satellite and EGSE are not much modified from KOMPSAT-1 heritage. It means that it is able to be accommodated the verified hardware and software modules used in KOMPSAT-1 satellite program if possible. The objective of EGSE is to provide hardware and software for efficient electrical testing of integrated KOMPSAT-2 satellite in three general categories. (1) Simulators for ground testing (*e.g.* solar-simulation power, earth scenes, horizons and sun sensor). (2) Ground station type satellite data acquisition and processing test sets. (3) Overall control of satellite using hardline datum. In KOMPSAT (KOrea Multi-Purpose SATellite) program, KOMPSAT-2 EGSE was developed to support satellite integration and test activities. The KOMPSAT-2 EGSE was designed in parallel with satellite design. Consequently, the KOMPSAT-2 EGSE was based on the KOMPSAT-1 heritage since the spacecraft design followed the heritage. The KOMPSAT-2 baseline was elaborated by taking advantage of experience from KOMPSAT-1 program. The EGSE of KOMPSAT-2 design concept is generic modular design with preference in part selection with commercial off-the-shelf which were proven from KOMPSAT-1 programs, flexible/user friendly operational environment (graphical interface preferred), minimized new design and self test capability.

Keywords: satellite, KOMPSAT, EGSE, SATS, TCTS, PMTS, ACTS, RFTS

1. INTRODUCTION

The objective of the EGSE is to provide a system design that facilities test and supports at integration, verification and test at satellite level. This paper shows how to build the EGSE according to the best commercial hardware and software standards that were verified during the testing of KOMPSAT-1 satellite. Moreover, the characteristics of KOMPSAT-2 EGSE improved from KOMPSAT-1 are described and those improvements are in the area of software design, GUI and flexibility in user operating system. Table 1 lists the acronyms and abbreviations used in this paper.

The main improved functions of KOMPSAT-2 EGSE are as followings:

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Table 1. Acronyms and abbreviations.

AI & T	Assembly, Integration and Test	FM	Flight Model
AOCS	Attitude & Orbit Control Subsystem	FSSA	Fine Sun Sensor Assembly
BDIFJ	Battery Disconnect In-flight Jumper	GRA	Gyro Reference Assembly
CES	Conical Earth Sensor	GPS	Global Positioning System
CMD	Command	IBU	Interface Buffer Unit
CSSA	Coarse Sun Sensor Assembly	RFTS	Radio Frequency Test Set
DDLS	Deployment Device Load Simulator	RIU	Remote Interface Unit
DDC	Deployment Device Controller	RWA	Reaction Wheel Assembly
EGSE	Electrical Ground Support Equipment	S/C	Spacecraft
EM	Engineering Model	SOH	State Of Health
ETB	Engineering Test Bed	TLM	Telemetry
ISATS	Integrated Spacecraft Automated Test System-For KOMPSAT-1	KOMPSAT	Korea Multi-Purpose Satellite

a) Generic modular design for software development

b) Flexible/user friendly operational environment

c) Self test capability.

The KOMPSAT-2 EGSE is a comprehensive set of equipments including hardware, software, and related ground support cables. The EGSE should provide the capabilities for testing and monitoring the performance of the KOMPSAT-2 at Engineering Test Bed (ETB), and Flight Model (FM) level integration and test. EGSE is expected to support the launch activity.

The EGSE should provide following major capabilities:

a) Provide test points for major signal paths

b) Control and/or generate stimuli and monitor hardline signals

c) Provide bus power to the spacecraft and payload

d) Provide battery-handling capability including simulation, charging and discharging

e) Provide communication link interface and measurement capabilities

f) Provide capability to perform satellite operation and monitor for test.

Figure 1 shows the simplified interconnection diagram for KOMPSAT-2 integration and test (FM configuration). The SATS are connected to each test set via Ethernet and connected to spacecraft via hardline. Single set of cables will be used for both ambient and environmental test configurations.

Most of the test sets are controlled and monitored under SATS (Spacecraft Automated Test System). The communication between test set and the SATS are made over Ethernet Reference EGSE communication network as depicted in Figure 2 (Park et al. 2000). Some other internal communication made among test set consoles. These interfaces are described in each test set interface subsections. The EGSE for KOMPSAT-2 consists of following major test set groups:

a) Spacecraft Automated Test System (SATS)

b) Telemetry and Command Test Set (TCTS)

c) Power Monitor Test Set (PMTS)

d) Solar Array Simulator (SAS)

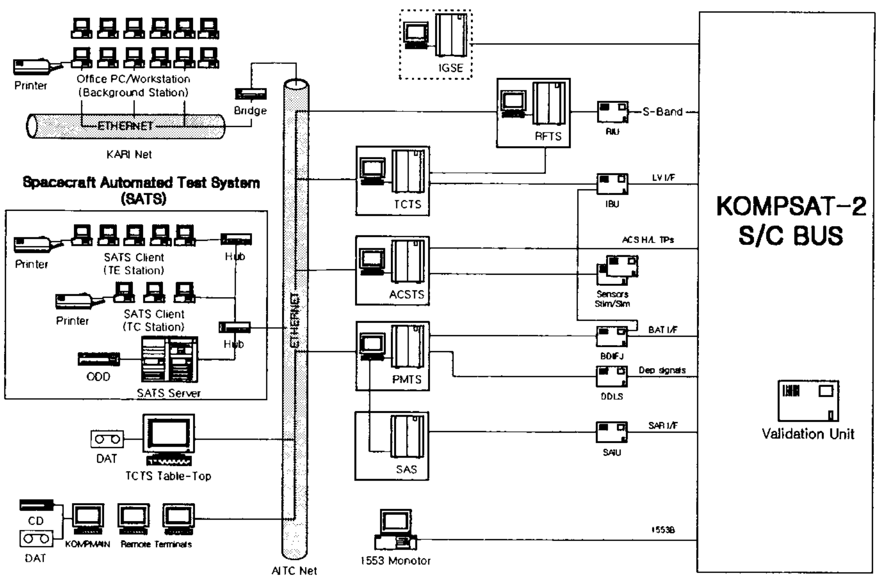

Figure 1. Simplified EGSE configuration.

e) Attitude Control Test Set (ACTS)

f) Radio Frequency Test Set (RFTS)

g) Remote Unit and cables

h) Test Aids.

2. SPACECRAFT AUTOMATED TEST SYSTEM (SATS)

The SATS is a data driven system where Test Conductor executes the ATSs (Automatic Test Sequence) generated by Test Engineers. The SATS interfaces with the test sets are made over Ethernet. It serves as a control node for all EGSE and spacecraft to perform overall Satellite integration and test. Figure 1 shows the configuration diagram of the overall EGSE and Spacecraft. The SATS transmits command and receives telemetry via TCTS. Also, the SATS control and monitor the status of other Test sets of EGSE and spacecraft hardline interfaces. And the SATS performs all post data processing, such as alarm checking, trending and permanent archiving and logging (Park et al. 2000a, 2002).

The KOMPSAT-2 SATS was newly designed in compared to KOMPSAT-1 ISATS(Integrated SATS). All kinds of SATS functions are designed in based on GUI for Man-machine interface to use easily by test-engineer, modularized software module to improve it easily and added self-test compatibility to check of the system health. In addition, RDBMS (Relational Database Management System) is selected in order to store data securely and to trace for the previous data.

The main functions and characteristics of SATS are:

a) Send commands to the spacecraft at a maximum rate of 41 commands per second via the TCTS

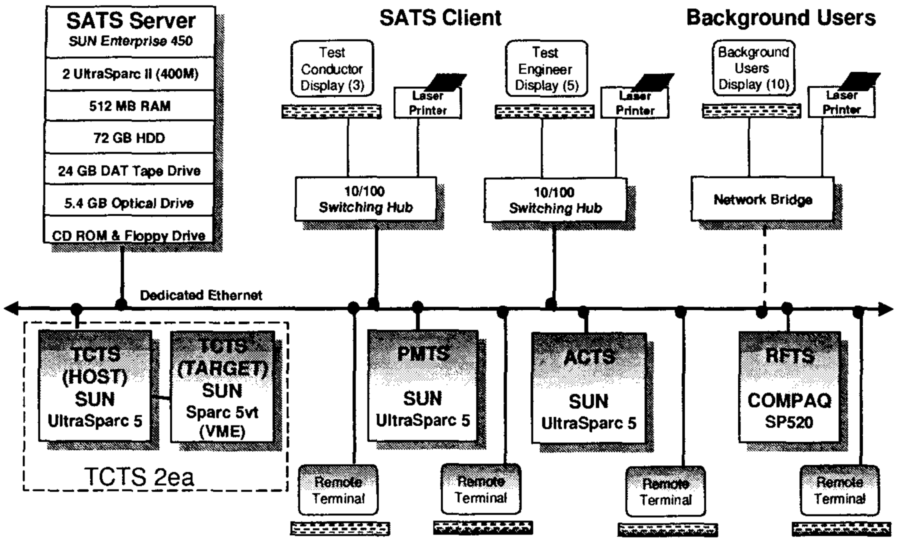

Figure 2. Data Processing network for EGSE.

b) Provide S/C commanding with command effects, constraints and critical commanding

c) Process and store spacecraft SOH telemetry at the 2 Kbps rate via TCTS

d) Perform limit checking and alarm processing on spacecraft and test set data

e) Process and store test set status data (hardline data) every second

f) Display spacecraft and test set data in real time

g) Generate reports of spacecraft, test set and tests history data

h) Retrieve, analyze and trend spacecraft and test set data

i) Monitor telemetry, commands and test events

j) Provide capability to create, update and print out databases

k) Provide the storage media to store and archiving test data.

The SATS consists of SUN Enterprise 450 Workstation and 3 TC (Test Conductor) Station Terminal include up to 10 background terminal, external storage devices (Optical disk and DAT) and laser printers as Figure 2. Each terminal can be connected for implementation its job through X-Manager. The background terminals provide capability to edit, compile and execute ATS and troubleshooting simultaneously. The 3 TC Terminals with graphic capabilities display the following data:

a) Control/Status display : Action, message, interaction display / Status of SATS and ATS

b) Alarm / Event Log display : Action list for alarms and mis-compare data / Real-time event data

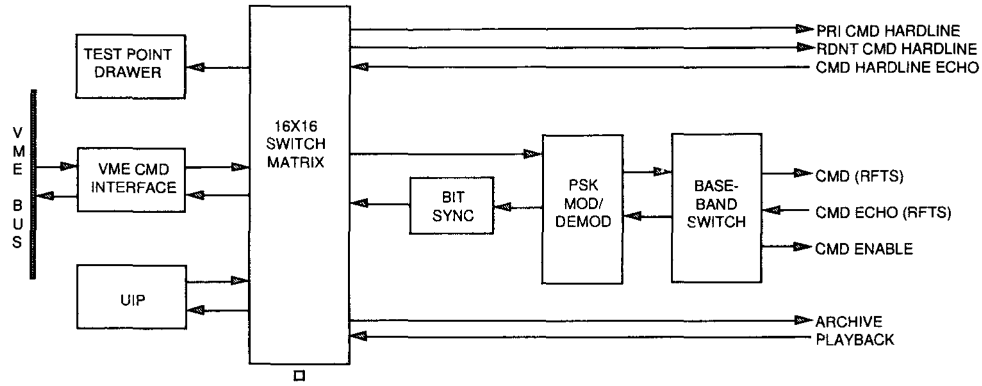

Figure 3. TCTS Command signal processor routing.

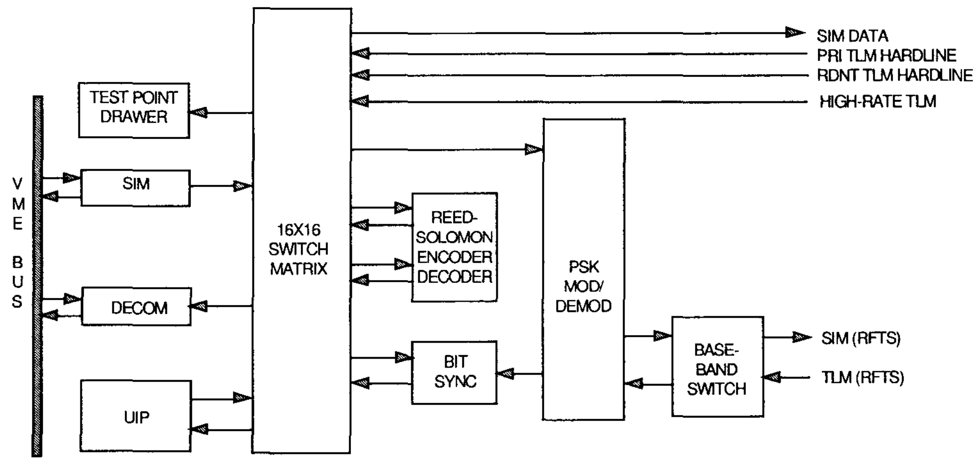

Figure 4. TCTS Telemetry signal processor routing.

c) Page/Parameter/Plot display : Real-time parameter page/trend/plot.

The SATS software is also composed by the following components as the central one in EGSE running:

a) Display component : man/machine interface for real-time and background processes

b) Procedure component : execution of ATS under the direction of the test conductor

c) Command component : control the configuration of the test sets and spacecraft.

d) Response component : acquiring and processing of spacecraft telemetry and test set status data

e) Database component : processing required for the creation, modification, and manipulation of databases.

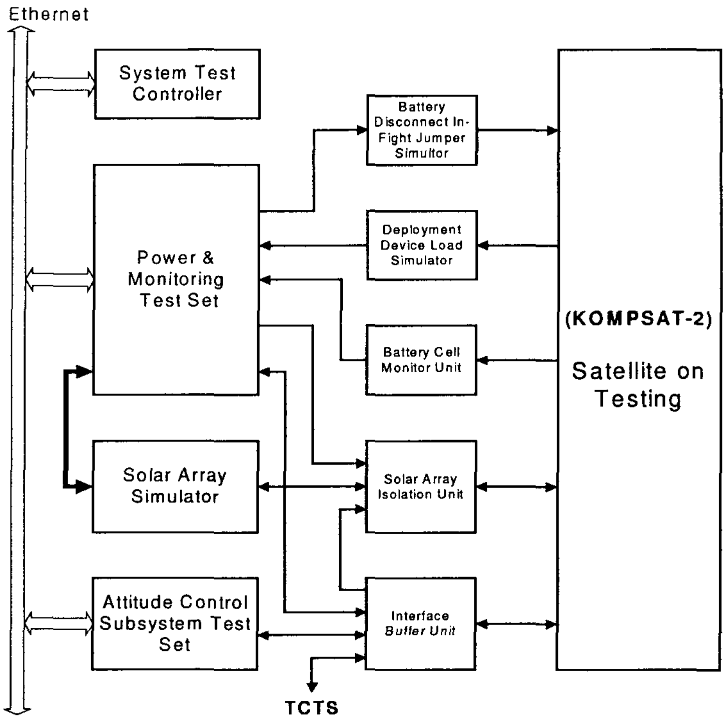

Figure 5. Configuration of the PMTS & ACTS.

3. TELEMETRY AND COMMAND TEST SET (TCTS)

The TCTS provides command and telemetry data interface between SATS and RFTS. The TCTS shall also provide direct hardline (Command, Telemetry and GSE-Enable) interface to the satellite as Figure 3 and from the satellite as Figure 4. The TCTS will receive command or memory uploads from SATS, and formats per CCSDS format and pass commands either directly to satellite hardline interface or via RFTS. And the TCTS will receive telemetry from satellite via either directly on hardline interface or from RFTS. The telemetry will be decoded per CCSDS and frame synchronized to be transferred to SATS. And the TCTS can be remote controlled and monitored from SATS via Ethernet communication link. The main functions and characteristics of TCTS are (Park et al. 2000b):

a) Format command to CCSDS format and transmit to RFTS or spacecraft hardline

b) Support uplink command rate of 2 Kbps and NRZ-M data format

c) BPSK modulation of command data to 1.024 Mhz subcarrier for further RFTS process

d) Receive command loop-back from RFTS and command verification

e) Receive command input either from SATS or local users terminal, and transmit

f) Receive and handle downlink telemetry from RFTS or spacecraft H/L as specified as below:

- SOH mode: 2.048 Kbps data submodulated onto 1.024Mhz baseband subcarrier

- Play Back mode (P/L): 1.5 Mbps direct modulated data

g) BPSK demodulate and recover SOH telemetry data from subcarrier

h) Perform bit synchronization to recover clock when only tones are passed from RFTS or Spacecraft hardline

i) Perform frame synchronization and handle data as below:

   - In 2K mode: Display and pass all data to STC
   - In 1.5M mode: Extract and display real-time SOH data and pass them to STC

j) Provide CSSDS PCM telemetry data simulation including Reed-Solomon encoding

k) Provide ports for command/telemetry data arching and playback

l) Provide external user interface panel for user to input or monitor major signals

m) Provide test point panel where user can monitor critical signals to aid troubleshooting

n) Provide SATC remote control and local control of the test set.

The TCTS provides switching and distribution network to process command and telemetry signals as shown in Figure 3 and Figure 4. The TCTS consist of SUN workstation (Ultra5), Telemetry and Command Processing Unit, Test Point Drawer, UIP (User Interface Drawer) and Recorder. To meet the above functional and performance characteristics, the Telemetry and Command Processing Unit is implemented as VME cards within the VME chassis as below:

a) Bit Synchronizer card

b) Telemetry Decom card

c) PCM Simulator card

d) PSK Mod/Demod card

e) Reed Solomon Encoding/Decoding card

f) Command Generator/Echo comparator card

g) Telemetry and Command Processor card.

The TCTS software is composed by the following components to perform the functions of TCTS.

a) SATS Interface

b) User Interface

c) Log manager

d) Host/Target interface and daemon.

4. POWER MONITOR TEST SET (PMTS)

The PMTS is subdivided into two consoles for KOMPSAT-2, which Power and Monitor Test Set (PMTS), Solar Array Simulator (SAS). The PMTS also includes a number of remote units, such as

Battery Disconnect In-Flight-Jumper Unit (BDIFJ), Solar Array Isolation Unit (SAIU), Deployment Device Load Simulator (DDLS), Spacecraft Interface Buffer Unit (IBU), and Battery Charge Monitor Unit (BCM). The Figure 5 shows the signal flow between test sets, PMTS and ACTS, and satellite through remote units. The PMTS can perform system level testing as the stand-alone mode because of having the built-in controller and as the master-slave mode under of the SATS control through the Ethernet. The SAS performs the solar Array Simulation under the PMTS control through the GPIB cable.

When Integrated System Testing, the PMTS provides all hardline interfaces between satellite or spacecraft and EGSE except the link interface for the RF signals. To test the normal states of satellite at the ground, the PMTS provides satellite on testing with the simulated data for the signals, which will generate by the orbiting satellite. To verify the responses of satellite for the simulated signals, the PMTS monitor the satellite status through test points and IFJ (In-Flight-Jumper)'s built-in. And, the PMTS supports the hardline interface of the link interface and launch vehicle interface. The PMTS incorporates the equipment and instrumentation to support system level testing of the Electrical Power Subsystem at the spacecraft level and satellite system testing and integration. In case of the Electrical Power Subsystem, the PMTS provides the primary power of satellite with the Solar Array Simulator (SAS) and has the battery charged/discharged to test the functions and routes of the electrical power generation/distribution at the ground (Youn et al. 2002). Also, the PMTS monitors the normal states of the primary and secondary power through the test points of satellite on testing. The SAS simulates the power generation pattern of satellite solar array on the orbit with the orbit analysis.

The PMTS provide the following capabilities:

a) Provide DC power to spacecraft array regulator module
b) Provide DC power to launch vehicle interface bus
c) Provide DC power to the spacecraft power bus at power control unit
d) Monitor spacecraft bus voltage, battery voltage, power control unit voltage and battery charge/discharge
e) Monitor battery temperature and battery pressure
f) Recondition and discharge battery.

Additionally, the PMTS provides the interface of baseband signals between the TCTS and the OBC of satellite. That is to say, the PMTS supports the simple communication between the EGSE and the satellite without the modulation/demodulation of the RF signals. And the PMTS provides the launch vehicle interface to perform the final satellite function test and charge the battery when the launch vehicle loading the satellite is laid on launch platform. This launch vehicle interface is used for the satellite function test in high bay of the Assembly, Integration and Test Center (AITC) as well as the launch site.

5. ATTITUDE CONTROL TEST SET (ACTS)

The ACTS, a test set related to AOCS, is an element of the EGSE. The ACTS provides the sensors with the stimulation signals and monitors the responses of actuators about the specific stimulation signals. As some hardware components of AOCS have been changed from those of KOMPSAT-1, ACTS has also something to change (Kwon et al. 2001). In KOMPSAT-2, the ACTS performs supporting 5 test sequences on AOCS test, the Valve Drive Electronics (VDE)'s monitoring, Fine Sun Sensor Assembly(FSSA)'s stimulating, Reaction Wheel's monitoring and sending command to STA's Sim. Those are below things.

a) Valve Drive Electronics (VDE): Continuously monitor valve drive signals for event detection while characterizing any one thruster valve for average voltage and pulse width

b) Fine Sun Sensor Assembly (FSSA): Stimulus FSSA using 3 lamps that is provided specific power from ACTS and monitoring each voltage on it

c) Conical Earth Sensor (CES): Stimulating CES using a thermo board, a test-aids, and monitoring its temperature on ACTS

d) Reaction Wheel Assembly (RWA): Providing the voltage to RWA for driving it and confirming rotation direction of RWA

e) Star Tracker Assembly (STA): Sending command to SIM-16, STA Simulator, and receiving relevant telemetry from SATS based on End to End Test (same as the role of VDS at ETB case).

6. RADIO FREQUENCY TEST SET

RFTS has a function of the modulation and demodulation of the S-band link signals between TCTS and KOMPSAT-2. The S-band link signals include the command, telemetry and ranging signal. The major components of the RF when integrated should be operated as a system to perform the command and telemetry functions to support the integration and test of KOMPSAT-2. Also the RFTS should provide the function of the telemetry demodulation, the command modulation, the ranging, and the RF signal characterization (Lim et al. 2000). The main function of RFTS is as followings:

a) Receive 16kHz BPSK modulated baseband command signals from the TCTS and phase modulate the data onto an S-band carrier frequency

b) Receive and demodulate the RF telemetry links a down link carrier signals and pass the resultant baseband signal to the TCTS

c) Generate a simulated ranging signal and modulate it onto the command link. And measure the delay from the demodulated baseband signal and compare the received ranging signal to the transmitted ranging signal

d) Provide for level setting of the command signals and measurements of both command and telemetry links

e) Provide the routing of signals and display of the current test set status to include configuration telemetry lock status, and attenuator settings.

Operating system of RFTS is newly designed using the PC workstation with visual C++ for verification of KOMSAT-2 RF function. During the satellite test, the RFTS will be remotely controlled by the SATS and received the command data from the SATS and transmitted the telemetry (RFTS status and measured data) to the SATS. The RFTS software will be provided the test configuration for the KOMSPAT-2 and provided S-band links interface between KOMPSAT-2 transponder receiver and transmitter through the remote interface unit (RIU). RIU have a select RF link from zenith or nadir antenna, protect RF interfaces into the satellite transponder from damage due to VSWR mismatches and RF amplitude levels, and provide loopback RF switching capabilities to validate RFTS operation itself.

7. SUMMARY

The KOMPSAT-2 EGSE design is based on the KOMPSAT-2 satellite requirements. The KOMP SAT-2 EGSE design concept is a generic modular design and a flexible/user friendly operational environment (graphical interface preferred). This EGSE, in present, was developed to provide electrical interface and data processing to support integration and test during the ETB and FM level, also it is necessary for launch campaign at launch site.

The technologies mentioned above have become more easily applicable due to the use of recent small satellite, and it is expected to be of assistance in the areas of telecommunication satellite and at the development phase of test equipments for satellites for meteorological observations.

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