Development of KOMPSAT-2 Vehicle Dynamic Simulator for Attitude Control Subsystem Functional Verification.

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Abstract:

In general satellite verification process, the AOCS (Attitude & Orbit Control Subsystem) should be verified through several kinds of verification test which can be divided into two major category like FBT (Fixed Bed Test) and polarity test. And each test performed in different levels such as ETB (Electrical Test Bed) and satellite level. The test method of FBT is to simulate satellite dynamics with sensors and actuators supported by necessary environmental models in ETB level. The VDS (Vehicle Dynamic Simulator) try to make the real situation as possible as the on-board processor will undergo after launch. The purpose of FBT test is to verify that attitude control logic function and hardware interface is designed as expected with closed loop simulation.

The VDS is one of major equipments for performing FBT and consists of software and hardware parts. The VDS operates in VME environments with target board, several commercial boards and custom boards based on the VxWorks real time operating system. In order to make time synchronization between VDS and satellite on-board processor, high reliable semaphore was implemented to make synchronization with the interrupt signal from on-board processor.

In this paper, the real-time operating environment used on VDS equipment is introduced, and the hardware and software configurations of VDS summarized in the systematic point of view. Also, we try to figure out the operational concept of VDS and AOCS verification test method with close-loop simulation.

Keywords: Satellite Control, VDS, Closed-loop simulation, VxWorks

1. INTRODUCTION

The functional test of satellite can be divided into two major category : at ETB (Electrical Test Bed) level and at FM(Flight Model) satellite level. In the AOCS (Attitude and Orbit Control Subsystem) case, the most of the AOCS function is simulated and verified at ETB level for the hardware and software interface verification. And after ETB test, the polarity of sensors and actuators are verified at FM satellite level and also the sensor stimulus and actuator response check can be done at this FM level test.

The KOMPSAT-2 ETB is setup with three processors EM (Engineering Model) and most of electronic box same as FM (Flight Model) box in functional point of view. Therefore the ETB could be considered as a satellite without mechanical structures.

The VDS (Vehicle Dynamic Simulator) equipment is developed for the AOCS functional test at ETB level test. The VDS software consists of all sensors and actuators model with dynamic model and necessary software model. And the VDS support all hardware interface requirements same as real sensors and actuators do.

The KOMPSAT-2 AOCS functional test has been performed in closed-loop test manner with VDS at ETB level successfully. In this paper, the systematic configurations of KOMPSAT-2 VDS equipment and operational concept of closed loop simulation is introduced.

2. VEHICLE DYNAMIC SIMULATOR

All of the output signals or data of sensors mounted on satellite depend on the position and attitude of satellite. For the sun sensor example, the output signal of sun sensor could be defined, if the sun vector is available at any given time in the sun sensor coordinate frame and the sun sensor software model is exist. In order to calculate the sun vector, the relative position of sun with respect to the satellite and the sensor mounting angle with respect to the basic satellite coordinate frame are required.

Even though the real sensors and actuators are available at ETB level, it is difficult to simulate the real on-orbit environment to verify whether the AOCS function is working properly or not using real sensors and actuators. Most of optical sensors need the optical stimuli to give certain attitude information to AOCS processor. And also it is impossible to give stimuli continuously to the optical sensors correctly at the given time and orbital position. For the actuators, it is difficult to make actuator feedback loop because no structure movement will be occurred at ETB. In this reason, the sensors and actuators are usually substituted with software model for the AOCS closed-loop functional verification test at ETB level.

For the closed-loop AOCS functional test, called as FBT (Fixed Bed Test), the VDS provides all of the electrical signal interface of sensors and have to monitor all of the electrical signals going to the actuators. The VDS receives the actuator drive signal first and then the dynamic model is executed based on the current actuator torque. And next step, VDS updates the satellite attitude base on the dynamic model calculation. Finally, the sensor models are run and updates all of the sensor output signals based on the new attitude information. The above sequence will be repeated continuously until to given simulation time and the execution cycle is synchronized to the RDU(Remote Drive Unit) 4Hz signal which is the minor cycle interrupt signal of the AOCS processor.

2.1 AOCS Closed-loop Test Configuration.

KOMPSAT-2 has several sensors that are the CSSA (Coarse Sun Sensor Assembly), FSSA (Fine Sun Sensor Assembly), GRA (Gyro Reference Assembly), STA (Star Tracker Assembly), TAM (Three Axis Magnetometer), CES (Conical Earth Sensor) and GPS. Also the DTM (Dual Thruster Module), MTA (Magnetic Torque Assembly), SADA (Solar Array Drive Assembly) and RWA (Reaction Wheel Assembly) are used as actuators for KOMPSAT-2.

Fig. 1 shows the configuration of AOCS closed loop test at ETB level. The Satellite Test Computer is the main controller which controls all of the command and telemetry interface with EGSE (Electrical Ground Support Equipment) during test. The VDS target processor controls all of sensor interfaces and actuator interfaces in VME bus with VxWorks real time environments. The initialization input file contains the initial position and attitude of satellite and key modeling parameters for each sensor and actuator model. The RDU is one of the ETB components, where all of the AOCS control logic and sensor data processing algorithm resides. As shown in figure, VDS provides all sensor interface signals and monitor all actuator driving signals in order to make close loop simulation.

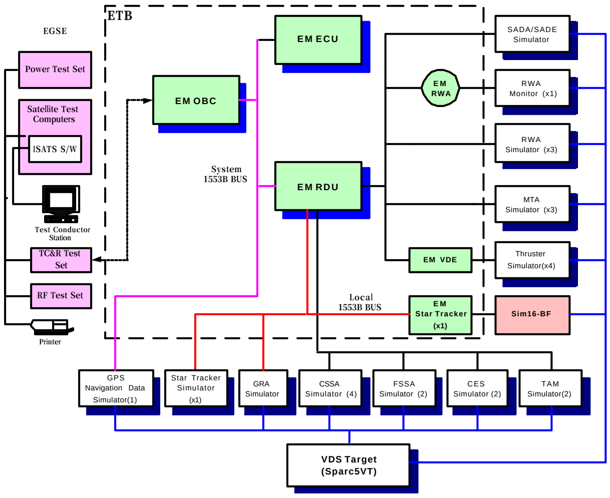

Fig. 1 KOMPSAT-2 AOCS FBT Test Configuration

2.2 VDS Hardware Configuration.

The VDS hardware consists of three parts : VME module, front panel and back panel.

Table 2.1 enumerates the boards mounted on VME module. The CES serial board is one of custom board to interface specific serial communication required for CES. Fig 2 displays view of VME module of KOMPSAT-2 VDS. The front panel is designed for the purpose of indication or monitoring several important signals. And all of the interface harness between VDS and ETB are connected through back panel.

Table 1 List of VME board

ITEMS	FUNCTION	REMARK
SPARC5VT	Main Processor	- Target board
XyCom203	Counter Board	- 250ms Interrupt generation - Pulse monitor & generation
DATEL628	D/A Board	- Analog sensor output
VMIC3113	A/D Board	- Analog input

VMIC2510	TTL I/O Board	- Bi-level interface
ASF-V6-1	1553B Board	- GPS RT simulation - GRA RT simulation - STA RT simulation
CES-Serial	Serial Interface Custom Board	- Custom board
A1, A2	Signal Conditioning Board	- Custom board

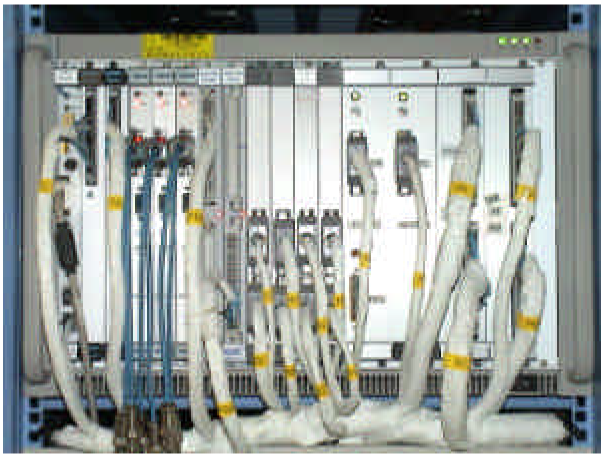

Fig. 2 View of VDS VME module.

2.3 VDS Software Configuration.

The VDS software consists of dynamic model, sensor models, actuator models, disturbance models, environment models, hardware models, interface I/O codes, and top level execution codes related to real time task control. The total lines of codes are estimated about 80,000 lines roughly. Each model developed based on the mathematical backgrounds and long time heritage and experience. KOMPSAT-2 VDS software stems from that of KOMPSAT-1 VDS. Most of sensor and actuator models are adapted from KOMPSAT-1 into KOMPSAT-2, while the star tracker model and interface implementation are newly added on KOMPSAT-2 project.

During initialization phase, all software models and hardware are initialized with initial input file. The input file contains the key modeling parameters of each model. Therefore if the real sensor is changed to another model, it is ease to change the software by modifying only the key parameter of input file. For the gyro example, it has many performance parameters like accuracy, drift, noise, scale factor, and stability parameters. Theses parameters are specified in input file and can be modified without the source code changing, if the real gyro is changed.

3. VDS OPERATION

Fig. 3 represents the data flow between VDS and ETB during AOCS closed-loop test. The VDS hardware have to have interfaces for all raw signals of ETB, since one of the requirements of VDS is to emulate all sensors and actuators, realizing close loop simulation. The actuator driving signals from RDU goes to VDS software through VDS hardware and I/O model codes. In opposite, the sensor model output goes to RDU through VDS hardware after low level signal conversion by I/O model codes.

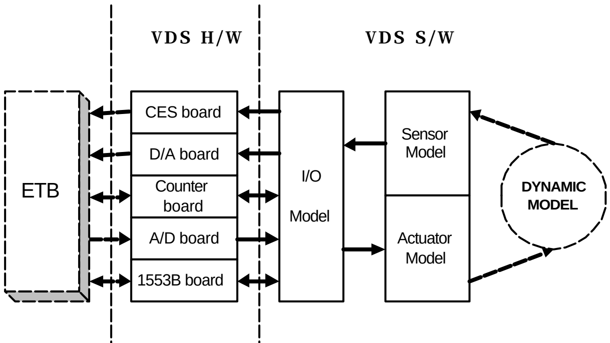

Fig. 3 Data flow diagram between VDS and ETB.

After software development, the final object code will be downloaded to target board via ether-net and then the top-level execution function is executed by manual command. Fig. 4 depicts the execution flow of top level VDS software operation. The main function initializes all hardware and software model first, and the stethoscope, a kind of real time data capture module is initialized for the data manipulations, after that, wait for 4Hz interrupt signal from ETB. Each time of the interrupt signal occurs, 1 cycle of model execution will be done. Fig. 5 shows the model execution sequence each time every interrupt signal arrives.

VDS uses the binary semaphore method to make synchronization between ETB and VDS. Therefore whenever the interrupt signal occurs, the waiting semaphore flag is transferred to waiting task. This means that the total software codes should be finished within 250ms interval. If the execution time of the take takes more than 250ms, task

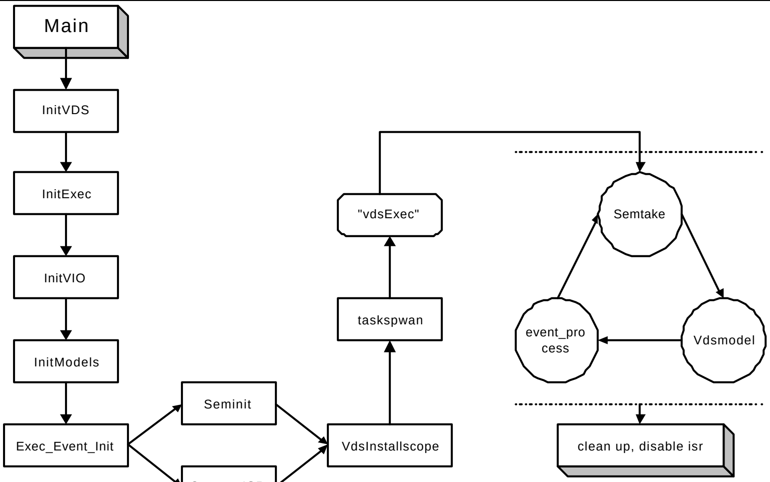

Fig. 4 VDS top level software execution flow.

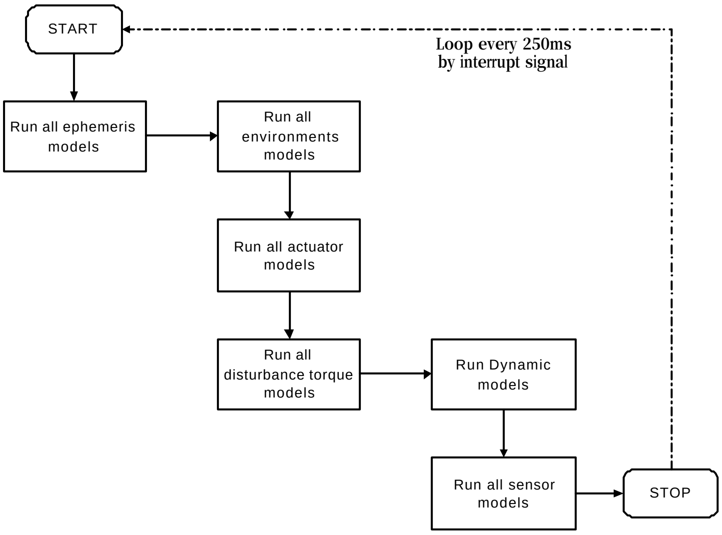

Fig. 5 Sub-function vdsmodel execution sequence.

overrun will occurr and the simulation data will not be valid any more.

In Fig. 5, when the sub-function vdsmodel is called for, the ephemeris model is executed first, and then environment model is run in order to propagate the time and position of sun, earth, moon and stars from previous status. Subsequently, the actuator model and disturbance model are used to calculate the torque input of the dynamic model. Based on dynamic model calculation, the satellite attitude is updated every 250ms interval. Finally, the sensor output data are calculated based on the new attitude and position information.

4. CONCLUSION

The KOMPSAT-2 AOCS functional test has been carried out extensively in closed-loop manner with VDS equipment. The VDS acts an important role as one of the ground test equipments for the closed-loop simulation and verification test. The VDS adopts the real time OS (VxWorks) to ensure a reliable and fast synchronization with satellite processor during whole test.

Due to lack of space, this paper describes only the essential features of VDS such as the top-level configuration of hardware and software and major operational concept of the AOCS closed-loop verification test.

In the future, the VDS will be developed for the next satellite project based on the KOMPSAT-2 VDS heritage.

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